Lecture Schedule

Course: ‘Physiology’

Course code: MF 2201-2

Speciality: 6B10101 ‘General Medicine’

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Year and Term: II, III

Lectures: 10 hours

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Head of the department: c.b.s., docent Zhakipbekova G.S.

Protocol of the meeting of the Department No. __*10a*___ dated '_*06*_' _*05*_ *2022*

Lecture No.1

1. Theme: Physiology of the nervous system

2. Learning goals: to study morpho-functional features of the spinal cord, the medulla oblongata and the hindbrain.

3. Lecture thesis:

The spinal cord is about about 45 cm long in men and about 42 cm in women, has a segmental structure (31-33 segments) - each part is associated with aspecific part of the body. The spinal cord includes five sections: cervical (C1-C8), thoracic (Th1-Th12), lumbar (L1-L3), sacral (S1-S5) and coccygeal (Co1-Co3).

Somatic neurons of the spinal cord.

The total number is about 13 million (3% are motoneurons, 97% are insertion neurons, including the vegetative nervous system).

On the cross section, it is clear that it consists of gray matter (accumulation of nerve cells) and white matter (nerve fibers, which are collected in conducting paths). In the center longitudinally, the central channel with cerebrospinal fluid (CSF) passes. Inside, there is a gray matter that looks like a butterfly and has anterior, lateral and posterior horns. The anterior horn has a short quadrangular shape and consists of cells of the motor roots of the spinal cord. The posterior horns are longer and narrower and include cells to which the sensitive fibers of the posterior roots come to. The lateral horn forms a small triangular protrusion and consists of cells of the vegetative part of the nervous system. The gray matter is surrounded by white, which is formed by the conductive paths of longitudinally running nerve fibers. All afferent entries to the spinal cord carry information from three groups of receptors: 1) from skin receptors: pain, temperature, touch, pressure, tickling, vibration; 2) from proprioceptors: muscle (muscle spindles), tendon (Golgi receptors), periosteum and sheaths of joints; 3) from receptors of internal organs - viscereoreceptors (mechano- and chemo-receptors).

The functions of the spinal cord are conductive and reflexive.

Conduction function is carried out using the descending and ascending pathways. Afferent information enters the spinal cord mainly through the posterior roots, efferent impulses in the anterior roots; the regulation of the functions of various organs and tissues of the body is fulfilled through the anterior roots (Bell-Majandi law). However, in recent years, in the anterior roots , a large number of primary afferent fibers have been discovered, the role of which is not yet clear.

Reflex function. With the participation of the spinal cord, primitive processes of regulating the activity of skeletal muscles are carried out, allowing to perform phase movements such as flexion or extension in the corresponding joints,as well as regulating muscle tone. The regulation of muscle tone is carried out with the participation of two types of reflexes of the spinal cord: myostatic and postural-tonic. Phase activity is represented by flexion reflexes and mechanisms that initiate locomotor movements (stepping movements). Myostatic reflexes are those that are often referred to as tendon reflexes, because in the clinic, to identify them, the corresponding muscle is usually hit by a neurological hammer on the tendon. These reflexes play an important role in maintaining muscle tone, balance, they aredirected against gravitational forces.

The brain stem is directly involved in the regulation of body posture, using for this purpose static and stato-kinetic reflexes. These reflexes are mechanisms forthe redistribution of muscle tone, which results in a posture that is convenient for the animal (and man) or returns to this posture from "uncomfortable" (respectively, postural and righting reflexes), and also maintains balance during acceleration - kinetic reflexes). Neurons of the vestibular nuclei, the red nucleus and the reticular formation are involved in their implementation.

The vestibular nuclei are excited under the influence of adequate stimuli acting on the vestibular apparatus. One of the main nucleus is the Deiters nucleus. From it, the vestibulospinal pathway begins, which effects the alpha-motoneurons of the spinal cord. The neurons of the vestibular nuclei excite the extensor alpha-motoneurons and simultaneously inhibit the flexor alpha motoneurons by the mechanism of reciprocal innervation. Due to this, during stimulation of the vestibular apparatus, the tone of the upper and lower extremities changes so that equilibrium is maintained. The Deiters vestibular nucleus is under the control of the cerebellum. From the vestibular apparatus to the cerebellum, the direct vestibulocerebellar path travels, that is, the cerebellum receives all the information from the vestibular apparatus. Together with information coming from the proprioceptors and from the skin receptors, it is processed in the cerebellar cortex (mostly in archicerebellum) and enters the fastigial nucleus of the cerebellum, from where it again goes to the vestibular nuclei, including Deiters ones. Thus, the activity of the vestibular nuclei is controlled. It is not by chance that the cerebellar pathology is manifested by about the same symptoms as the pathology of the vestibular apparatus and the vestibular nuclei.

At the same time, from the vestibular nuclei of the medulla oblongata, the path goes to the so-called medial longitudinal bundle.

Static reflexes are conventionally divided into postural-tonic and righting (rectifying). Both types of reflexes result from irritation of the receptors of the vestibular apparatus, proprioceptors of the muscles and receptors of the fascia of the neck and also (righting) – when the receptors of the skin are activated. The main structure involved in the realization of these reflexes is the vestibular nuclei.

The red nucleus and reticular formation are also involved in these reflexes. Pose-tonic reflexes arising from cervical muscles are sometimes called cervical-tonic, and those arising from the vestibular apparatus are called vestibular-tonic. But, taking into account that normally receptors of the neck muscles and the vestibular apparatus are simultaneously excited, it is advisable to speak of postural-tonic reflexes. In animals and humans, these reflexes are well detected at an early age. For example, in infants, a labyrinth tonic reflex is observed: in a child lying on his back, the tone of the extensors of the neck, back, and legs is elevated; If, however, the child is overturned on the stomach, the tone of the flexors of the neck, back, limbs is increased. They also have a symmetric cervical tonic reflex: in the child lying on his back, with passive flexion of the head, there is an increase in the tone of the flexors of the arms and an increase in the tone of the extensors of the legs. When the head is straightened, opposite processes are observed.

Red nucleus. It is located in the region of the midbrain. The neurons of this nucleus receive information from the cerebral cortex (as a component of the extrapyramidal system), the cerebellum (paleocerebellum, or rather, from the emboliform and globose nuclei of the cerebellum) and, thus, the red nucleusreceives all the information about the position of the body in space, the state of the muscular system and skin. The neurons of the red nucleus through the rubrospinal tract affect the alpha motoneurons of the spinal cord, and, unlike the neurons of thevestibular nucleus, they mainly cause activation of the flexor alpha motoneurons and inhibit the activity of the extensor alpha motoneurons. Due to this, the red nucleus jointly with the vestibular nuclei participates in the posture regulation.

The reticular formation of the brainstem is a structure that runs in the rostral (to the cortex) direction from the spinal cord to the thalamus. In addition to participating in the processing of sensory information (non-specific channel), the reticular formation also performs the functions of the motor system. It has been found that there are two clusters of neurons of the reticular formation involved in this: these are the neurons of the medulla oblongata and the neurons of the pons. The neurons of the reticular formation of the medulla oblongata act in exactly the same way as the neurons of the red nucleus: they activate the flexor alpha- motoneurons and inhibit the extensor alpha-motoneurons. The neurons of the reticular formation of the pons, on the contrary, act as neurons of the vestibular nuclei. Thus, it is possible to conditionally divide all motor systems of the brain stem into 2 classes (according to their effect on the muscles): flexor systems that increase the activity of flexors are the neurons of the red nucleus and the reticular formation of the medulla oblongata and 2) extensor systems — neurons of the vestibular nuclei and reticular neurons of the pons.

The reticular formation, like the vestibular nuclei and neurons of the red nucleus, receives information from the cerebral cortex (extrapyramidal path) and is closely connected with the cerebellum: some of the information from the cerebellum goes to the neurons of the medulla oblongata (from the emboliform andglobose nuclei of the cerebellum), and from the fastigial nucleus - to neurons localized in the bridge. Therefore, the reticular formation is also involved in the regulation of posture. Probably due to the fact that the reticular formation is a collector of nonspecific sensory flow, it is probably based on this information that is involved in the regulation of muscular activity, the role of associative cortex areas in which the concept of future movement originates, then this idea is realized with the participation of the basal ganglia, cerebellum, red nucleus, vestibular nucleus, reticular formation (with the participation of the extrapyramidal system), and also – and this is the most significant, with the participation of the pyramidal system – axons of giant Bets cells directly to the alpha-motoneurons of the spinal cord or to the intercalary neurons, and through them to the alpha-motoneurons. Extrapyramidal and pyramidal pathways are a single mechanism by which complex purposeful movement is performed while maintaining balance and orientation in space.

In the primary motor cortex (precentral gyrus, field 4) are neurons that innervate the motor neurons of the muscles of the face, trunk and limbs. It has a clear topographic projection of the muscles of the body. The projections of the muscles of the lower limbs and trunk are located in the upper, areas of the precentral gyrus and occupy a relatively small area, and the projections of the muscles of the upper limbs, face and tongue are located in the lower sections of thegyrus and occupy a large area

The secondary motor cortex (field 6) is located in the frontal lobes on the lateral surface of the hemispheres, in front of the precentral gyrus (premotor cortex) and on the medial side of the hemisphere (additional motor area). It performs the highest motor functions associated with the programming and coordination of voluntary movements. The cortex of the field 6 receives most ofthe impulses from the basal nuclei and the cerebellum and is involved in recoding information about the program of complex movements. When stimulating thecortex of field 6, there are more complex coordinated movements than when stimulating the primary motor cortex, for example, turning the head, eyes and corpus in the opposite direction, appropriate contractions of flexor muscles or extensor muscles on the opposite side. In the premotor cortex is the center of motorspeech Broca. The pyramidal neurons of the motor column can excite or inhibit themotor neurons of the stem and spinal centers, for example, innervating one muscle. The adjacent columns in the functional plan overlap, and the pyramidal neuronsthat regulate the activity of one muscle are usually located not in one, but inseveral columns.

The main efferent connections of the motor cortex are carried out via pyramidal and extrapyramidal pathways, starting from giant pyramidal cells. Large pyramidal cells have fast-conducting axons and background impulse activity of about 5 Hz, which, when moving, increases to 20-30 Hz. These “fast” pyramidal cells innervate large (high-threshold) gamma-motoneurons in the motor centers of the brain stem and spinal cord, which regulate phasic movements. Thin, slowly conducting myelinated axons depart from small pyramidal cells. These cells have a background activity of about 15 Hz, which increases or decreases during movement. They innervate the small (low-threshold) gamma-motoneurons in the stem and spinal, motor centers that regulate muscle tone.

4. Visual material:

- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback:

1. To which system of the body are the spinal, medulla and hindbrain attributed?
2. What are the functions of the spinal cord?
3. What is a brainstem?
4. What structures form the midbrain?
5. What are the functions of the midbrain?
6. What is the cerebral cortex?

Lecture No.2

1. Theme: Physiology of the analyzers.

2. Learning goals: to study structural and functional features of the Visual, olfactory, auditory, vestibular and taste analyzers

3. Lecture thesis:

The most important information comes from the external environment through a visual analyzer. The peripheral part of the visual analyzer is especially complicated. It is represented by the eyeball. The latter is a system that refracts light rays. Refractive media include the cornea, anterior chamber fluid, the lens andthe vitreous body. The iris, like a diaphragm in a camera, regulates the flow oflight. Circular muscles embedded in it, receive parasympathetic innervation, radial - sympathetic. With an increase in the tone of the parasympathetic nerve system, the size of the pupil decreases, with an increase in the tone of the sympathetic one, it increases. The lens has the shape of a biconvex lens. The main function of the lens is to refract the rays of light passing through the lens and focus the image on the retina. The refractive power of the lens is not constant and, due to the fact thatit can take a more convex shape, ranges from 19 to 33 diopters. Change in the shape of the lens (accommodation) is achieved by contraction or relaxation of the ciliary muscle, which is attached to the lens capsule by means of Zinn ligaments. Itis assumed that the mechanism of accommodation is provided by subcortical and cortical visual centres. These formations regulate the tone of the ciliary muscle. Due to the fact that the lens is not an ideal lens, the rays of light passing through its peripheral part are refracted more strongly, as a result of which the image is distorted - a spherical aberration. Light of different wavelengths is also refractedby the lens unequally, and chromatic aberration occurs. Astigmatism is a defect in the light-refracting medium of the eye, associated with the uneven curvature oftheir refractive surfaces. The first three neurons of the visual pathways are embedded in the retina: cells with a rod-shaped end and cones, which transmit impulses to bipolar cells, the latter - to the ganglion cells. Axons of ganglion cells make up the optic nerve. In the region of the Sella turcica, a partial cross of the optic nerve occurs, and two optic tracts are formed. Each carries the fibres of the right and left eyes. They end in the subcortical centres: the lateral geniculate bodies, the anterior colliculi of the midbrain and the pulvinar of the thalamus. From here the fibres are sent to the occipital region of the cortex.

Information processing in the centres. Information processing in the visual analyzer begins at the periphery - directly on the retina. The photoreceptor itself (rod or cone) is designed in such a way that,under the influence of the appropriate wavelength of light; a change occurs in it: the chromophore group of the visual pigment (cis-retinal) absorbs a quantum of light and, under the influence of excess energy, it transforms into another form (trans retinal). This leads to the fact that the retinal splits off from the protein (opsin); at the same time, a signal, most likely calcium ions, is released. These ions approach the membrane of the receptor and cover the sodium channels. As a result, hyperpolarization occurs (generation of receptor potential). This is the only exception to the rule when the receptor potential is hyperpolarizing, and not depolarizing (as in all other receptor formations). What happens next? The receptor cell is in contact with the bipolar cell, which is in a constant hyperpolarizing state in dark conditions. This condition occurs under the influence of a continuously released mediator from the photoreceptor.

The receptors of the olfactory analyzer are embedded in the nasal mucosa, in the area of the superior nasal concha. They are sensitive hair cells located among the supporting cells included in the epithelium. Nerve fibres extending from sensory cells make up the olfactory nerves ending in olfactory bulbs. The latter hasa very complex structure - they consist of six layers of specialized neurons, in which the primary processing of information takes place. The axons of these cells are sent to the subcortical centres, the neurons of which give axons that enter the cortical centres - in the area of the hippocampus.

Structure of the organ of hearing.

Hearing is a subjective perception of the mechanical energy of air vibrations. Perception of this form of energy is performed by the special organ of hearing, which consists of three parts: the outer, middle and inner ear.

The external ear consists of the auricle and an external auditory canal.

The auricle is a fold of the skin, freely projecting on the head surface, based on the elastic cartilage plate. The external ear canal in an adult has a length of up to 2.5 cm, is lined with skin, a feature of which is the presence of glands secreting cerumen (earwax). Cerumen and hairs have a protective value, since they prevent the penetration of foreign bodies into the deeper parts of the external auditory meatus. On the border between the outer and middle ear the tympanic membrane (the eardrum) is stretched. Its thickness is about 0.1 mm. The tympanic membrane is a connective tissue plate of oval shape, 9 and 11 mm in diameter, the outer side of which is covered with epidermis. Near the center the membrane is pulled intothe middle ear, as at this point the end of the handle of the malleus is weaved into its tissue. The membrane has elasticity, providing resistance to the pressure wave, which spreads through the ear canal. Due to the fact that the resistance of the tympanic membrane is the smallest at a frequency of oscillations of 800-900 per second, and due to the fact that the oscillations of the tympanic membrane die out very quickly, it is an excellent pressure transmitter and hardly distorts the shape of the sound wave.

The middle ear is represented by a middle ear cavity having an irregular shape, with a capacity of 0.75 ml. Its outer wall is presented by the tympanic membrane. An essential part of the middle ear is a chain of three bones: 1) malleus (a hammer) 2) incus (an anvil) and 3) stapes (a stirrup).

The hammer is woven into the eardrum by the handle, and the other side is articulated with an anvil. In turn, the long process of the anvil is articulated with the stapes head. The latter is connected to the edge of the oval window located on the inner wall of the tympanic cavity (the lower oval hole) by means of an annular ligament and rests against the membrane that tightens it. In addition to the lower oval hole on the inner wall of the tympanic cavity, there is an upper circular opening (a round window) leading to the top of the cochlea.

In the cochlea there is a liquid, the oscillations of which appear at the oval window and pass along the tunnels of the cochlea, reach the round window without fading, and stick out its membrane into the middle ear cavity. If this window were not present, then the oscillations would be impossible because of the incompressibility of the liquid. The tympanic cavity through the opening in the anterior wall is communicated by means of an auditory tube with a pharyngeal cavity. The length of the auditory tube is 3.5 cm on average and 2 mm in diameter. With the act of swallowing, the opening of the tube into the pharynx opens, which leads to equalization of pressure in the middle ear with external atmospheric pressure. This structure provides the same air pressure on both sides of the tympanic membrane. Otherwise, with a large pressure difference outside the membrane and inside the middle ear, for example, with very strong sound, lifting on the airplane and other influences, a rupture of the tympanic membrane may occur.

The inner ear includes the bone labyrinth, which lies in the pyramid of the temporal bone and is a complex channel. Inside the bone labyrinth is a membranous labyrinth, repeating the shape of the bone labyrinth. The diameters of the membranous labyrinth are smaller than the corresponding diameters of the sections of the bone labyrinth, and therefore there is a narrow space between the outer surface of the membranous labyrinth and the inner surface of the bonelabyrinth filled with liquid called perilymph.

The membranous labyrinth is a closed system of cavities and channels, also filled with liquid called endolymph. The bone labyrinth consists of three sections: the vestibule, the cochlea and the semicircular canals.

The vestibule is a middle part of the inner ear. It communicates with the semicircular canals at the back and with the cochlea in front. On the outer wall of the vestibule facing the tympanic cavity, there is an oval window. In the vestibule on the beginning of the cochlea there is a round window, tightened by the so-called secondary tympanic membrane.

The vestibular apparatus is the organ of perception of the position of the body and the preservation of equilibrium. Any change in the position and movement of the body in space causes irritation of the receptors of the vestibular apparatus, resulting in reflexes providing coordinated tonic contractions of the muscles, by means of which the position of the body is leveled and equilibrium is maintained.

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The main taste sensations are sweet, bitter, salty and sour. The remaining taste sensations, of which there are many, are combinations of these four basic ones. For the perception of taste irritations, food temperature matters. Too hot or too cold food lowers the sensation. For example, hot tea seems less sweet than chilled. The watermelon from the refrigerator is almost tasteless. The taste of food is most pronounced at 24 ° C. Taste receptors are capable of adaptation to bitterand sweet taste. The sensation of the sweet is perceived by the front part of the tongue, especially its tip, the feeling of bitter – by the back part (root). The lateral surfaces of the tongue are more sensitive to sour and salty than to sweet and bitter.

4. Visual material:
- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback
1. To which system of the body are the visual and olfactory analyzers attributed?
2. What are the functions of the visual analyzer?
3. What are the functions of the olfactory analyzer?
4. What are the functions of the auditory analyzer?
5. What are the functions of the vestibular analyzer?
6. What are the functions of the taste analyzer?

Lecture No.3

1. Theme: Physiology of the cardiac activity. Haemodynamics.

2. Learning goals: to study functional features of the cardiac muscles.

3. Lecture thesis:

In the process of life activity, in accordance with changes in the organs and systems needs in the blood supply, there is a constant change in the work of the heart. The cardiac activity satisfies the needs of the body with the help of nervous influences that change the function of the myocardium.

* chronotropic effect – the rate of the heart contractions
* inotropic effect – the strength (amplitude) of the cardiac activity.
* bathmotropic effect – excitability of the cardiac muscle
* dromotropic effect - conductivity of the heart

The parasympathetic nervous system causes negative effects, the sympathetic nervous system – postive.

The heart has developed parasympathetic and sympathetic innervation. Parasympathetic preganglionic fibers, which supply the heart, are the axons of nerve cells located in the dorsal and ventral nuclei of the vagus nerve within the medulla oblongata. These fibers go in the structure of the vagus nerve, which after passing into the pectoral cavity branch into the upper, middle, and lower cardiac nerves. Entering the heart, preganglionic parasympathetic fibers terminate on neurons that form parasympathetic ganglia in the heart. From these cells, short postganglionic parasympathetic fibers begin abundantly innervating the elementsof the conductive system and muscle fibers (see figure below).

Sympathetic preganglionic cardiac fibers begin from neurons located in the lateral horns of the five upper thoracic segments of the spinal cord. The axons of these neurons terminate on the cervical and upper thoracic sympathetic ganglia. In these ganglia, there are the second neurons of the sympathetic nervous system are located. From them, the processes forming the postganglionic nerve fibers leave;by the way, most of them begin from the cells of the upper thoracic (stellate) ganglion.

Postganglionic fibers enter in the structure of the branches of the cardiac nerves, come in the heart and terminate on different structures of the myocardium (see figure above).

When the vagus nerve is excited, acetylcholine is excreted in nerve endings, and when the sympathetic nerve is excited, noradrenaline is released; these neurotransmitters are rapidly degraded by specific enzymes. Therefore, they have an effect only at the site of their secretion, and its effect is sort.

Therefore, the transection of both vagus nerves leads to an increase in heart rate. The cessation of the impulses to come along sympathetic nerves (with extirpation of stellate ganglia) does not lead to a persistent slowing of the rhythm of heartbeats, since the tonic activity of neurons in sympathetic centers is poorly expressed.

Reflex regulation of the cardiac activity is carried out with the participation of the vagus nerve nucleus, the centers of the sympathetic nervous system, as well as of the centers of the hypothalamic region of the diencephalon and the centers of the cerebral cortex.

From the numerous exteroceptors (visual, auditory, nociceptive, etc.) and interoceptors, these centers receive impulses that excite them. From these centers by efferent nerve fibers impulses go to the heart and change its activity in one direction or another, depending on the need to adapt the heart activity to current conditions of existence.

So, for example, when a person is exposed to cold or painful stimuli, the tone of the sympathetic nervous system rises, therefore, the strength and rhythm of the heart beats increase. Under the heat, the tone of the vagus nucleus increases, therefore, the heartbeat rate slows down.

An important effect on the heart is irritation of the vascular interoceptors, especially located in the so-called reflexogenic zones. The most important among them are baro- and chemoreceptors of the aorta arch and carotid sinus, receptors of the pulmonary artery and veins, and others.

In the heart, there are different reflexes implemented, what ensures adjusts heart activity to the needs of other systems and the whole organism. Signals from various receptors of the digestive tract, organs of urination, muscle and other systems come to the neurons of the cardiac activity centers and are realized on the heart by sympathetic and parasympathetic influences.

An example of such a reflex regulation of cardiac activity is the Golts reflex. If the intestine of a frog is irritated by spatula, then a cardiac arrest may occur due to reflexive excitation of the vagus nucleus. By the same mechanism, there is the oculomotor reflex of Danini-Ashner: during pressing on the eyeballs, the pulse slows down.

The heart has a large number of receptors, which are found in all layers of the heart – epicardium, myocardium, endocardium. Mostly, they refer to mechanoreceptors, but in the heart there are also chemoreceptors. Adequate irritations of these receptors lead to reflexes that change activity of the heart, adapting it to the current activity of the body. Such reflexes are said to be cardiocardiac ones.

The change in cardiac activity happens with strong emotions: fear, anger, joy, anxiety, etc. Heartbeat get quickening, and even arrhythmia ("heart freezes") usually occur. The influence of emotions on cardiac activity indicates a significant role of the cerebral cortex and hypothalamus in the regulation of the heart.

Humoral regulation of the cardiac activity

A number of substances entering the blood from the glands, other organs and tissues have essential value in the regulation of the heart functions. They are acetylcholine, which mainly slows down and inhibits the activity of the heart, norepinephrine, which intensifies and increases the contraction of the heart. The adrenaline enters the bloodstream from the adrenal glands and acts on the heart as well as the excitation of the sympathetic nervous system – it increases the amplitude of the contractions and the heart rate. However, due to hypertension, epinephrine can simultaneously increase the tone of the center of the vagus nerve. Therefore, when adrenaline is injected into the blood, the heart beats often slow down. Thyroid hormone – thyroxine – increases the frequency of the heart contractions.

Humoral factors of the regulation of cardiac activity include certain electrolytes. The change in the concentration of potassium and calcium has a very significant effect on the automaticity, excitability, and contractility of the heart.

A significant increase of the potassium level in the blood inhibits the activity of the heart, and excess calcium level in a certain range acts in the opposite direction.

Thus, the regulation of the heart is carried out by a whole complex of central and peripheral nervous apparatus and neuro-humoral factors, adjusting the heart activity to the needs of the organism.

Innervation of blood vessels

Vessels of the body are supplied with vasoconstrictive (pressor) and vasodilative (depressor) nerves.

Vessels are supplied with two types of receptor perceiving the neurotransmitter: alpha-receptors and beta-receptors. The influence of noradrenaline and adrenaline on the alpha-receptors cause vasoconstriction, on beta-receptors – dilation. Vascular dilation under the influence of noradrenaline, i.e., sympathetic nerves, is indicated for vessels of skeletal muscles, vessels of the brain and heart.

It should be noted that the coronary vessels constrict with the stimulation of parasympathetic fibers passing through the vagus nerve. It is believed that an increase in parasympathetic influences can be of great importance in the development of the stenocardia.

Vasomotor center

Neurons that regulate vascular tone are located in several parts of the central nervous system: the spinal cord, medulla oblongata, diencephalon, and cerebral cortex.

The vasomotor center was discovered opened by Ovsyannikov F.V. in 1971. Neurons of the vasoconstrictor center are in constant tonus, which provides a certain narrowing of the vessels. At the same time, irritation of the areas of the medulla oblongata adjacent to the vasoconstrictor center, leads to vasodilation anda drop in blood pressure.

Therefore, in the medulla oblongata, there are two parts: vasoconstrictive and vasodilative. If the former is irritated, the pressor effect (increase in arterial pressure) occurs; while if the last one irritated – the depressor effect (lowering of arterial pressure) takes place. It is believed that the excitation of vasodilative neurons of the center suppresses the activity of vasoconstrictor neurons, which leads to vasodilation. Perhaps, the opposite relationships take place.

Vasoconstrictive and vasodilative parts of the vasomotor center do not have sharp boundaries, overlapping each other at the bottom of the fourth ventricle. The neurons of the vasoconstrictor center located in the medulla oblongata influence on the activity of the neurons of the sympathetic nervous system located in the lateral horns of the spinal cord. These nerve cells constitute the spinal vasoconstrictor center.

In the hypothalamus there are higher subcortical vegetative centers, including the vasomotor ones. Irritation of certain areas of the hypothalamus leads to a constriction of arteries and arterioles and an increase of blood pressure. The cerebral cortex also participates in the regulation of vascular tone. The evidence is the effect of destruction and irritation of certain areas of the cerebral cortex on blood pressure, the possibility of developing conditioned vasomotor reflexes, as well as changes in the tone of blood vessels in a person during emotions. Most vascular reactions are components of the complex organization of unconditioned and conditioned reflexes.

Thus, the vasomotor center is represented by neurons of different levels of the central nervous system, beginning with the spinal cord and ending with the cortex of the brain.

Higher centers located in the cerebral cortex and hypothalamus fulfill their influence through bulbar and spinal centers. The latter, due to their wide afferent and efferent connections to the entire cardiovascular system, play a leading role in maintaining vascular tone.

Reflex regulation of the vascular tone

The lumen of the vessels is determined by the tone of the vasomotor center. This tonic activity of neurons is provided by impulses coming to this center from receptors located in the vascular system itself, in the internal organs and on the surface of the body.

Especially of great importance for the regulation of vascular tone are reflexes caused by stimulation of receptors in the vessels themselves. They are primarily baroreceptors, which change their activity with fluctuations in blood pressure, and chemoreceptors, whose activity varies with the composition of the blood. The main role in the regulation of arterial pressure is performed by receptors located in three regions of the vascular bed: aortic arch, carotid artery branching region, and in the place where the upper and lower cava veins enter in the right atrium. These areas, called the vascular reflexogenic zones.

Humoral regulation of the vascular tone

Humoral regulation is carried out by chemical substances (hormones, metabolic products, etc.) circulating in the blood or formed in tissues during stimulation. These biologically active substances either constrict or dilate the vessels. Vasoconstrictor substances include: adrenaline, noradrenaline, vasopressin, angiotensin II, serotonin.

Vasodilators include acetylcholine, histamine, kinins and some metabolic products.

On the electrocardiogram, each cardiac cycle contains the 6 waves: P, Q, R, S, T, and U. P wave reflects the period of atrial excitation. Segment P-Q is the period of passage of the impulse through the atrioventricular node. The QRST complex reflects the process of excitation in the ventricles. A downwardly directedQ wave corresponds to excitation of papillary muscles. The highest, upwardly directed R wave reflects the spread of excitation in the base of the ventricles. The S wave directed downward corresponds to the full coverage of the ventricles by excitation. T wave and segment S-T reflect metabolic processes in the myocardium.

The blood and lymph continuously move through the vessels of a human body, which form dense networks in organs and tissues. This movement results in supplying the cells and tissues with oxygen, nutrients, immune substances, hormones, and other necessary chemicals. It also carries away from tissues waste product of metabolism and carbon dioxide. It equalizes body temperature and helps maintain normal water and electrolyte balance.

Arteries are the vessels that carry blood from the heart to the organ.

Veins are the vessels that carry blood from the organs to the heart.

In systemic circulation, arteries carry arterial blood, veins – venous.

In the pulmonary circulation, vice versa: arteries contain venous blood,venous – arterial.

From the ventricles, blood circulations begin; in the atrium – end.

Pulmonary circulation

From the right ventricle, pulmonary circulation begins. Pulmonary circulation serves for the oxygen enrichment of the blood in the lungs. From the right ventricle, pulmonary trunk begins, which branches within the lungs in arteries, which as well branch becoming capillaries. In the capillary network, surrounding alveoli, the blood releases carbon dioxide and is saturated with oxygen. Enriched with oxygen arterial blood moves from the capillaries to the veins, which merging in four pulmonary veins, entering into left atrium of the heart. Pulmonary circulation ends in the left atrium.

Systemic circulation

Coming to the left atrium arterial blood passes through mitral valve into the left ventricle, from which systemic circulation begins.

The systemic circulation provides organs and tissues with oxygen and nutrients. It begins from the left ventricle of the heart. From the left ventricle aorta carrying arterial blood originates. Then aorta branches on arteries, which run to all organs and tissues, and in their mass further branch in arterioles and further – in capillaries. Through the capillary wall exchange of oxygen and metabolic substances occurs between the blood and the tissues. Arterial blood, flowing in capillaries, gives to the tissues nutrients and oxygen, and takes from the tissues waste product of metabolism including carbon dioxide. Capillaries come together forming venules; the latters coming together forms veins. The blood that enters into venous vessels is poor in oxygen and enriched with carbon dioxide.

Eventually, veins get together in two major trunks – superior vena cava and inferior vena cava. These vessels enter in the right atrium of the heart. At this point systemic circulation ends.

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Movement of the Blood in the Vessels

Owing to heart contractions, the blood is erupted with force in the systemic and pulmonary circulations. Since the blood vessels are the system of tubes, then the blood movement in vessels happens in accordance with the laws of hydrodynamics, i.e. laws of liquid motion.

According to these laws, movement of fluid is determined by both factors: pressure, under which the fluid is driven, and resistance, which flowing liquid undergoes due to friction against vessel walls. The first factor contributes to flowing of the fluid, but the last factor prevent to motion.

The main patterns of haemodynamic

Laws of hydrodynamics imply that the flow of the blood in the vesseldepends on: 1) force of the heart contraction and the volume of the blood erupted (which cause value of potential energy providing the blood flow); 2) resistance, which flowing liquid undergoes due to friction against vessel walls; overcoming of this resistance consumes energy at the most.

In contrast to movement of liquid in tubes under the continuous pressure, the blood flows from the heart to the vessels not continuously, but as intermittent stream. The heart throws into the blood vessels individual portions of blood only during systole. Despite this fact, the blood flows in the vessels as continuous jet. Blood flow becomes continuous owing to elasticity of walls of aorta, pulmonary trunk, and large arteries which are attributed to the blood vessel of elastic type.

Part of kinetic energy of blood pressure which is developed by the heart during systoles, is spent on stretching of aorta and its main branches. In this case, kinetic energy is transformed to energy of elastic tension of arterial walls. When systole ends, arterial walls due to elasticity return to initial state providing pressure which evenly moves the blood in the vessels during diastole.

Turbulent or laminar blood flow

Resistance to blood flow and viscosity also depend on the nature of the blood flow – turbulent or laminar. In conditions of resting state, laminar, i.e., bloodflow by layers, is observed in almost all parts of the circulatory system, without turbulence and intermixing of the layers. Near the wall of the vessel, there is alayer of plasma, the speed of which is limited by the fixed surface of the vessel wall; the layer of erythrocytes moves at a high speed along the axis of a vessel. Thelayers slide relatively to each other, which creates resistance (friction) to the blood flow as for heterogeneous liquid. With a decrease in the blood velocity, the viscosity increases, under physiological conditions, this manifests itself in vessels with a small diameter. Exceptions are capillaries, in which the effective viscosityof the blood reaches the plasma viscosity due to the peculiarities of the movement of red blood cells. They slide, moving one behind the other (one in the chain) inthe "lubricating" layer of the plasma and deforming in accordance with the diameter of the capillary.

Turbulent flow is characterized by the presence of whirls, while the blood moves not only in parallel to the axis of the vessel, but also perpendicular to it. Turbulent flow is observed in the proximal parts of the aorta and pulmonary trunk during the expelling of the blood from the heart; local whirls can be created in the places of branching and narrowing of the arteries, in the region of steep artery bends. The movement of blood can become turbulent in all large arteries with increasing volume blood flow velocity (for example, with intensive muscle work) or a decrease in blood viscosity (with severe anemia). Turbulent movement significantly increases the internal friction of the blood, and to move it requires much more pressure, in this case the load on the heart increases.

Arterial blood pressure

As it is indicated above, value of blood pressure depends on both factors: volume of the blood entering in arteries as a result of cardiac output and resistance against bloodstream in the vessels.

In accordance with this, arterial blood pressure rises, if cardiac output increases. Cardiac output is the effective volume of blood expelled by ventricle of the heart per unit of time (generally per minute); it usually refers to left ventricle output. It is equal to the beat (contraction) volume multiplied by the heart rate. Normal values are 4 to 8 liters per minute.

On contrary, reducing of cardiac output leads to decreasing of arterial pressure. So, for example, during insufficient contractile function of the heart, cardiac output may drop down, and, as a sequence, systemic arterial blood pressure decreases.

During the rising the strength of cardiac contraction or rising the cardiac rate (e.g. during physical labor), arterial blood pressure increases, since the cardiac output being increased.

Under the constant cardiac output, value of arterial blood pressure is not equal in different parts of vascular system.

In the aorta, where the blood is expelled with strength, there is the highest pressure achieving 130-140 mm Hg. Art. With the distance from the heart increased, arterial pressure falls down, since energy creating the pressure is spent on overcoming the resistance against the blood flow.

The stronger vascular resistance, the more energy is spent for the blood to be moved, consequently, the more value of decreasing the pressure on the distance of the given vessel.

The pressure in the large and medium arteries falls just by 10 per cent, but in arterioles and capillaries – by 85 per cent. Distribution of the blood pressure values in different parts of vascular system is shown in the figure below.

Resistance to blood flow rises with decreasing the vessel lumen and with increasing its length. That is why, in the arteries of large and medium diameters, but with short length, the degree of blood pressure fall is not so high. For example, in aorta with a diameter of 8 cm and with a length of just several cm.

In arterioles and capillaries (in very narrow vessels) which forms largelength of blood vessel system, degree of blood pressure fall is the most significant. If lengths of all human capillaries are summed up, then it may be equal to about 100 thousand km. However, the most sharp blood pressure fall is observed in arterioles. The cause in the fact that due to big number of arterioles (several hundred thousand), total value of their internal surface by decades times as muchas the total surface of the rest larger arteries

Blood flow velocity in arterioles is still high: it is just by 2-3 times lesser than in aorta.

Blood flow velocity in the vessels

The blood flow velocity is higher in center of the vessel, than at its walls.

There are volume and linear blood flow velocity to be distinguished.
Volume velocity is amount of blood which passes through cross-section of the vessel per time unit on entire distance of vascular system.

Volume velocity (ml per sec) per unit of the body weight may be different in various organs, since value of blood flow in the different parts of the body is unequal. For example, blood flow for kidneys and liver per 100 g of their mass is equal to 420 and 150 ml/sec accordingly; for muscles of the arms and legs (in the resting state) this velocity is equal to 2-3 ml/sec.

Linear velocity is the way, which a blood particle passes per time unit; in various parts of the body are different. The blood as any liquid flows quicker in those places where total lumen of the vessels is the narrowest (e.g. water flows quicker in the less wide (narrow) part of the river).

Peculiarities of the Blood Flow in Veins

Valves and mechanical pressure during the contraction of skeletal muscles contributes to the movement of the blood in veins. Semilunar valves open in the heart direction. If in the certain place muscles contract, then this contraction squeezes the vein contributing to the flowing the blood to the heart.

When muscles relax, then the blood cannot move back in opposite direction due to the vein lumen has been closed by valves.

4. Visual material:

- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback

1. What is the minute volume of the blood?
2. Which functions does the heart fulfil?
3. How many phases in the cardiac cycle?
4. What is blood pressure?
5. What is arterial pulse?
6. What does haemodynamics study?

Lecture No. 4

1. Theme: Physiology of the lymphatic system. Functions of the haematopoietic organs. Immunity.

2. Learning goals: to study laws of haemodynamics, the haematopoietic organs, notion of the immunity, types of immunity.

3. Lecture thesis:

The lymphatic system is part of the circulatory system and an important part of the immune system, comprising a network of lymphatic vessels that carry a clear fluid called lymph (from Latin, lympha meaning "water") directionally towards the heart.

Unlike the circulatory system, the lymphatic system is not a closed system. The human circulatory system processes an average of 20 liters of blood per day through capillary filtration, which removes plasma while leaving the blood cells. Roughly 17 litres of the filtered plasma are reabsorbed directly into the blood vessels, while the remaining three litres remain in the interstitial fluid. One of the main functions of the lymph system is to provide an accessory return route to the blood for the surplus three litres.

The other main function is that of defense in the immune system. Lymph is very similar to blood plasma: it contains lymphocytes. It also contains waste products and cellular debris together with bacteria and proteins. Associated organs composed of lymphoid tissue are the sites of lymphocyte production. Lymphocytes are concentrated in the lymph nodes. The spleen and the thymus are also lymphoid organs of the immune system. The tonsils are lymphoid organs that are also associated with the digestive system. Lymphoid tissues contain lymphocytes, and also contain other types of cells for support. The system also includes all the structures dedicated to the circulation and production of lymphocytes (the primary cellular component of lymph), which also includes the bone marrow, and the lymphoid tissue associated with the digestive system.

The blood does not come into direct contact with the parenchymal cells and tissues in the body (except in case of an injury causing rupture of one or more blood vessels), but constituents of the blood first exit the microvascular exchange blood vessels to become interstitial fluid, which comes into contact with the parenchymal cells of the body. Lymph is the fluid that is formed when interstitial fluid enters the initial lymphatic vessels of the lymphatic system. The lymph isthen moved along the lymphatic vessel network by either intrinsic contractions of the lymphatic passages or by extrinsic compression of the lymphatic vessels via external tissue forces (e.g., the contractions of skeletal muscles), or by lymph hearts in some animals.

The organization of lymph nodes and drainage follows the organization of the body into external and internal regions; therefore, the lymphatic drainage of the head, limbs, and body cavity walls follows an external route, and the lymphatic drainage of the thorax, abdomen, and pelvic cavities follows an internal route. Eventually, the lymph vessels empty into the lymphatic ducts, which drain into one of the two subclavian veins, near their junction with the internal jugular veins.

The lymphatic system consists of lymphatic organs, a conducting network of lymphatic vessels, and the circulating lymph.

The primary or central lymphoid organs generate lymphocytes from immature progenitor cells.

The thymus and the bone marrow constitute the primary lymphoid organs involved in the production and early clonal selection of lymphocyte tissues. Bone marrow is responsible for both the creation of T cells and the production and maturation of B cells. From the bone marrow, B cells immediately join the circulatory system and travel to secondary lymphoid organs in search of pathogens. T cells, on the other hand, travel from the bone marrow to the thymus, where they develop further. Mature T cells join B cells in search of pathogens. The other 95% of T cells begin a process of apoptosis, a form of programmed cell death.

Secondary or peripheral lymphoid organs, which include lymph nodes and the spleen, maintain mature naive lymphocytes and initiate an adaptive immune response. The peripheral lymphoid organs are the sites of lymphocyte activation by antigens. Activation leads to clonal expansion and affinity maturation. Mature lymphocytes recirculate between the blood and the peripheral lymphoid organs until they encounter their specific antigen.

Secondary lymphoid tissue provides the environment for the foreign or altered native molecules (antigens) to interact with the lymphocytes. It is exemplified by the lymph nodes, and the lymphoid follicles in tonsils, Peyer's patches, spleen, adenoids, skin, etc. that are associated with the mucosa-associated lymphoid tissue (MALT).

In the gastrointestinal wall the appendix has mucosa resembling that of the colon, but here it is heavily infiltrated with lymphocytes.

The lymphatic vessels, also called lymph vessels, conduct lymph between different parts of the body. They include the tubular vessels of the lymph capillaries, and the larger collecting vessels–the right lymphatic duct and the thoracic duct (the left lymphatic duct). The lymph capillaries are mainly responsible for the absorption of interstitial fluid from the tissues, while lymph vessels propel the absorbed fluid forward into the larger collecting ducts, where it ultimately returns to the bloodstream via one of the subclavian veins. These vessels are also called the lymphatic channels or simply lymphatics.

The lymphatics are responsible for maintaining the balance of the body fluids. Its network of capillaries and collecting lymphatic vessels work to efficiently drain and transport extravasated fluid, along with proteins and antigens, back to the circulatory system. Numerous intraluminal valves in the vessels ensure a unidirectional flow of lymph without reflux. Two valve systems are used to achieve this one directional flow—a primary and a secondary valve system. The capillaries are blind-ended, and the valves at the ends of capillaries use specialised junctions together with anchoring filaments to allow a unidirectional flow to the primary vessels. The collecting lymphatics, however, act to propel the lymph bythe combined actions of the intraluminal valves and lymphatic muscle cells.

Functions

The lymphatic system has multiple interrelated functions:

It is responsible for the removal of interstitial fluid from tissues

It absorbs and transports fatty acids and fats as chyle from the digestive system. Chyle is milky fluid consisting of fat droplets and lymph. It drains from the lacteals of the small intestine into the lymphatic system during digestion.

It transports white blood cells to and from the lymph nodes into the bones The

lymph transports antigen-presenting cells, such as dendritic cells, to the lymph nodes where an immune response is stimulated.

Fat absorption

Lymph vessels called lacteals are in the beginning of the gastrointestinal tract, predominantly in the small intestine. While most other nutrients absorbed by the small intestine are passed on to the portal venous system to drain via the portal vein into the liver for processing, fats (lipids) are passed on to the lymphaticsystem to be transported to the blood circulation via the thoracic duct. (There are exceptions, for example medium-chain triglycerides are fatty acid esters of glycerol that passively diffuse from the GI tract to the portal system.) The enriched lymph originating in the lymphatics of the small intestine is called chyle. The nutrients that are released to the circulatory system are processed by the liver, having passed through the systemic circulation.

Blood formation and regulation of the blood system

Blood system includes the blood and organs in which the formation and destruction of the blood cells take place, as well as organs involved in the redistribution of the blood. It includes: blood circulating in the vessels, red bone marrow, spleen, lymph nodes and liver.

In the red bone marrow, from a single so-called multipotential hematopoietic stem cell (hemocytoblast), all kinds of the blood cells arise. There are three types of blood lineages: 1) leukocyte, from which granulocytes, monocytes, and lymphocytes originate; 2) erythrocyte producing red blood cells; 3) megakaryocytic one, from which platelets are formed.

Stem cells are not differentiated; these cells are similar in appearance to lymphocytes, are capable of self-maintenance and differentiation in all blood cell lineages. Differentiation of the stem cell is a multi-stage process, which is starting with the formation of morphologically similar progenitor cells of each lineage. Then, proliferation and gradual differentiation of the cells happen, which are specific for each lineage in the form of granulocytopoiesis (three kinds of granulocytes), monocytopoiesis, lymphopoiesis (B- and T-lymphocytes), erythropoiesis. During the development, the cells acquire morphological, histochemical and functional characteristics of each type of blood cell and at a certain stage lose the ability to split.

It is believed that the differentiation of blood cells is determined by the stromal cells of the organ in which this differentiation take place. Bone marrow stromal cells determine differentiation towards myelocytopoiesis, i.e. granulpoiesis, monocytopoiesis, erythropoiesis and thrombopoiesis. The spleen cells determine differentiation towards lymphopoiesis.

There is a point of view that liver Kupffer cells, also known as stellate macrophages, all tissular macrophages (connective tissue histiocytes, spleen macrophages, bone marrow, lymph nodes, osteoclasts, microglial cells of nervous tissue, etc.), which are united in a mononuclear phagocyte system, are derived from hematopoietic cells – monocytes, rather than reticular cells and endothelium.

An important factor in the regulation of hematopoiesis is the hemopoetic sensitivity of the progenitor cells of all three lineages. The fundamental importance of this property is expressed in the fact that hemopoetic-sensitive cells are able to respond to distant humoral stimuli. Hemopoietins stimulate the proliferation of hematopoietic cells. There are erythropoietins, leukopoietins, and thrombopoietins.

In developing embryos, blood formation occurs in aggregates of blood cells in the yolk sac, called blood islands. As development progresses, blood formation occurs in the spleen, liver and lymph nodes. When bone marrow develops, it eventually assumes the task of forming most of the blood cells for the entire organism. However, maturation, activation, and some proliferation of lymphoid cells occurs in the spleen, thymus, and lymph nodes. In children, haematopoiesis occurs in the marrow of the long bones such as the femur and tibia. In adults, it occurs mainly in the pelvis, cranium, vertebrae, and sternum.

Regulation of erythropoiesis

Normally, a constant number of erythrocytes is maintained in a humanblood. About 200-250 billion erythrocytes are formed during one day. At the same time, 0.8% of erythrocytes are degraded daily and the same number is produced again. If there is an increased destruction of erythrocytes, then their formation increases. The erythropoiesis stimulant is erythropoietin, which is hormone of glycoprotein nature with a molecular weight of 40,000-70,000.The main place of erythropoietin secretion are the kidneys.

It is possible that erythropoietin is produced in a certain amount in other organs and tissues. The most frequent stimulus for the erythropoietin production is hypoxia, which causes increased multiplication of hematopoietic cells. In particular, increased production of erythropoietin and erythrocytes happens in high-altitude areas with a low partial pressure of oxygen in the air; this also takes place during blood loss, mass degradation of erythrocytes, and hemolytic anemia.

To create a normal amount of red blood cells, other humoral stimulants are also needed. Active factors of hematopoiesis include vitamin B12 (cyanocobalamin) and folic acid. The first is 1000 times more active than folic acid. Vitamin B12 is called an external factor of hematopoiesis, as it enters the body with food. It is found in meat, eggs, yeast, bran; especially liver is rich withit. Vitamin B12 can be absorbed only if there is a so-called gastric intrinsic factorin the stomach, which is a mucoprotein secreted by the parietal cells of the stomach.

Vitamin B12 interacts with gastric intrinsic factor forming a biologically active complex that is absorbed, then is deposited in the liver; from there it enters the bone marrow, where it stimulates erythropoiesis. It is believed that vitamin B12 and intrinsic factor contribute to the synthesis of globin. Vitamin B12 and folic acid provide the synthesis of DNA in developing nuclear forms of erythrocytes. Erythropoiesis is weakened if the intake of vitamin B12 decreases or the production of the gastric intrinsic factor providing the absorption of this vitamin also decreases (due to impairment of vitamin B12 absorption during aging, people over age 60 are at risk of deficiency). Secretion of intrinsic factor might be reduceddue to various diseases of the stomach, for example, connected with atrophy of its mucosa. In these cases, pernicious anemia caused by B12-deficiency develops.

Plasma proteins, hormones, especially the pituitary hormones, and metabolic products can have a significant effect on hematopoiesis.

Erythrocytes are destroyed in the spleen, liver, and bone marrow. The more erythrocytes are destroyed, the more degrading products are produced stimulating hematopoiesis; thereby the red blood cells provide adaptive self-regulation of hematopoiesis.

Regulation of leukopoiesis

The lifetime of different types of leukocytes varies from a few hours to several weeks.

Leukocytes are destroyed in the reticular tissue and on the surface of the mucosa of the digestive tract. Along with the destruction, new leukocytes are continuously formed. The number of leukocytes in the blood depends on thehumoral and nerve factors.

Leukopoiesis is stimulated by the degrading products produced during the destruction of the leukocytes themselves. The more leukocytes are destroyed, the more they are formed. The stimulating effect on leukopoiesis is caused by the degrading products of the tissues when they are damaged or during the inflammatory process develops. The injection of the proteins or nucleic acids into the body leads to neutrophilic leukocytosis with the appearance of young forms of neutrophils (stabs, myelocytes). Similar effect is possessed by pyrogens (substances that raise body temperature), endotoxins of bacteria, hormones of the cortical layer of the adrenal glands (glucocorticoids), pituitary gland (adrenocorticotropic hormone, somatotropic hormone). An increase in the number of neutrophils in these cases happens owing to the marrow granulocyte reserve.

Viral infection and antigens lead to excessive production of lymphocytes, what increases their amount in the blood. It is supposed that the effects increasing the formation of leukocytes lead to the production of leukopoietins, although the chemical compound and the location of secretion of the latters are not yet clear.

The nervous system has certain influence on the amount of the leukocytes in the blood. Excitation of the sympathetic nervous system, painful irritation, emotional stress lead to an increase in the number of leukocytes in the blood. The level of the white blood cells is also increased during muscular work, digestion due to redistribution of leukocytosis. It occurs due to the release of leukocytes in the blood circulation from the blood depots – from the spleen and the sinuses of the bone marrow. Leukocytosis due to digestion may be formed as a conditionedreflex.

The organs of the blood system contain a large number of receptive areas. In experimental conditions, it has been shown that the stimulation of these receptors causes various reflex reactions. There is a two-sided link between the organs of the blood system and the central nervous system. The organs of the blood system receive impulses from the central nervous system that regulates their state. At the same time, the organs of the blood system are the place of reflexes changing the state of themselves and other body systems. These mechanisms are aimed atmaintaining the constancy of the blood compound, as the internal environment of the body.

Regulation of thrombopoiesis

This phenomenon is least studied. It was found that blood plasma of healthy people has thrombopoietic activity. Thrombopoietins are attributed to proteins with high molecular weight belonging to gamma-globulins. Thrombopoietins are not homogeneous. Some of them stimulate the platelets formation in the bone marrow, others provide release of platelets into the blood.

4. Visual material:

- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback

1. What is the lymph?
2. From which constituents the lymph is being formed?
3. Which functions does the lymph fulfil?
4. Which organs are attributed to the haemopoietic ones?
5. What is immunity?
6. Which types of immunity do you know?

Lecture No. 5

1. Theme: Physiology of endocrine glands.

2. Learning goals: to study functions of the haematopoietic organs, notion of the immunity, types of immunity.

3. Lecture thesis:

Hypophiseal-hypothalamic system

The hypothalamic-hypophysial interaction is a highest level of hierarchy regulating functions of endocrine glands. The hypothalamus controls hypophysis, the hypophysis, in turns, controls other (peripheral) glands of an organism. At the same time, peripheral glands also influence on hypophysis and hypothalamus by feedback. Let’s see the hypothalamic-hypophysial system in more details.

Hormones of the Hypophysis

Hypophyseal hormones activate peripheral glands making them to secrete hormones. Hormones of the hypophysis have common term “tropins”.

Six important peptide hormones plus several less important one are secreted by the anterior pituitary, and two important peptide hormones are secreted by the posterior pituitary. The hormones of the anterior pituitary play major roles in the control of metabolic functions throughout the body.

Hormones secreted by anterior pituitary:

* Growth hormone
* Adrenocorticotropin (corticotropin)
* Thyroid-stimulating hormone (thyrotropin)
* Prolactin
* Two separate gonadotropic hormones, follicle-stimulating hormone and luteinizing hormone

Hormones released by posterior pituitary (but produced by hypothalamus):

* Antidiuretic hormone (also called vasopressin)
* Oxytocin

Hypothalamus

Almost all secretion by the pituitary is controlled by either hormonal or nervous signals from the hypothalamus.

Secretion from the posterior pituitary is controlled by nerve signals that originate in the hypothalamus and terminate in the posterior pituitary. In contrast, secretion by the anterior pituitary is controlled by hormones called hypothalamic releasing (liberins) and hypothalamic inhibitory (statins) hormones (or factors) secreted within the hypothalamus itself and then conducted to the anterior pituitary through minute blood vessels called hypothalamic-hypophysial portal vessels.

Regulation of hormone production

Regulation of synthesis and releasing hormones is provided by complex neurohumoral mechanisms. Changes in physiologic processes or changes in the level of any substances contained in the blood (under the influences from environment) lead to irritation of special nerve endings located in organs or sensory neurons of the CNS. These afferent signals achieve hypothalamic neurons and vegetative nervous system. Then, hypothalamic (via hypophysis) and autonomic neurons send efferent impulses to endocrine organs. Thus regulating effect on the producing and releasing the hormones is performed.

4. Visual material:

- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback

1. Which organs are attributed to the endocrine system?
2. What are hormones?
3. Which types of regulation of endocrine activity do you know?

Lecture No. 6

1. Theme: Functions of the digestive system

2. Learning goals: to study functions of the digestive system, particularly digestion of the oral cavity and the stomach, to reveal meaning of the digestive process for life activity of the organism; to study functions of the small intestine, toreveal meaning of the liver and the pancreas for digestion

3. Lecture thesis:

Digestion is a physiological process, owing to which food undergoes physical and chemical transformations; after this, nutrients are absorbed from the digestive tract and enter the blood and lymph.

The digestive tract carries out the following main functions: secretion, motion, absorption, excretion.

The digestive tract begins with a mouth vestibule followed by the oralcavity, where the food is mechanically processed and begins to undergo chemical transformation under the influence of a secret coming from the salivary glands. Then the oral cavity continues in narrow part of the digestive tract – pharynx and esophagus, through which a food lump follows into the stomach – the most expanded part of the digestive tract. In the stomach food undergoes further chemical transformations under the influence of gastric juice, secreted by theglands of the stomach. The stomach continues into the small intestine – the narrowest and longest part of the gastrointestinal tract.

In the small intestine, the most significant chemical transformation of nutrients takes place, since this organ is the place where pancreatic juice, which is very rich in enzymes, intestinal juice secreted by glandular intestine cells, bile produced by the liver come to. In the small intestine, absorption of breakdown products of proteins, fats, carbohydrates, and mineral salts occurs, which is provided by a special structure of the intestinal mucosa and its cellular elements. The small intestine continues into the broader part of the digestive tract – the large intestine.

Here, digestion is terminated; the absorption of water, mineral salts and the formation of fecal masses mainly take place. The digestive tract ends with anus, through which the undigested remnants of the food are removed from the body

Digestion in the oral cavity

The following processes take place in the oral cavity: grinding the food, wetting it with the saliva, partial breakdown of the carbohydrates, and forming a food lump. The tongue takes part in the gustatory sensation, chewing, and the swallowing a food lump. Teeth mechanically grind the food.

Salivary glands. In the oral cavity, salivary glands open and release their secretion. They are divided into two groups: small glands, which are embedded in the thickness of the mouth and tongue mucous membrane and according to their position are called palatine, buccal, lingual, labial and dental; large glands located outside the mucous membrane. Of these, the largest is the parotid gland located in submandibular fossa. With its upper part it attaches to the external ear canal; its front part lies on the masticatory muscle, and the lower part reaches the angle ofthe mandible. Its excretory duct penetrates the masticatory muscle and reach the vestibule of the oral cavity opening at the level of the upper second molar.

Organic substances of the saliva include: protein mucous compound (mucin), certain number of globulins, amino acids, urea, etc. The content of inorganic substances (salts of calcium, potassium, etc.) in saliva is 2-3 times less than organic ones.

Saliva contains two enzymes that cause hydrolytic breakdown of the carbohydrates to glucose. The first enzyme, amylase, or ptyalin, degrades the starch (polysaccharide) to the maltose (disaccharide). The second enzyme, maltase, degrades the maltose in two glucose molecules. The optimum effect of these enzymes is achieved in a slightly alkaline Ph. Saliva does not contain enzymes that break down proteins and fats.

Digestion in the stomach

There are three types of glands: cardiac glands (in the proximal part of the stomach), fundic (oxyntic) glands (the dominating type of gland), and pyloric glands. The cardiac glands mainly contain mucus-producing cells called foveolar cells. The bottom part of the oxyntic glands is dominated by zymogenic (chief) cells that produce pepsinogen (an inactive precursor of the pepsin enzyme). Parietal cells, which secrete hydrochloric acid (HCl) are scattered in the glands, with most of them in the middle part. The upper part of the glands consists of mucous neck cells; in this part the dividing cells are seen. The pyloric glands contain mucus-secreting cells.

After ingestion of various food substances the quantity and quality of gastric juice are different. In experiments on dogs with fistulas, it has been shown that juice is secreted at the most amounts for meat, and at fewer amounts for bread and at far fewer for milk. Releasing the juice begins in 5-9 minutes, but the duration of its releasing for different foods is also different. The juice is being secreted formeat for 7 hours, for bread for 10 hours, and for milk for 6 hours. The everyday consumption of different foods changes the quality of the gastric juice. In the juice, which is released when meat enters, there is more hydrochloric acid than in juice secreted for digestion of bread and milk. Depending on the type of food, the content of enzymes in the gastric juice, i.e. its digestive capacity, also varies. Most of all pepsin is contained in the juice secreted for bread digestion, least of pepsin issecreted for milk.

Digestion in the small intestine

In the small intestine, the most significant processes of digestion and the absorption of breakdown products into the blood and lymph take place. The chemical transformation of food in the small intestine happens under the influence of enzymes contained in the pancreatic and intestinal juice with the participation of bile, which is formed in the liver. Absorption of chemically modified nutrient substances is carried out owing to the special structure of the mucous membrane of the small intestine.

Major duodenal papilla

In the descending part of the duodenum there is a longitudinal fold terminating in the so-called major duodenal papilla, an opening of the Common bile duct and Pancreatic duct into the duodenum. The sphincter of Oddi (also hepatopancreatic sphincter or Glisson's sphincter) is a muscular valve that controls the flow of digestive juices (bile and pancreatic juice) through the major duodenal papilla.

Liver

The most important feature of the hepatic blood circulation is the fact that the liver is connected to two large blood vessels: the hepatic artery and the portal vein. The hepatic artery carries oxygen-rich blood from the aorta, whereas the portal vein carries blood rich in digested nutrients from the entire gastrointestinal tract and also from the spleen and pancreas. These blood vessels subdivide into small capillaries that enter the lobule and fuse there in liver sinusoids, which pass along the lobule.

Bile

Bile is being formed continuously in the cells of the liver. But it enters through the common bile duct into the duodenum only during digestion. When digestion stops, bile is stored in the gallbladder. Therefore, it is necessary to distinguish the liver bile, which comes directly from the liver into the intestine, andgallbladder bile, which flows from the gallbladder. The latter is more concentrated,darker and thicker, since, in the gallbladder, there is a partial absorption of bile water.

In humans, 500-700 ml of bile is formed per a day. Compound of the bile comprises: water (90%), organic and inorganic substances. Organic substances include bile acids and bile pigments, as well as lecithin, cholesterol, fats, soaps and mucins. Inorganic substances are represented by mineral salts. Bile acids are formed from cholesterol in the liver. In humans, they are predominantly compounds of cholic and desoxycholic acid with glycerol and taurine. Bile pigments include bilirubin and biliverdin. These pigments are formed from hemoglobin, which is released when erythrocytes are destroyed. In an acidic environment, bilirubin is oxidized to biliverdin giving bile a greenish color.

The bile secretion is caused by a number of substances. Large polypeptides, extracts of meat, gastric juice, hormone secretin stimulate the production of bile by humoral way. Bile secretion is especially enchanced by bile itself. In naturalsettings, the bile is absorbed from the intestine into the blood and stimulates the liver to secret bile. Bile activates other digestive processes. Under the influence of bile, the action of all enzymes that break down proteins, fats, and carbohydrates is enhanced. Bile especially sharply (15-20 times) increases the activity of lipase. Bile emulsifies fats to fine particles, and under such conditions, lipase more intensively breaks down them into glycerol and fatty acids. Glycerin as a highly soluble in water compound is rapidly absorbed into the intestine. Fatty acids arenot soluble in water, but connecting with bile acids they form complex paired soluble compounds that well penetrate through the intestinal wall.

Bile enhances the formation of pancreatic juice by humoral way. Under the influence of bile, the motor function of the intestine is activated, which improves the movement of the chyme mass through the intestinal tract.

Digestion in the duodenum

Chyme that enters the duodenum is exposed to pancreatic juice, bile and intestinal juice. Under the influence of these juices, there is a breakdown of proteins, fats, and carbohydrates. Chemical transformations in the duodenum are of great importance for digestion, since, in the duodenum, products that are easily absorbed into the blood are produced.

Intestinal juice

Intestinal juice contains enzymes: polypeptidases, nucleases, lipase, phospholipase (lipolytic enzyme), amylase, maltase degrading maltose into two glucoses, sucrase splitting sucrose into glucose and fructose, lactase breaking down lactose into glucose and galactose, cholinesterase, enterokinase.

The glands of the small intestine begin to secrete intestinal juice under the influence of mechanical and chemical stimuli that act directly on the mucous membrane.

Motor function of the small intestine

The intestinal movements contribute to the mixing of the chyme mass and its movement along the direction from the stomach to the large intestine. There are two main types of movement of the intestine: pendular and peristaltic.

Pancreatic juice

Pancreatic juice is a colorless transparent liquid of alkaline reaction (pH 7.8-8.4). Pancreatic juice contains the following enzymes: lipase, amylase, and protease (trypsin, chymotrypsin and pancreopeptidase E (elastase), which break down proteins in a slightly alkaline reaction). In the juice, which comes from the pancreas, proteases are inactive and are called, respectively, trypsinogen, chymotrypsinogen and proelastase.

The content of different enzymes in the pancreatic juice may vary depending on the nature of the food ingested. If food is rich in fats, the amount of lipase in the pancreatic juice increases; accordingly, the amount of amylase increases if diet enriched with carbohydrates; increase of trypsin in pancreatic juice is associated with protein-rich food. These phenomena reflect the adaptive reactions of the digestive system to changing conditions of feeding.

Mechanism of pancreatic juice secretion

Pancreatic juice is released into the duodenum during reflexive and neurohumoral stimulation of the pancreas.

Reflexive secretion of pancreatic juice. It was established that the pancreatic juice is secreted after 2-3 min from the beginning of feeding. The secretion also happens at the sight and smell of food. This proves that the secretion of pancreatic juice occurs by two ways – unconditioned and conditioned reflexes. An unconditioned stimulus is food, which irritates the receptors of the oral cavity, pharynx and stomach. Nerve impulses that arise in these receptors are directed to the medulla oblongata reaching the unconditioned reflex center of digestion; then they pass through the vagus nerve to the pancreas causing its secretion. Conditioned-reflex stimuli are the appearance and smell of food, the feeding environment, the conversation and the imagination of food intake. These signals achieve the neurons of the cerebral cortex.

In both cases, the secretory nerve for the pancreas is the vagus nerve.

Excitation of pancreatic secretion by humoral way is carried out by intestinal hormones formed in the mucous membrane of the duodenum and pyloric part of the stomach.

It has been established that, the cells of the duodenal mucosa initially produce not active prosecretin. Then under the influence of hydrochloric acid entering the duodenum from the stomach with chyme, prosecretin converts into theactive form – secretin. The latter is absorbed into the bloodstream and stimulates the secretion of the pancreas. It turned out that extracts from the duodenum containother substances which also increase the content of enzymes in the pancreatic juiceby humoral way.

Secretion of pancreatic juice is enhanced by acetylcholine, gastrin, bile acids, water, especially carbonated, cranberry juice, etc. Thus, humoral factors are important regulators of pancreatic activity. However, their influence is controlled by the nervous system.

The secretion of the pancreatic juice is inhibited by adrenaline, atropine, and a number of hormones of the pituitary gland.

Digestion in the Large Intestine

From the small intestine, the remnants of undigested food enter the initial part of the colon - the cecum. Such a transition is regulated by means of the ileocecal valve (or Bauhin's valve) and sphincter located at the point where the ileum enters the cecum. Such an arrangement ensures the transfer of the chyme mass to the large intestine in separate small portions. The ileocecal valve prevents the chyme movement to be in back direction from the colon to the small intestine.

The large intestine extends from the end of the small intestine to the anus and divides into the following parts: the cecum with the appendix; ascendingcolon; transverse colon; sigmoid colon, and rectum. The total length of the large intestine is 1-1.5 m, the width reaches 7 cm.

In appearance, the large intestine differs from the small one.

The large intestine has a larger diameter, longitudinal muscular fibers, or the taenia coli, characteristic convexes (haustra). The taenia coli are formed due to the fact that the outer layer of the muscular layer is not compact, but the bundles of its smooth muscles are collected into three longitudinal bands extending along the entire length of the colon. In the areas between the tenia, haustras are formed due to an insignificant amount of longitudinally located smooth muscles.

Chyme enters the large intestine being almost completely digested, with the exception for plant fibers and a very small amount of proteins, carbohydrates, and fats. The glands of the large intestine produce juice that does not contain enzymes, but is rich in mucus. In this part of the intestine, water is intensively absorbed. The remnants of food are glued together with mucus, get firmed converting into fecal masses.

The large intestine contains a large number of microorganisms. The large intestine houses over 700 species of bacteria that perform a variety of functions, as well as fungi, protozoa, and archaea. Species diversity varies by geography and diet. The microbes in a human distal gut often number in the vicinity of 100 trillion, and can weigh around 200 grams (0.44 pounds). This mass of mostly symbiotic microbes has recently been called the latest human organ to be "discovered" or in other words, the "forgotten organ". Some of them cause fermentation of plant fiber, during which the latters is breakdown to simple carbohydrates, which are partially absorbed into the blood. Under the influence of putrefactive bacteria, the components of the protein are broke down and poisonous substances are produced: indole, skatole, phenol, etc., which enter the blood. However, in natural conditions, there is no poisoning of the body, since these substances are detoxicated in the liver.

Evidence is the experience on the operated animal by Eck's method.

The operation is that the portal vein is cut and directly connected to the inferior vena cava. In such conditions, the animal dies very quickly since the bloodflowing from the gastrointestinal tract, including from the large intestine, enters thegeneral circulatory system bypassing the liver. The toxic substances of intestinal origin contained in the portal blood poison the animal. The ability of the liver to protect the body from toxic substances is called detoxifying one, or barrier function of the liver. This function is of great importance for the body, since not only products of protein decay are neutralized in the liver, but also products that are formed during metabolism in the body or are absorbed from the outside, for example, various medicinal substances.

4. Visual material:
- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback

1. What organs are attributed to the digestive system?
2. What is digestion?
3. What types of regulation of digestion do you know?
4. What role does the colon microflora play in the digestive process?
5. What nutrients are absorbed by the large intestine?
6. What types of regulation of motility of the large intestine do you know?

Lecture No. 7

1. Theme: Physiology of respiration.

2. Learning goals: to study functional features of the respiratory system and the main lung volumes.

3. Lecture thesis:

The meaning of breathing for life

An organism can exist normally only with the constant energy supply necessary for all vital processes. The only source of energy for humans and animals is the energy stored in the chemical bonds between atoms and molecules of nutrients. So, in 1 mole of glucose (180 g), there is about 680 kcal in the bonds between the atoms of H, C and O. This energy is released in the body as a result of oxidative processes. Therefore, the body needs constant supply of oxygen from the environment.

Oxidation of organic cellular substances results in carbon dioxide is being formed, which is then released into the environment.

The oxygen comsumed by the body, the process of oxidation of substrates in cells, and carbon dioxide removal – together constitute respiration. Without food, a person dies after 60-70 days, without water – after 3 days, and without breathing – in 3 minutes. In elementary creatures, such as unicellular organisms, oxygen consumption and carbon dioxide release are carried out through the cellular membrane. In complex organisms, gas exchange between the environment and a body is performed by a system of special organs.

Organs of respiration

The respiratory tract consists of the nasal cavity, pharynx, larynx, trachea, bronchi, and lungs.

In the respiratory system, it is distinguished two parts 1) the airway pathways (the nasal cavity, pharynx, larynx, trachea, and bronchi) and 2) therespiratory part presented by the lung parenchyma, where gas exchange occurs between the air contained in the lung alveoli and the blood.

The peculiarities of the respiratory tract structure are 1) the presence of a cartilaginous frame in the walls, as a result of which the walls of the respiratory tract do not collapse, and 2) the presence of a ciliated epithelium lining the mucous membrane, which has cilia oscillating in the direction of the exhaled air what allow to expel foreign substances contaminating the respiratory tract with the mucus. All of the lower respiratory tract including the trachea, bronchi, and bronchioles is lined with respiratory epithelium. This is a ciliated epithelium interspersed with goblet cells which produce mucus, and club cells with actions similar to macrophages.

The blood-air barrier is formed by a very thin layer of alveolar cell cytoplasm, the basal membrane of the alveolus, the basal membrane of the capillary and the very flattened cytoplasm of the capillary endothelial cells. Two basal membranes almost fuse where the alveolar and endothelial cells are located opposite each other. The exchange of gases between the air of the alveoli and the capillaries takes place by passive diffusion. The lung surfactant is a three-layered chemical structure with a thickness of about 30 nm, covering the alveolar epithelium. The biochemical composition of surfactant is a complex mixture of phospholipids (most of them), proteins and glycoproteins. The surfactant prevents the collapse of the alveoli, also fixes the inhaled particles of dust, which are then processed by alveolar macrophages.

Mechanisms of inhalation and exhalation

Pulmonary respiration involves the exchange of air between the environment and the lungs (external respiration) and the exchange of gases between the alveolar air and the blood. Atmospheric air enters the lungs through airways during inhalation; during exhalation, air with a high content of carbon dioxide is removed from lungs in the same way into the environment. In the lungs, both opposite processes as oxygen diffusion into the blood and diffusion of carbon dioxide from the blood into the alveolar air happen.

The inhalation mechanism

The act of inspiration is provided by contraction of the external intercostal muscles and diaphragm. The intercostal muscles raise the ribs, slightly rotate them about the axis and move them to the sides; during the contraction of intercostal muscles, the sternum moves forward. As a result, the volume of the thoracic cavity increases in anteroposterior and lateral directions. At the same time, the diaphragm goes down what leads to lowering of its level by 3-4 cm, this, in turns, leads to an increase in the size of the thoracic cavity in the vertical direction and its volume by almost 1000 ml. Gowing down, the diaphragm presses on the organs of the abdominal cavity, which lead to protrusion anterior abdominal wall. With intensified deep inspiration, some other muscles of the abdominal press and chest also contract.

The lungs remain constantly in a stretched state. This is because of the fact that the growth of the thoracic cavity after birth outruns the growth of the lungs.

In addition, atmospheric air produces one-sided (from the inside) pressure on the lungs through the airways, so the atmospheric air stretching the lungs presses them against the pleura and thoracic cavity. As a consequence, the pleural cavity is a narrow, hermetically sealed cavity between its visceral and parietal layers. However, the lung tissue possessing great elasticity counteracts to stretching. This so-called elastic force of the lungs reduces the amount of air pressure on the lungs and pleura.

The pressure in the pleural cavity is lower than the atmospheric pressure by 4-9 mm Hg. Therefore, pleural pressure is called negative, conditionally assuming atmospheric pressure (760 mm Hg) as zero. The more the lungs stretch, the higher their elastic force becomes and the lower the pressure in the pleural cavity (during inspiration it is 4 mm Hg mm, during exhalation – 9 mm Hg, and with a deep inspiration the pressure can drop to 3 mm Hg)

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Entering air into the lungs is a passive process and is caused by a difference in pressure between the lungs and the environment. During inhaling, the volume of the thoracic cavity increases, pressure in the pleural cavity becomes more negative. As a result, the resistance of the lungs to stretching decreases and they are stretched. The volume of the lungs increases, so the air pressure in the lungs decreases becoming lower than the atmospheric pressure. The difference in air pressure between the atmosphere and in the alveoli of the lungs is the direct cause of the movement of air from the environment into the lungs – an inhalation takes place.

The mechanism of exhalation

The exhalation act begins with relaxation of the external respiratory muscles and diaphragm. As a consequence, the volume of the lungs decreases due to the elastic forces of the lungs and the pressure of the internal organs, as well as the gravity of the chest.

A decrease of the thoracic cavity volume causes an increase of pleural pressure. It becomes less negative. As a result of this, and under the action of the elastic traction of the lungs, the volume of the lungs reduces, the air pressure in them becomes higher than the atmospheric pressure, and the air is removed into the environment. Exhalation ends when the elastic traction of the lung is balanced by increasing pressure in the pleural cavity.

Patterns of breathing

Depending on which muscles are mainly involved in the act of breathing, there are thoracic, abdominal (diaphragmatic), and miscellaneous patterns of breathing. Abdominal breathing is a pattern of inspiration and expiration in which most of the ventilatory work is done with the abdominal muscles. The contractile force of the abdomen is used to elevate the diaphragm.

Thoracic breathing is when inhalation made by expanding the thorax, using the intercostal muscles to elevate the ribs, as compared to abdominal breathing using the diaphragm. Usually, in males, the type of breathing is abdominal; in women, it is thoracic. However, the type of breathing varies depending on certain conditions and physical work. Women involved in physical work have the abdominal type of breathing being predominated. In pregnancy, on the contrary, the type of breathing is thoracic, since the diaphragm movement down is difficult.

Vital capacity of the lungs. Lung volumes and lung capacities

The air movement in the lungs during breathing is called lung ventilation. It is characterized by minute ventilation, i.e., the amount of air that passes through the lungs per minute. Minute ventilation is calculated by multiplying the volume of air that enters the lungs for one inhalation by the rate of respiratory movements per minute.

At rest, an adult inhales and exhales about 500 ml of air (tidal volume). The frequency of breathing in adults is 16-20 times per minute. Consequently, the minute volume of respiration is average 6-8 liters. In children, breathing is more frequent: the newborn has it equal to 60 times per minute, the child of 5 years – 25 times, and adolescents of 15-16 years – 16-20 times per minute. Respiration sharply increases during physical work, sport exercises and can reach 40-45 times or more per minute.

The frequency of breathing is caused by the temperature of environment and the body, emotions, as well as many other factors. In people trained for physical loads, the respiration rate is lower, but the minute ventilation is higher due to a greater depth of inhaling. It should be borne in mind that part of the air circulating in the respiratory tract is in the larynx, trachea, bronchi, and bronchioles, where there is no exchange of gases between air and blood. This air is called the air of anatomical dead space. There is also physiologic dead space distinguished. Ifanatomical one includes respiratory tract beginning from nose and terminating withbronchioles (the portions of the respiratory tract that are ventilated but not perfusedby pulmonary circulation), then physiologic dead space is the sum of the anatomic and alveolar dead spaces (the latter is the space in alveoli occupied by air but does not participate in oxygen–carbon dioxide exchange).

The volume of the anatomical dead space is small, on average it is about 140 ml. However, it should be borne in mind that with every breath, not all air is renewed, but less by this amount. So, during a calm inspiration, 500 – 140 = 360 ml of air enters the alveoli of the lungs, where gas exchange takes place. The higher the minute ventilation at the expense of the depth of breathing, the lower therelative air volume of dead space. Therefore, rare and deep breathing is much moreeffective for supplying the body with oxygen, since in this case the ventilation of the alveoli increases.

Diffusion of gases in the lungs

In the lungs, oxygen and carbon dioxide are exchanged between air and blood. This exchange is caused by the difference in the partial pressure of gases in the alveolar air and in the blood flowing in the lung capillaries.

The partial pressure of a gas is a measure of thermodynamic activity of the gas's molecules. Gases dissolve, diffuse, and react according to their partial pressures, and not according to their concentrations in gas mixtures or liquids.

This general property of gases is also true in chemical reactions of gases in biology. This is true across a very wide range of different concentrations of oxygen present in various inhaled breathing gases or dissolved in blood.

Diffusion of gases from the environment into the liquid and from the liquid into the air obeys the laws of motion of gases. If a mixture of gases is located above the liquid, then each gas dissolves in the liquid corresponding to its partial pressure, that is, to the pressure that accounts for its share of the total pressure of the gas mixture (Henry's law). The partial pressure is proportional to the content ofeach gas in the mixture. Thus, at an atmospheric pressure of 760 mmHg and temperature of 22 °C, the partial pressure of atmospheric oxygen (pO2) is 20.94% of 760 mmHg and is equal to 159 mmHg. Under the same conditions, the partial pressure of the carbon dioxide gas (pCO2) is 0.03% of 760 mmHg and it is equalto 0.2 mm Hg. The rest of the atmospheric pressure is nitrogen (557.8 mm Hg) andwater vapor (20 mmHg) and inert gases: argon, neon, helium, krypton, xenon and hydrogen (6.9 mm Hg).

Gases from the area of high partial pressure pass into the area with a low partial pressure. Therefore, inhaled (atmospheric), exhaled and alveolar air differs in content of oxygen and carbon dioxide (see table below).

Diffusion of gases in the lung capillaries

As indicated above, carbon dioxide diffuses from the lung capillaries blood into the alveolar air due to its lower partial pressure in the alveolar air compared with its tension in the venous blood.

At the same time, oxygen enters the blood from the alveolar air forming oxyhemoglobin in the erythrocytes. Oxyhemoglobin is an acid that dissociates more strongly than carbonic acid. Therefore, it displaces carbon dioxide from potassium bicarbonate by the following reaction: HHb + O2 + KHCO3 = KHbO2
+ H2CO3

Carbonic acid is split by the same carbonic anhydrase into CO2 and H2O, since this enzyme catalyzes the process in one or the opposite direction depending on the composition of the environment.

Carbon dioxide diffuses into the alveolar air, the concentration of HCO3– drops in the blood plasma. This leads to the fact that carbhemoglobin also breaks down into hemoglobin and CO2. The latter diffuses into the alveolar air.

Gaseous exchange between blood and tissues

In the tissue capillaries, arterial blood gives away oxygen and absorbs carbon dioxide. Diffusion of oxygen from the blood in the tissue is due to the difference in the partial pressure of this gas in the blood, where it is high, and in the cellular protoplasm, where it is low.

Cells very intensively consume oxygen, so its tension in them can be zero. In the tissue fluid, it is 20-40 mmHg, and in the arterial blood – 102 mmHg, which results in oxygen continuously entering the tissue fluid, and from the latter goes into the cells. Simultaneously, carbon dioxide enters the blood from the cells through the tissue fluid. Its tension in the cells can reach 60 mmHg. In the tissue fluid, it fluctuates and on average is 46 mmHg, and in the arterial blood – 40 mmHg.

Regulation of respiration

Regulation of respiration is carried out by reflex and humoral mechanisms. Both mechanisms provide the rhythmic nature of breathing and the change in its intensity, adapting the organism to various conditions of the surrounding and internal mediums.

The breathing center and its automatism

The respiratory center is called a set of specialized nerve cells located in different parts of the central nervous system, which provide coordinated rhythmic breathing. In the beginning of the 19th century, it was found that the excitation causing contraction of the respiratory muscles occurs in the medulla oblongata. After intersection the brain below the medulla oblongata breath stops and experimental animals die. Groups of nerve cells located in the medulla oblongata, providing rhythmic contractions of the respiratory muscles, constitute a vital breathing center.

In 1885, Mislavsky N.A. established that the respiratory center is located in the reticular formation of the medulla oblongata, in the region of the bottom of the IV ventricle. The center is paired: from the groups of nerve cells in the right half of the medulla, the impulses go to the respiratory muscles of the right half of the body, and accordingly, from the groups of cells in the left half – to the muscles of the left half of the body.

The respiratory centers are presented in the medulla oblongata and the pons. Within medulla oblongata it consists of the inspiratory center and the expiratory center. They work in the coordination of pontine breathing centers (pneumotaxis and apneustic)

Impulses that arise in the inspiratory center spread from the brain along descending motor ways and reach the motor neurons located in the anterior horns of cervical and thoracic segments of the spinal cord. From the motor neurons of the III-IV cervical segments, axons that form the diaphragmatic nerves supplying the muscles of the diaphragm begin. From the nerve cells located in the anterior horn of the thoracic region of the spinal cord, the intercostal nerves that innervate the intercostal muscles originate.

For the normal activity of the respiratory center, constant information on the state of the internal environment of the body and the respiratory organs themselves is required. Motoneurons of the spinal cord receive signals about the degree of stretching of these muscles during inspiration from the proprioceptors of the thoracic muscles cells.

These signals can change the number of motoneurons involved in the ventilation activity, and, consequently, determine the features of respiration. Thus, the regulation of respiration is provided at the level of the spinal cord

The bulbar respiratory center receives afferent impulses from the mechanoreceptors of the lungs, respiratory tracts and respiratory muscles, from the chemo- and pressure-receptors of vascular reflexogenic zones. Especially important for the regulation of breathing is information coming from the mechanoreceptors of the lungs through sensitive nerve fibers passing through the vagus nerves

The respiratory center is characterized by an automatism, i.e. the ability to generate rhythmic impulses without any other excitations to be involved. Rhythmic activity of the neurons of the respiratory center is preserved even after cutting all afferent nerves coming to it.

The automatic rhythmic excitation of the respiratory center is caused by the metabolic processes occurring in it and its high sensitivity to the tension of carbon dioxide. Carbon dioxide is always contained in the blood and is the most powerful stimulus for respiratory center neurons.

Reflexive regulation of respiration

Inhalation and exhalation are provided by the following nervous processes. Owing to the automatism and irritative effects of carbon dioxide, in the inspiratory center, nerve impulses arise; then they spread along efferent pathways to respiratory muscles. As a result, the latters contract resulting in an inhalation. Stretching of the lungs causes excitation of mechanoreceptors located in the walls of the alveoli. Impulses of these receptors spread through sensitive neural fibers of the vagus nerve to the neurons of the expiratory center and excite it. Simultaneously, impulses from inspiratory neurons enter the centers of pneumotaxis, and from the latter come to the neurons of the expiratory center and also excite it.

Arisen excitation of the expiratory center reciprocally inhibits the inspiratory center and its impulses to the respiratory muscles cease. As a result, the lungs get collapsed, exhalation occurs. Owing to this, excitation of the lungs mechanoreceptors and expiratory center stops. The inhibitory effect of the expiratory center neurons for the inspiratory center also ceases. Then again the excitation of inspiratory neurons happens and a new inhalation takes place.

Thus, each inhalation causes exhalation, and the exhalation stimulates the inhalation. This is the reflexive self-regulation of breathing. It is performed, as it can be seen from the above, on the principle of automatic control with a feedback mechanism. In other words, it is caused by the interaction between the regulating (respiratory center) and the regulated (respiratory muscles and lungs) systems.

Other receptive zones also participate in reflex regulation. So, with exhalation, mechanoreceptors of the respiratory muscles are stimulated, which reflexively stimulates the inspiration.

Humoral regulation of respiration

Environmental conditions continuously changing, different physiological state of a human organism (rest, work, emotions, etc.) require the adaptation of breathing rhythm and intensity to cover the body's need for oxygen. In addition to reflexive regulation, breathing changes significantly under the influence of humoral factors. Specific humoral regulator of respiratory movements is the tension of CO2 which accumulates in the blood. It causes the excitation of the respiratory center.

Defense respiratory reflexes

These reflexes occur when the mucous membrane of the respiratory tract is irritated with harmful substances. Defense respiratory reflexes either prevent the permeating the harmful substances into respiratory tract, or contribute to their removal from the body. For example, breathing in ammonia makes a personstopping exhale. At the same time, a reflexive narrowing of the bronchial lumen and a complete closure of the glottis (area between the vocal folds) take place.

Defense reflexes are on the basis of coughing and sneezing, which arisewhen respiratory tract is irritated with mucus, dust, chemicals, and foreign bodies. Before a cough, a person makes inhalations and then the glottis reflexively closes. Owing to the following sharp contraction of the respiratory muscles and the opening of the glottis, air is pushed out of the lungs. A strong stream of air takes dust, mucus, and foreign bodies outside.

Before the sneezing, a strong inhalation also occurs, the glottis closes, the soft palate rises insulating the nasopharynx from the oral cavity. Then, with the opening the glottis, there is a strong exhalation through the nose with a characteristic sound and the removal of substances that have irritated the mucous membrane.

4. Visual material:

- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback

1. What are the main functions of the respiratory system?
2. What are the main lung volumes?
3. What is the main humoral factor of respiration?

Lectures No. 8

1. Theme: Physiology of the excretory system. Skin functions.

2. Learning goals: to study functional features of the skin

3. Lecture thesis:

Skin performs the following functions:

Protection: an anatomical barrier from pathogens and damage between the internal and external environment in bodily defense; Langerhans cells in the skin are part of the adaptive immune system. Perspiration contains lysozyme that break the bonds within the cell walls of bacteria.

Sensation: contains a variety of nerve endings that react to heat and cold, touch, pressure, vibration, and tissue injury; see somatosensory system and haptics.

Heat regulation: the skin contains a blood supply far greater than its requirements which allows precise control of energy loss by radiation, convection and conduction. Dilated blood vessels increase perfusion and heatloss, while constricted vessels greatly reduce cutaneous blood flow and conserve heat.

Control of evaporation: the skin provides a relatively dry and semi-impermeable barrier to fluid loss. Loss of this function contributes to the massive fluid loss in burns.

Aesthetics and communication: others see our skin and can assess our mood, physical state and attractiveness.

Storage and synthesis: acts as a storage center for lipids and water, as well as a means of synthesis of vitamin D by action of UV on certain parts of the skin.

Excretion: sweat contains urea, however its concentration is 1/130th that of urine, hence excretion by sweating is at most a secondary function to temperature regulation.

Absorption: the cells comprising the outermost 0.25–0.40 mm of the skin are "almost exclusively supplied by external oxygen", although the "contribution to total respiration is negligible". In addition, medicine can be administered through the skin, by ointments or by means of adhesive patch, such as the nicotine patch or iontophoresis. The skin is an important site of transport in many other organisms.

Water resistance: The skin acts as a water-resistant barrier so essential nutrients are not washed out of the body.

4. Visual material:

- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback

1. What are the main functions of the skin?
2. What are the main sensations arising from the influence of external factors on the skin?
3. What are thermoreceptors?
4. What types thermoreceptors can you name?

Lectures No. 9

1. Theme: Physiology of excretory system. The mechanism of urine formation, its regulation.

2. Learning goals: to study the processes of the urine formation and mechanisms of its regulation.

3. Lecture thesis:

Introduction to the Urination System

In the metabolic process, a number of compounds are formed and accumulated that cannot be used by an organism, and some of them are toxic. In addition, foreign and sometimes poisonous substances can enter from outside the body and circulate. Both are removed from the body with the help of excretory organs.

The organs of excretion are the kidneys, sweat glands, and lungs. The intestines also take part in the excretion processes.

The kidneys remove water, a number of metabolic products, salts excess, foreign and toxic products after their inactivation in other organs. In particular, many medicinal substances and the products of their metabolism are removed by the kidneys. Sweat glands remove water and salt. Kidneys and sweat glands play a very important role in maintaining the constancy of osmotic pressure, ionic composition, and pH of the internal environment.

Lungs take part in excretory processes removing carbon dioxide, water, and some volatile substances from the body, for example ether vapors, chloroform, etc.

Through the mucous membrane of the intestine, certain metabolic products, for example bile pigments and salts of heavy metals, are released from the blood.

Nephron

The structural and functional unit of the kidneys is the nephron, since the whole set of processes of urine formation is fulfilled in it. Each nephron begins with a microscopic two-layered cap-like capsule and called the Shumlyansky-Bowman's capsule. The capsule covers the networks of capillaries, called the glomerulus or Malpighian glomerulus. Together with the glomerulus, the capsule forms renal or Malpighian corpuscle (see the figures below).

Between the layers (parietal and visceral layers) of the Bowman's capsule, there is a narrow cavity (Bowman's space), from which the lumen of the renal tubule begins. The inner (visceral) layer of the capsule is formed by flat epithelial cells located on a thin basal lamina (basement membrane) and tightly fit to all sidesof the capillary. Between the epithelial cells of the capsule visceral layer, there are narrow slits. In turn, between the endothelial cells of the capillaries, there are also holes about 0.1 μm in diameter.

Thus, the blood circulating in the capillaries is separated from the capsule space only by a thin basal membrane.

From the space of the Bowman's capsule, the initial part of the renal tubule, the so-called proximal convoluted tubule, begins. It is directed to the renal medulla of the kidney. On the boundary between the kidney cortex and medulla, the tubule narrows and straightens, forming loop of Henle in the medulla, which consists of a descending and ascending limbs (see figure above). In the medullar layer, the ascending limb passes into the distal convoluted tubule.

The distal convoluted tubules open into so-called collection ducts, which beginning in the cortical layer pass into the medullar one, then reach the tops of the pyramids and through the papillar holes open into the kidney calyxes. In each kidney, there are more than 1 million nephrons.

The length of the nephron tubules is different - from 18 to 50 mm, and the total length of all nephron tubules is very high - about 100 km.

The surface of the columnar cells facing to the tubule lumen has a brush border, which, according to electron microscopic studies, is formed by microvilli. Due to this, the total surface of all renal tubules reaches 40-50 m^2.

Nephron has a number of features of blood supply. This contributes to the main function of the kidneys.

Renal Corpuscule

The branching of the renal artery forms arterioles, each of which enters the Shumnlyansky-Bowman's capsule; in this capsule, arteriole breaks up to the capillary network forming the Malpighian glomerulus. These capillaries then fuse with each other again forming an arteriole, through which arterial blood flows out from the Malpighian glomerulus. Arteriole, which delivers the blood to the glomerulus, is called afferent, and arteriole, which carries blood away from the capsule, is said to be efferent.

In the capillaries of the Malpighian glomerulus, the blood pressure is high – 70-80 mmHg (instead 20 mmHg usual for other capillaries). Firstly, this is caused by the fact that the renal artery branches directly from the abdominal aorta and its path to the kidney is short, and, secondly, by the fact that the diameter of the afferent arteriole (bringing blood to the glomerulus) is approximately 2 times greater than that of the efferent one.

In the capillaries of the Malpighian glomerulus, the blood pressure is high – 70-80 mmHg (instead 20 mmHg usual for other capillaries). Firstly, this is caused by the fact that the renal artery branches directly from the abdominal aorta and its path to the kidney is short, and, secondly, by the fact that the diameter of the afferent arteriole (bringing blood to the glomerulus) is approximately 2 times greater than that of the efferent one.

Filtration, reabsorption, and secretion

Three processes – the filtration, reabsorption, and secretion – take place in the formation of urine.

4. Visual material:
- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback
1. What is the structural and functional unit of the kidneys?
2. How many phases of the process of urinatine formation?
3. How is urine formation regulated?

Lecture No. 10
Theme: The human reproductive system. Male and female reproductive systems. Age features.
2. Learning goals: to study the human reproductive system, its age features, functions of the male reproductive system.
3. Lecture thesis:

Reproduction, or the ability to reproduce itself, is one of the basic properties of all living organisms beginning from bacteria ending with mammals. Owing to it, the existence of each species is kept, continuity between parental individuals and offspring is maintained.

Structure and Functions of Male Sexual Organs

The internal male genital organs include testes, or testicles, vas deferens, prostate gland, bulbourethral (Cooper) glands, and seminal vesicles. The external genitalia include the male penis and scrotum.

Testes (testicles). They are the male reproductive glands, where spermatozoa are formed with the male hormone. Testes are paired oval formations located in the scrotum. From the outside, epididymis adjoins to the testis. Outside the most part of testes are covered with a serous membrane – peritoneum, behind which there is a dense connective tissue envelope called tunica albuginea. Thin connective tissue septa, begining from the tunica albuginea, divide the testicle substance by 100-250 lobules. In each lobule, there are 1-2 convoluted seminiferous tubules. In the apex of the lobule, the convoluted tubules gradually become straight tubules.

The lumen of the convoluted seminiferous tubule is lined with a layer of supporting (trophic) cells and many rows of the germ cells located at different stages of spermatogenesis. Sertoli cells – the true epithelium of the seminiferous epithelium, critical for the support of germ cell development into spermatozoa. In the connective tissue septa (between tubules) of the testis near the capillaries, there are aggregations of large polygonal so-called interstitial glandular cells (Leydig cells), in which male sex hormones are formed. They produce testosterone in the presence of luteinizing hormone (LH).

Spermatogenesis

Upon reaching the sexual maturity, in the convoluted seminiferous tubules, the processes of spermatogenesis begin, leading to the formation of male sex cells – spermatozoa. The testis produces spermatozoa continuously throughout the period of the sexual activity of the organism. Spermatogonia, i.e. cells of the spermatogenic epithelium, multiply and transform into spermatocytes of the first, then second order and then into the spermatids. During this period, the number of chromosomes (meiosis) is reduced, as a result of which a haploid set of chromosomes remains in the spermatids. Spermatids no longer divide, but through the complex restructuring they develop and turn into mature spermatozoa.

Spermatozoa are formed in a very large amount.

The seminal fluid released during ejaculation contains tens or hundreds of millions of spermatozoa.

Spermatozoa are small in size and possess the ability to actively move. Spermatozoa of vertebrates have a flagellate shape; their length in humans is 60 microns. In spermatozoa, the head, mid piece, tail and mid piece are distinguished. The head includes a nucleus surrounded by a thin layer of protoplasm. The head contains a hyaluronidase enzyme that can dissolve the membranes that cover the ovum. The ability of spermatozoa to move independently is due to the movement of their tail.

4. Visual material:
- presentation of lecture material;
- posters on the topic of the lesson;
- tables, schemes.

5. Bibliography: See appendix No. 1

6. Post-lecture feedback
1. What is the function of the human reproductive system?
2. By which organs the male reproductive system is represented?
3. What hormones are secreted by male gonads?

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5	‘Paragraph’ information system ‘Medicine’ section	https://online.zakon.kz/Medicine
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