EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body
Course – 1 Semester – 2
Number of credits – 8
Almaty 2022

Lecture №1

The Functions of Muscles, Muscle Attachments. Functional Groups of Muscles, Innervation and Blood Supply,Muscle Names and Learning Strategy.

Outcomes:

1. Describe the various functions and characteristics of muscular tissue
2. Describe the connective tissue components of a muscle and their relationship to the internal organization of a muscle and compartmentalization of muscle groups
3. Name the types of muscle bone attachments and explain the shortcoming of calling their attachments origins and insertions;
4. Distinguish between intrinsic and extrinsic muscles;
5. Distinguish between spinal and cranial nerves

Muscles constitute nearly half of the body's weight and occupy a place of central interest in several fields of health care and fitness. Physical and occupational therapists must be well acquainted with the muscular system to plan and carry out rehabilitation programs. Athletes and trainers, dancers and acrobats, and amateur fitness enthusiasts follow programs of resistance training to strengthen individual muscle groups through movement regimens based on knowledge of muscle, bone, and joint anatomy. Nurses employ their knowledge of the muscular system to give intramuscular injections correctly and to safely and effectively move patients who are physically incapacitated.

The Functions of Muscles

Collectively, the three types of muscle serve the following functions:

• Movement. Muscles enable us to move from place to place and to move individual body parts; they move body contents in the course of breathing, blood circulation, feeding and digestion, defecation, urination, and childbirth; and they serve various roles in communication—speech, writing, facial expressions, and other body language.

• Stability. Muscles maintain posture by preventing unwanted movements. Some are called antigravity muscles because, at least part of the time, they resist the pull of gravity and prevent us from falling or slumping over. Many muscles also stabilize the joints by maintaining tension on tendons and bones.

• Control of body openings and passages. Muscles encircling the mouth serve not only for speech but also for food intake and retention of food while chewing. In the eyelid and pupil, they regulate the admission of light to the eye. Internal muscular rings control the movement of food, bile, blood, and other materials within the body. Muscles encircling the urethra and anus control the elimination of waste. (Some of these muscles are called sphincters, but not all; this is clarified later.)

• Heat production. The skeletal muscles produce as much as 85% of one's body heat, which is vital to the functioning of enzymes and therefore to all metabolism.

• Glycemic control. This means the regulation of blood glucose concentration within its normal range. The skeletal muscles absorb, store, and use a large share of one's glucose and play a highly significant role in stabilizing its blood concentration. In old age, in obesity, and when muscles become deconditioned and weakened, people suffer an increased risk of type 2 diabetes mellitus because of the decline in this glucose-buffering function.

Muscle Connective Tissues, Fascicles, and Compartments

Skeletal muscles vary considerably in size, shape, and arrangement of fibers. They range from extremely tiny strands such as the stapedium muscle of the middle ear to large masses such as the muscles of the thigh. Some skeletal muscles are broad in shape and some narrow. In some muscles the fibers are parallel to the long axis of the muscle; in some they converge to a narrow attachment; and in some they are oblique.

Each skeletal muscle fiber is a single cylindrical muscle cell. An individual skeletal muscle may be made up of hundreds, or even thousands, of muscle fibers bundled together and wrapped in a connective tissue covering. Each muscle is surrounded by a connective tissue sheath called the epimysium. Fascia, connective tissue outside the epimysium, surrounds and separates the muscles. Portions of the epimysium project inward to divide the muscle into compartments. Each compartment contains a bundle of muscle fibers. Each bundle of muscle fiber is called a fasciculus and is surrounded by a layer of connective tissue called the perimysium. Within the fasciculus, each individual muscle cell, called a muscle fiber, is surrounded by connective tissue called the endomysium.

Skeletal muscle cells (fibers), like other body cells, are soft and fragile. The connective tissue covering furnish support and protection for the delicate cells and allow them to withstand the forces of contraction. The coverings also provide pathways for the passage of blood vessels and nerves.

Commonly, the epimysium, perimysium, and endomysium extend beyond the fleshy part of the muscle, the belly or gaster, to form a thick ropelike tendon or a broad, flat sheet-like aponeurosis. The tendon and aponeurosis form indirect attachments from muscles to the periosteum of bones or to the connective tissue of other muscles. Typically a muscle spans a joint and is attached to bones by tendons at both ends. One of the bones remains relatively fixed or stable while the other end moves as a result of muscle contraction.

Skeletal muscles have an abundant supply of blood vessels and nerves. This is directly related to the primary function of skeletal muscle, contraction. Before a skeletal muscle fiber can contract, it has to receive an impulse from a nerve cell. Generally, an artery and at least one vein accompany each nerve that penetrates the epimysium of a skeletal muscle. Branches of the nerve and blood vessels follow the connective tissue components of the muscle of a nerve cell and with one or more minute blood vessels called capillaries.

Questions for control

1. List some functions of the muscular system other than movement of the body.

2. Describe the relationship of endomysium, perimysium, and epimysium to each other. Which of these separates one fascicle from another? Which separates one muscle from another?

3. Distinguish between direct and indirect muscle attachments to bones.

4. Define belly, action, and innervation.

5. Describe the five basic muscle shapes (fascicle arrangements).

6. Distinguish between a synergist, antagonist, and fixator. Explain how each of these may affect the action of a prime mover.

Basic literature:

1. Saladin, Kenneth S: Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education) на англ. яз.
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Lecture 2
Biophysics 1
The Nerve-Muscle Relationship
Behavior of Skeletal Muscle Fibers.

LECTURE OUTLINE

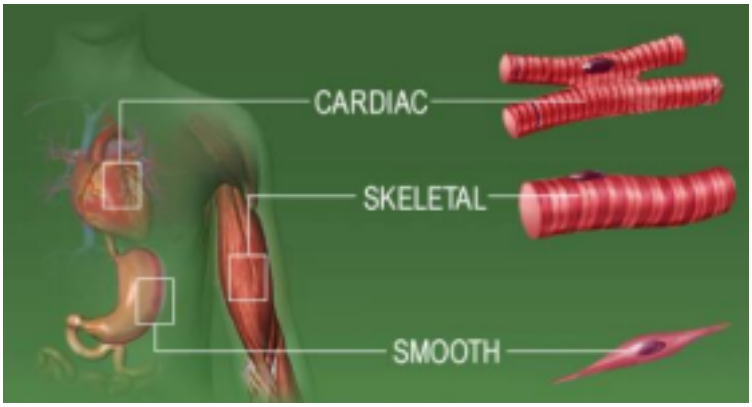
1. Human Muscle system
2. Types of muscle
3. A muscle's length-tension curve
4. Stress-strain curves.

Learning outcomes:

- Learning the Human Muscle system
- Solving of standard and situational problems.

Muscle is a soft tissue found in most animals. Muscle cells contain protein filaments of actin and myosin that slide past one another, producing a contraction that changes both the length and the shape of the cell. Muscles function to produce force and motion. They are primarily responsible for maintaining and changing posture, locomotion, as well as movement of internal organs, such as the contraction of the heart and the movement of food through the digestive system via peristalsis.

Human muscle system, the muscles of the human body that work the skeletal system, that are under voluntary control, and that are concerned with movement, posture, and balance. Broadly considered, human muscle—like the muscles of all vertebrates—is often divided into striated muscle (or skeletal muscle), smooth muscle, and cardiac muscle. Smooth muscle is under involuntary control and is found in the walls of blood vessels and of structures such as the urinary bladder, the intestines, and the stomach. Cardiac muscle makes up the mass of the heart and is responsible for the rhythmic contractions of that vital pumping organ; it too is under involuntary control. With very few exceptions, the arrangement of smooth muscle and cardiac muscle in humans is identical to the arrangement found in other vertebrate animals.



Muscles are predominantly powered by the oxidation of fats and carbohydrates, but anaerobic chemical reactions are also used, particularly by fast twitch fibers. These chemical reactions produce adenosine triphosphate (ATP) molecules that are used to power the movement of the myosin heads.

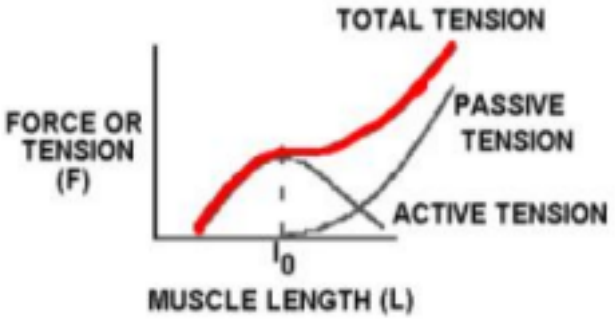
The term muscle is derived from the Latin *musculus* meaning "little mouse" perhaps because of the shape of certain muscles or because contracting muscles look like mice moving under the skin.

The muscular system consists of all the muscles present in a single body. There are approximately 650 skeletal muscles in the human body, but an exact number is difficult to define.

The action a muscle generates is determined by the origin and insertion locations. The cross sectional area of a muscle (rather than volume or length) determines the amount of force it can generate by defining the number of "sarcomeres" which can operate in parallel. Each skeletal muscle contains long units called myofibrils, and each myofibril is a chain of sarcomeres. Since contraction occurs at the same time for all connected sarcomeres in a muscles cell, these chains of sarcomeres shorten together, thus shortening the muscle fiber, resulting in overall length change. The amount of force applied to the external environment is determined by lever mechanics, specifically the ratio of in-lever to out-lever. For example, moving the insertion point of the biceps more distally on the radius (farther from the joint of rotation) would increase the force generated during flexion (and, as a result, the maximum weight lifted in this movement), but decrease the maximum speed of flexion. Moving the insertion point proximally (closer to the joint of rotation) would result in decreased force but increased velocity. This can be most easily seen by comparing the limb of a mole to a horse—in the former, the insertion point is positioned to maximize force (for digging), while in the latter, the insertion point is positioned to maximize speed (for running).

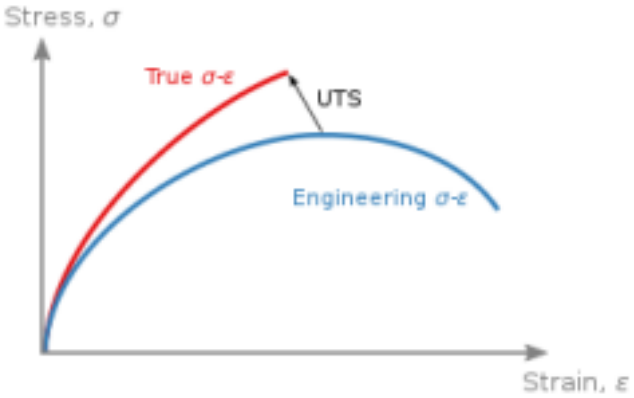
A muscle's length-tension curve

A muscle's length-tension curve illustrates how its force comes from two sources: Active tension derives from the interaction between myosin and actin active tension. Passive tension can develop in the muscle's complex connective tissue.



Length-tension curves appear in other forms, including force-angle curves and stress-strain curves. All the curves share the same characteristic shape, because the variables graphed on the x and y axes are just scaled versions of length and force.

Stress-strain curves: Stress, a measure of force per area, replaces force on the y-axis. Strain, an expression of the percentage of elongation beyond resting length, replaces absolute length on the x axis.



Force-angle curves: Joint angle replaces length as the x-axis variable. To use a flexor muscle group as an example, flexors are short when the joint is flexed and elongated when the joint is extended.

Moment-angle curves: As long as a muscle's moment arm is relatively constant throughout the range of motion of the joint that the muscle crosses, then the muscle's moment-angle curve has a shape that is similar to that of its force-angle curve.

Consider a bar of original cross sectional area being subjected to equal and opposite forces pulling at the ends so the bar is under tension. The material is experiencing a stress defined to be the ratio of the force to the cross sectional area of the bar, as well as an axial elongation:

$$\sigma = \frac{F}{A_0}$$
$$\varepsilon = \frac{L - L_0}{L_0} = \frac{\Delta L}{L_0}$$

Subscript 0 denotes the original dimensions of the sample. The SI unit for stress is newton per square metre, or pascal (1 pascal = Pa = 1 N/m^2), and strain is unitless. Stress-strain curve for this material is plotted by elongating the sample and recording the stress variation with strain until the sample fractures. By convention, the strain is set to the horizontal axis and stress is set to vertical axis. Note that for engineering purposes we often assume the cross-section area of the material does not change during the whole deformation process. This is not true since the actual area will decrease while deforming due to elastic and plastic deformation. The curve based on the original cross section and gauge length is called the *engineering stress-strain curve*, while the curve based on the instantaneous cross-section area and length is called the *true stress-strain curve*. Unless stated otherwise, engineering stress-strain is generally used.

The questions for self - control:

1.Human Muscle system

2. Types of muscle
3. A muscle's length-tension curve
4. Stress-strain curves.

Recommended literature:

1.An Introduction by Roland Glaser. Biophysics. Second edition. Springer. 2012
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Lecture 3
Human tissue 1-2
Muscle tissue: smooth and striated skeletal muscle tissue. Nerve tissue. General features of Nerve tissue.

LECTURE OUTLINE

- General features of Muscle Tissue. Terminology.
- Skeletal Muscle.
- Organization of the Skeletal Muscle.
- Neurons. Classification of neuron types.

LEARNING OUTCOMES

1. list the 3 major muscle types and compare their structure, function, location.
2. define the structure and functions of the Skeletal Muscle.
3. define the relationships among muscle fascicles, muscle fibers, myofibrils, myofilaments.
4. recognize Skeletal muscle in micrographs.
5. list the features of Nerve tissue that distinguish it from other basic tissues. 6. list the nerve tissue cell types and describe the structure, function, location. 7. describe a neuron's organelles in terms of their location, impulse transmission, neuronal repair.
8. recognize the type of nerve tissue cells in micrographs.

The main function of muscular tissues is to contract, providing the movement. The structural elements of muscular tissues have some general features:
1) the extended form;
2) special organelles – myofibrils and myofilaments in sarcoplasm, lying along the cells or fibers;
3) glycogen and myoglobin inclusions (monomer Hb, red, capable to bind and emit O2); 4) two-layer sarcolemma (cytolemma covered with the basal membrane).

Classification. There are 2 kinds of muscular tissue: smooth and striated (or cross-striped). The smooth tissue develops from the mesenchyme, except for the specialized kinds developing from the neuroectoderm (the iris muscles) and ectoderm (myoepithelial cells of the glands). The striated tissue develops from the mesoderm; it can be skeletal and cardiac.

CROSS-STRIPED (striated) SKELETAL MUSCULAR TISSUE. It makes up the muscles of the trunk, extremities and head. It contracts deliberately and quickly, but gets tired quickly. It develops from somite myotomes. Their cells turn into myoblasts which multiply and merge into the symplasts – muscular tubules. In their cytoplasm myofibrils are formed, and the basal membrane of sarcolemma is formed above thecytolemma. A part of the myoblasts turns into low-differentiated

cells –*myosatellites*. They settle down between the cytolemma and the basal membrane of sarcolemma. A nerve ending connects with each myosymplast. The structure of the myosymplast.Its thickness is 20 microns, the length – from 2 to 12 cm, the number of the nuclei – up to ten thousand (they are oval and lie under sarcolemma). Up to 1000 myofibrils lie in the center along the myosymplast. Between them there is glycogen, myoglobin, mitochondrions and a tubule of sarcoplasmic reticulum which deposits Ca-ions. The sarcoplasmic reticulum tubules form circular tanks around the light disks of myofibrils which contact with the cytolemma tubule. It is necessary for the muscle contraction and is called the Tsystem. Myofibrils consist of proteins and myofilaments. Proteins, constructing the myofibril,include 4 groups:

1) contracting proteins – actin and myosin,
2) regulating proteins – troponin and tropomyosin,
3) structural protein – α-actinin,
4) elastic proteins – titin and nebulin.

Myofilaments, constructing the myofibril, consist of chains from actin and myosin. Myosin molecules have myosin bridges made of lateral chains with the head composed of ATP (or of the side chains with the head of the ATP). Thin actin molecules are partially blocked with thick myosin molecules. This creates cross striated fibers in the form of altering dark and light disks. The Light disks contain one kind of proteins – actin, which dissipates light equally. Therefore, they are called isotropic or I-disks. In the middle of light disks there is a septum – a *telophragma*or aZ *line*contracted fromα-actininprotein. The Z-line crosses all parallel I-disks and is attached to the cytolemma. It binds the myofilaments into the myofibril. In dark disks actin and myosin are blocked. They dissipate light in different ways, so dark disks possess double refraction and are called anisotropic or A-disks. In the middle of an A-disk there is a light H-band without actin. M-line is amesophragmawhichpasses through it. The structural and functional unit of the myofibril is SARCOMERE. It is a section of the myofibril between two Z-lines (an A-disk and two halves of I disks).

The nervous tissue unites the organism into the whole. It consists of neurons and the neuroglia. Neurons accept irritation, form a nervous impulse and transfer it to other cells. The neuroglia creates conditions for the neuron's life. The NEURON has a body and processes. The body (perikaryon) contains a large light nucleus with nucleoli. The processes are of 2 kinds: dendrites and axons. Dendrites can be numerous; they transfer impulses to the neural body. There is only one axon (neurit) which transfers impulses from the neural body. The cytoplasm has organelles and inclusions of melanin and lipofuscin. The granular endoplasmic reticulum forms basophilic masses called Nissl substance*(basophilic, chromatophilic, tigroid substance*); it is present in the body and dendrites, but never in the axon. It synthesizes enzymes for synapsis. Disintegration of the tigroid substance is called tigrolysis; it occurs when the neuron is overexcited. Special neuron organelles are neurofibrils, a complex composed of neurotubules and neurofilaments. Their function is bidirectional intracellular transport of substances. Anterograde transport moves substances from the perikaryon to the synaptic terminals. Retrograde transport returns substances from the processes to the cell body for the control of their integrity.

Questions for self-control:

1. Define the classification of the muscle tissue.
2. Define groups of protein do myofibrils contain?
3. What is a structural unit of the skeletal muscle?
4. What are the nervous tissue components?
5. Define neuron types.

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Lecture №4
Behavior of the whole Muscle. Muscle Metabolism

Outcomes:

1. explain how skeletal muscle meets its energy demands during rest and exercise;
2. explain the basis of muscle fatigue and soreness;
3. discuss why extra oxygen is needed even after an exercise has ended;
4. distinguish between two physiological types of muscle fibers, and explain their functional roles;
5. discuss the factors that affect muscular strength; and
6. discuss the effects of resistance and endurance exercises on muscles.

Muscle contractions are fueled by adenosine triphosphate (ATP), an energy-storing molecule. Four potential sources of ATP power muscle contractions.

Free ATP
Low levels of ATP exist within the muscle fibers and can immediately provide energy for contraction. However, the pool is very small and after a few muscle twitches will be exhausted.

Phosphocreatine
Phosphocreatine, also known as creatine phosphate, can rapidly donate a phosphate group to ADP to form ATP and creatine under anaerobic conditions. Enough phosphocreatine is present in the muscle to provide ATP for up to 15 seconds of contraction.
The reaction of phosphocreatine + ADP to ATP + creatine is reversible. During periods of rest, the store of phosphocreatine is regenerated from ATP.

Glycolysis
Glycolysis is the metabolic reaction which produces two molecules of ATP through the conversion of glucose into pyruvate, water, and NADH in the absence of oxygen. The glucose for glycolysis can be provided by the blood supply, but is more often converted from glycogen in the muscle fibers. If glycogen stores in the muscle fibers are expended, glucose can be created from fats and proteins. However, this conversion is not as efficient. Pyruvate is continually processed into lactic acid. With pyruvate accumulation, the amount of lactic acid produced is also increased. This lactic acid accumulation in the muscle tissue reduces the pH, making it more acidic and producing the stinging feeling in muscles when exercising. This inhibits further anaerobic respiration, inducing fatigue.
Glycolysis alone can provide energy to the muscle for approximately 30 seconds, although this interval can be increased with muscle conditioning.

Cellular Respiration
While the pyruvate generated through glycolysis can accumulate to form lactic acid, it can also be used to generate further molecules of ATP. Mitochondria in the muscle fibers can convert pyruvate into ATP in the presence of oxygen via the Krebs Cycle, generating an additional 30 molecules of ATP.
Cellular respiration is not as rapid as the above mechanisms; however, it is required for exercise

periods longer than 30 seconds. Cellular respiration is limited by oxygen availability, so lactic acid can still build up if pyruvate in the Krebs Cycle is insufficient.

Cellular respiration plays a key role in returning the muscles to normal after exercise, converting the excess pyruvate into ATP and regenerating the stores of ATP, phosphocreatine, and glycogen in the muscle that are required for more rapid contractions.

Muscle Fatigue

Muscle fatigue occurs following a period of sustained activity.

Lactic Acid Accumulation

Long-term muscle use requires the delivery of oxygen and glucose to the muscle fiber to allow aerobic respiration to occur, producing the ATP required for muscle contraction. If the respiratory or circulatory system cannot keep up with demand, then energy will be generated by the much less efficient anaerobic respiration.

In aerobic respiration, pyruvate produced by glycolysis is converted into additional ATP molecules in the mitochondria via the Krebs Cycle. With insufficient oxygen, pyruvate cannot enter the Krebs cycle and instead accumulates in the muscle fiber. Pyruvate is continually processed into lactic acid. With pyruvate accumulation, lactic acid production is also increased. This lactic acid accumulation in the muscle tissue reduces the pH, making it more acidic and producing the stinging feeling in muscles when exercising. This further inhibits anaerobic respiration, inducing fatigue.

Lactic acid can be converted back to pyruvate in well-oxygenated muscle cells; however, during exercise the focus in on maintaining muscle activity. Lactic acid is transported to the liver where it can be stored prior to conversion to glucose in the presence of oxygen via the Cori Cycle. The amount of oxygen required to restore the lactic acid balance is often referred to as the oxygen debt.

Ion Imbalance

Contraction of a muscle requires Ca^{+}ions to interact with troponin, exposing the actin binding site to the myosin head. With extensive exercise, the osmotically active molecules outside of the muscle are lost through sweating. This loss changes the osmotic gradient, making it more difficult for the required Ca^{+}ions to be delivered to the muscle fiber. In extreme cases, this can lead to painful, extended maintenance of muscle contraction or cramp.

Nervous Fatigue and Loss of Desire

Nerves are responsible for controlling the contraction of muscles, determining the number, sequence, and force of muscular contractions. Most movements require a force far below what a muscle could potentially generate, and barring disease nervous fatigue is seldom an issue. However, loss of desire to exercise in the face of increasing muscle soreness, respiration, and heart rate can have a powerful negative impact on muscle activity.

Metabolic Fatigue

Depletion of required substrates such as ATP or glycogen within a muscle result in fatigue as the muscle is not able to generate energy to power contractions. Accumulation of metabolites from these reactions other than lactic acid, such as Mg^{2+} ions or reactive oxygen species, can also induce fatigue by interfering with the release of Ca^{+}ions from the sarcoplasmic reticulum or through reduction in the sensitivity of troponin to Ca^{+}.

Exercise and Aging

With sufficient training, the metabolic capacity of a muscle can change, delaying the onset of muscle fatigue. Muscle specified for high-intensity anaerobic exercise will synthesise more glycolytic enzymes, whereas muscle for long endurance aerobic exercise will develop more capillaries and mitochondria. Additionally, with exercise, improvements to the circulatory and

respiratory systems can facilitate better delivery of oxygen and glucose to the muscle.
With aging, levels of ATP, CTP, and myoglobin begin to decline, reducing the muscle's ability to function. Muscle fibers shrink or are lost and surrounding connective tissue hardens, making muscle contraction slower and more difficult. Exercise throughout life can help reduce the impact of aging by maintaining a healthy oxygen supply to the muscle.

Questions for control

1. From which two molecules can ADP borrow a phosphate group to become ATP? What is the enzyme that catalyzes each transfer?
2. In a long period of intense exercise, why does muscle generate ATP anaerobically at first and then switch to aerobic respiration?
3. List four causes of muscle fatigue.
4. List three causes of excess postexercise oxygen consumption.
5. What properties of fast glycolytic and slow oxidative fibers adapt them for different physiological purposes?

Basic literature:

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Lecture №5
Muscles of the head and neck

Outcomes:
1. name and locate the muscles that produce facial expressions;
2. name and locate the muscles used for chewing and swallowing;
3. name and locate the neck muscles that move the head; and
4. identify the attachments, action, and innervation of these muscles.

Muscles of Facial Expression
Humans have much more expressive faces than other mammals because of a complex array of muscles that insert in the dermis andsubcutaneous tissues. These muscles tense the skin and produce such expressions as a pleasant smile, a threateningscowl, a puzzled frown, or a flirtatious wink. They add subtle shades of meaning to our spoken words. Facial muscles also contribute directly to speech, chewing, and other oral functions. All but one of these muscles are innervated by the facial nerve (cranial nerve VII). This nerve is especially vulnerable to injury from lacerations and skull fractures, which can paralyze the muscles and cause parts of the face to sag. The only muscle in this table not innervated by the facial nerve is the levator palpebrae superioris, innervated by the oculomotor nerve (CN III).
The Scalp. The occipitofrontalis overlies the dome of the cranium. It is divided into the frontalis of the forehead and occipitalis at the rear of the head, named for the frontal and occipital bones underlying them. They are connected to each other by a broad aponeurosis, the **galea aponeurotica** (GAY-lee-uh APO-oh-new-ROT-ih-cuh).
The Orbital and Nasal Regions. The orbicularis oculi is a sphincter of the eyelid that encircles and closes the eye. The levator palpebrae superioris lies deep to the orbicularis oculi, in the eyelid and orbit, and opens the eye. Other muscles in this group move the eyelids and skin of the forehead and dilate the nostrils.
The Oral Region. The mouth is the most expressive part of the face, and lip movements are necessary for intelligible speech; thus, it is not surprising that the muscles here are especially diverse. The orbicularis oris is a complex of muscles in the lips that encircles the mouth; until recently it was misinterpreted as a sphincter, or circular muscle, but it is actually composed of four independent quadrants that interlace and give only an appearance of circularity. Other muscles in this region approach the lips from all directions and thus draw the lips or angles (corners) of the mouth upward, laterally, and downward. Some of these arise from a complex cord called the **modiolus** just lateral to each angle of the lips. Named for the hub of a cartwheel, the modiolus is a point of convergence of several muscles of the lower face. You can palpate it by inserting one finger just inside the corner of your lips and pinching the corner between the finger and thumb, feeling for a thick knot of tissue.
The Mental and Buccal Regions. Adjacent to the oral orifice are the mental region (chin) and buccal region (cheek). In addition to muscles already discussed that act directly on the lower lip, the mental region has a pair of small mentalis muscles extending from the upper margin of the mandible to the skin of the chin. In some people, these muscles are especially thick and have a visible dimple between them called the mental cleft. . The buccinator is the muscle in the cheek.

It has multiple functions in chewing, sucking, and blowing. If the cheek is inflated with air, compression of the buccinator blows it out. Sucking is achieved by contracting the buccinators to draw the cheeks inward, and then relaxing them. This action is especially important to nursing infants. To feel this action, hold your fingertips lightly on your cheeks as you make a kissing noise. You will notice the relaxation of the buccinators at the moment air is sharply drawn in through the pursed lips. The platysma is a thin superficial muscle of the upper chest and lower face. It is relatively unimportant, but when men shave they tend to tense the platysma to make the concavity between the jaw and neck shallower and the skin tauter.

Extrinsic Muscles of the Tongue. The tongue is a very agile organ. It pushes food between the molars for chewing (mastication) and later forces the food into the pharynx for swallowing (deglutition); it is also, of course, of crucial importance to speech. Both intrinsic and extrinsic muscles are responsible for its complex movements. The intrinsic muscles consist of a variable number of vertical fascicles that extend from the superior to the inferior sides of the tongue, transverse fascicles that extend from right to left, and longitudinal fascicles that extend from root to tip. The extrinsic muscles listed here connect the tongue to other structures in the head. Three of these are innervated by the hypoglossal nerve (CN XII), whereas the fourth is innervated by both the vagus (CN X) and accessory (CN XI) nerves.

Muscles of Chewing. Four pairs of muscles produce the biting and chewing movements of the mandible: the temporalis, masseter, and two pairs of pterygoid muscles. Their actions include depression to open the mouth for receiving food; elevation for biting off a piece of food or crushing it between the teeth; protraction so that the incisors meet in cutting off a piece of food; retraction to draw the lower incisors behind the upper incisors and make the rear teeth meet; and lateral and medial excursion, the side-to-side movements that grind food between the rear teeth. All of these muscles are innervated by a mandibular branch of the trigeminal nerve (CN V).

Hyoid Muscles—Suprahyoid Group. Several aspects of chewing, swallowing, and vocalizing are aided by eight pairs of hyoid muscles associated with the hyoid bone. The suprahyoid group is composed of the four pairs superior to the hyoid—the digastric, geniohyoid, mylohyoid, and stylohyoid.

Hyoid Muscles—Infrahyoid Group. Fix hyoid bone from below…allowing suprahyoid muscles to open mouth

Omohyoid (omo = shoulder)
Sternohyoid (sterno = chest, sternum)
Thyrohyoid (thyro = shield, thyroid cartilage)
Sternothyroid (sterno = chest, sternum, thyroid cartilage)

Flexors of the Neck. The prime mover of neck flexion is the sternocleidomastoid, a thick muscular cord that extends from the upper chest (sternum and clavicle) to the mastoid process behind the ear.. The three scalenes, located on the side of the neck, are named for being arranged somewhat like a staircase. Their actions are similar sothey are considered collectively.

Extensors of the Neck. The extensors are located mainly in the nuchal region (back of the neck;) and therefore tend to hold the head erect or draw it back. The trapezius is the most superficial of these. It extends from the nuchal region over the shoulders and halfway down the back. It is named for the fact that the right and left trapezii together form a diamond or trapezoidal shape. The splenius is a deeper, elongated muscle with splenius capitis and splenius cervicis regions in the head and neck, respectively. It is nicknamed the “bandage muscle” because of the way it wraps around still deeper neck muscles. One of those deeper muscles is the semispinalis, another elongated muscle with head, neck, and thoracic regions.

Questions for control

1. Name two muscles that elevate the upper lip and two that depress the lower lip.
2. Name the four paired muscles of mastication and state where they insert on the mandible.
3. Distinguish between the functions of the suprahyoid and infrahyoid muscles. 4. List the muscles of neck extension and flexion.

Basic literature:

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OMiF1214 Morphology and physiology of human body
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Lecture №6
Muscles of the Anterior Abdominal Wall; Muscles of the Pelvic Floor; Muscles of the Back. Muscles of Respiration

Outcomes:

1. name and locate the muscles of the abdominal wall, back, and pelvic floor;
2. name and locate the muscles of respiration and explain
3. how they affect airflow and abdominal pressure;
4. identify the skeletal attachments, action, and innervation fof these muscles.

Muscles of Respiration

We breathe primarily by means of muscles that enclose the thoracic cavity—the diaphragm, external intercostal, internal intercostal, and innermost intercostal muscles. The diaphragm is a muscular dome between the thoracic and abdominal cavities, bulging upward against the base of the lungs. It has openings for passage of the esophagus, major blood and lymphatic vessels, and nerves between the two cavities. Its fibers converge from the margins toward a fibrous central tendon. When the diaphragm contracts, it flattens slightly and enlarges the thoracic cavity, causing air intake (inspiration); when it relaxes, it rises and shrinks the thoracic cavity, expelling air (expiration).

Three layers of muscle lie between the ribs: the external, internal, and innermost intercostal muscles. The 11 pairs of external intercostal muscles constitute the most superficial layer. They extend from the rib tubercle posteriorly almost to the beginning of the costal cartilage anteriorly. Each one slopes downward and anteriorly from one rib to the next inferior one. The 11 pairs of internal intercostal muscles lie deep to the external intercostals and extend from the margin of the sternum to the angles of the ribs. They are thickest in the region between the costal cartilages and grow thinner in the region where they overlap the internal intercostals. Their fibers slope downward and posteriorly from each rib to the one below, at nearly right angles to the external intercostals. Each is divided into an intercartilaginous part between the costal cartilages and an interosseous part between the bony part of the ribs. The two parts differ in their respiratory roles. The innermost intercostal muscles vary in number, as they are sometimes absent from the upper thoracic cage. Their fibers run in the same direction as the internal intercostals, and they are presumed to serve the same function. The internal and innermost intercostals are separated by a fascia that allows passage for intercostal nerves and blood vessels.

The primary function of the intercostal muscles is to stiffen the thoracic cage during respiration so that it does not cave inward when the diaphragm descends. However, they also contribute to enlargement and contraction of the thoracic cage and thus add to the air volume that ventilates the lungs.

Many other muscles of the chest and abdomen contribute significantly to breathing: the sternocleidomastoid and scalenes of the neck; pectoralis major and serratus anterior of the chest; latissimus dorsi of the lower back; internal and external abdominal obliques and transverse abdominal muscle; and even some of the anal muscles.

Muscles of the Anterior Abdominal Wall

- Three layers of muscle enclose the lumbar region and extend about halfway across the anterior abdomen.
- The most **superficial layer** is the ***external abdominal oblique***. Its fibers pass downward and anteriorly.
- The **next deeper layer** is the ***internal abdominal oblique,*** whose fibers pass upward and anteriorly, roughly perpendicular to those of the external oblique.
- The **deepest layer** is the ***transverse abdominal*** *(transversus abdominis),* with horizontal fibers.
- Anteriorly, a pair of **vertical *rectus abdominis*** muscles extends from **sternum to pubis**.

Muscles of the Pelvic Floor;

- The floor of the pelvic cavity is formed mainly by an extensive muscle called the *levator ani*
- Inferior to this is the **perineum**, diamond-shaped region between the thighs •
  bordered by four bony landmarks
    - **pubic symphysis anteriorly**
    - **coccyx posteriorly**
    - **ischial tuberosities laterally**
  - **urogenital triangle – anterior half of perineum**
  - **anal triangle – posterior half of perineum**
- three layers of muscles and fasciae that span pelvic outlet
  - penetrated by anal canal, urethra, and vagina
- three layers or compartments of the perineum
  - **superficial perineal space** – three muscles
    - ***Ischiocavernosus*** *[ischio = ischium of hip bone; cavernosus = corpus cavernosum of the penis or clitoris],*
    - ***Bulbospongiosus*** *[bulbo = bulb of the penis; spongiosus = corpus spongiosum of the penis],*
  - ***superficial transverse peritoneal***

Muscles of the Back

Muscles of the back primarily extend, rotate, and laterally flex the vertebral column. The most prominent superficial back muscles are the latissimus dorsi and trapezius, but they are concerned with upper limb movements. Deep to these are the serratus posterior superior and inferior. They extend from the vertebrae to the ribs. They aid in deep breathing.

Deep to these is a prominent muscle, the erector spinae, which runs vertically for the entire length of the back from the cranium to the sacrum. It is a thick muscle, easily palpated on each side of the vertebral column in the lumbar region. (Pork chops and T-bone steaks are cut from erector spinae muscles.) As it ascends, it divides in the upper lumbar region into three parallel columns. The most lateral of these is the **iliocostalis,** which from inferior to superior is divided into the iliocostalis lumborum, iliocostalis thoracis, and iliocostalis cervicis (lumbar, thoracic, and cervical regions). The next medial column is the longissimus, divided from inferior to superior into the longissimus thoracis, longissimus cervicis, and longissimus capitis (thoracic, cervical, and cephalic regions). The most medial column is the **spinalis,** divided into spinalis thoracis, spinalis cervicis, and spinalis capitis. The functions of all three columns are sufficiently similar that we will treat them collectively as the erector spinae.

Questions for control

1. Which muscles are used more often, the external intercostals or internal intercostals?

Explain.

2. Explain how pulmonary ventilation affects abdominal pressureand vice versa.
3. Name a major superficial muscle and two major deep muscles of the back. 4. Define perineum, urogenital triangle, and anal triangle.
5. Name one muscle in the superficial perineal space, one in the urogenital diaphragm, and one in the pelvic diaphragm.
6. State the function of each.

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Lecture №7
Muscles Acting on the Shoulder and Upper Limb
Outcomes:

1. name and locate the muscles that act on the pectoral girdle, shoulder, elbow, wrist, and hand;
2. relate the actions of these muscles to the joint movements
3. describe the skeletal attachments, action, and innervation of these muscles

Muscles that act on the pectoral girdle extend from the axial skeleton to the clavicle and scapula. The scapula is only loosely attached to the thoracic cage and is capable of considerable movement—rotation (as in raising and lowering the apex of the shoulder), elevation and depression (as in shrugging and lowering the shoulders), and protraction and retraction (pulling the shoulders forward and back). The clavicle braces the shoulder and moderates these movements.

Anterior Group.

Muscles of the pectoral girdle fall into anterior and posterior groups. The major muscles of the anterior group are the pectoralis minor and serratus anterior. The pectoralis minor arises by three heads from ribs 3 to 5 and converges on the coracoid process of the scapula. The serratus anterior arises from separate heads on all or nearly all of the ribs, wraps laterally around the chest, passes across the back between the rib cage and scapula, and ends on the medial (vertebral) border of the scapula.

Posterior Group.

The posterior muscles that act on the scapula include the large, superficial trapezius, already discussed, and three deep muscles: the levator scapulae, rhomboid minor, and rhomboid major. The action of the trapezius depends on whether its superior, middle, or inferior fibers contract and whether it acts alone or with other muscles. The levator scapulae and superior fibers of the trapezius rotate the scapula in opposite directions if either of them acts alone. If both act together, their opposite rotational effects balance each other and they elevate the scapula and shoulder, as when you lift a suitcase from the floor. Depression of the scapula occurs mainly by gravitational pull, but the trapezius and serratus anterior can depress it more rapidly and forcefully, as in swimming, hammering, and rowing.

Muscles Acting on Arm

Nine muscles cross the shoulder joint and insert on humerus two are axial muscles because they originate on axial skeleton

– pectoralis major – flexes, adducts, and medially rotates humerus
– latissimus dorsi – adducts and medially rotated humerus

Seven scapular muscles – originate on scapula

- deltoid rotates and abducts arm, intramuscular injection site
- teres major extension and medial rotation of humerus
- coracobrachialis flexes and medially rotates arm

–

Remaining four form the rotator cuff that reinforce the shoulder joint

– tendons of the remaining four scapular muscles form **the rotator cuff –**

"SITS" muscles – for the first letter of their names

– supraspinatus【supra = above; spin = spine of scapula 】

– infraspinatus【infra = below, under; spin = spine of scapula 】

– teres minor

– subscapularis【sub = below, under 】

– tendons of these muscles merge with the joint capsule of the shoulder as they cross it in route to the humerus

– holds head of humerus into glenoid cavity

– supraspinatus tendon most easily damaged

Muscles Acting on Forearm

• elbow and forearm capable of flexion, extension, pronation, and supination – carried out by muscles in both brachium (arm) and antebrachium (forearm) – muscles with bellies in the arm (brachium)

– **principal elbow flexors** – anterior compartment

• brachialis and biceps brachii

– brachialis produces 50% more power than biceps brachii

– brachialis is prime mover of elbow flexion

– **principal elbow extensor** – posterior compartment

• triceps brachii

– prime mover of elbow extension

• muscles with bellies in the forearm (antebrachium)

• most forearm muscles act on the hand and wrist

• brachioradialis – flexes elbow

• anconeus – extends elbow

• pronator quadratus – prime mover in forearm pronation

• pronator teres – assists pronator quadratus in pronation

• supinator – supinates the forearm

–

• **Anterior Muscles Acting on Wrist and Hand**

• extrinsic muscles of the forearm

• intrinsic muscles in the hand itself

• extrinsic muscle actions

• flexion and extension of wrist and digits

• radial and ulnar flexion

• finger abduction and adduction

• thumb opposition

• **<u>Anterior (Flexor) Compartment – superficial layer</u>**

• flexor carpi radialis

• flexor carpi ulnaris

• flexor digitorum superficialis

• palmaris longus

• **<u>Anterior (Flexor) Compartment – deep layer</u>**

• flexor digitorum profundus

• flexor pollicis longus

Posterior Muscles Acting on Wrist & Hand

extension of wrist and fingers, adduct / abduct wrist extension and abduction of thumb (pollicis) brevis - short, ulnaris - on ulna side of forearm

- **Posterior (Extensor) Compartment – superficial layer**
  - extensor carpi radialis longus
  - extensor carpi radialis brevis
  - extensor digitorum
  - extensor digiti minimi
  - extensor carpi ulnaris
- **Posterior (Extensor) Compartment – deep layer**
  - abductor pollicis longus
  - extensor pollicis brevis
  - extensor pollicis longus
  - extensor indicis

Questions for control

1. Name a muscle that inserts on the scapula and plays a significant role in each of the following actions:
   a. pushing a stalled car,
   b. paddling a canoe,
   c. squaring the shoulders in military attention,
   d. lifting the shoulder to carry a heavy box on it, and
   e. lowering the shoulder to lift a suitcase.
2. Describe three contrasting actions of the deltoid muscle.
3. Name the four rotator cuff muscles and describe the scapular surfaces against which they lie.
4. Name the prime movers of elbow flexion and extension.
5. Identify three functions of the biceps brachii.
6. Name three extrinsic muscles and two intrinsic muscles that flex the phalanges.

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Course – 1
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Lecture 8
Human tissue 3-4
Blood. Hemopoiesis Erythrocytes, leukocytes, platelets. Hemopoiesis

LECTURE OUTLINE
· General features of the Blood.
· Basic cell types. Staining properties. Formed elements.
· Hematopoiesis. Organization of the Skeletal Muscle.
· General features of Hematopoiesis.
· Development of hematopoietic tissues. General structure of mature hematopoietic tissues.

LEARNING OUTCOMES
1. list the name, structure and functions of each formed element in blood. 2. recognize the formed elements in a micrograph of a blood smear.
3. describe the structural and functional characteristics of a stem cell.
4. compare mature circulating blood cells and hematopoietic stem cells.
5. recognize differences in the erythrocytes produced during each phase.

BLOOD refers to the blood system which includes 3 parts: 1 – blood producing organs (the hematopoietic organs make blood cells, the liver – plasma proteins), 2 – peripheral blood and lymph, as well as blood cells in tissues; 3 – blood destroying organs (the spleen and the liver). Blood is an intravascular liquid tissue made up of structural elements and liquid intercellular substance – plasma. In adults blood makes 6–8 % of the body weight, in newborns – 13–15 %, in children till 14 years old – 9 %. The structural blood elements include about 99 % *of erythrocytes, and about 1 % of leukocytes and platelets (thrombocytes)*. In the course of blood analysis the ***hemogram*** is made. The hemogram includes the basic parameters: hematocrit (Ht,the number of formed elements) – 30–35 %, the number of erythrocytes – 4–5,5*1012/l(=per liter of) blood; leukocytes – 3–10*109/l; platelets – 130–400*109/l; There are 2 types of hematopoiesis:
1) embryonic – it is histogenesis, the formation of blood like a tissue;
2) postnatal – it is physiological regeneration, renewal of blood.
EMBRYONIC HEMATOPOIESIS begins in the yolk sac mesenchyme where the first stem cells (SC) which originate the blood cells and vessels are formed. Later SC migrate through the vessels into the embryo`s body – first into the liver and then into the thymus, spleen, lymph nodes and bone marrow.During the 2nd–3rd weeks of the development the mesenchymal cells form blood islets in the wall of the YOLK SAC. In the islet center the cells lose their processes and differentiate into hematopoietic stem cells. On the islet periphery the cells are flattened and form vascular walls: the endothelial, smooth muscle and connective tissue layers. POST- EMBRYONIC HEMATOPOIESIS. It is physiological regeneration of blood. The bone marrow is the universal hematopoietic organ, which stores SC reserves. In the thymus the T-cells (helpers and suppressors) are formed. In the spleen, lymph nodes and lymphoid follicles of the mucosa the final forms of T and B-lymphocytes develop. The founder of the monophyletic theory, Maksimov, was the first who

suggested that all blood cells are formed from SC morphologically similar to small lymphocytes. This was confirmed in the experiments that showed that SC form
colonies of various blood cells inthe tissue culture. *SC are pluripotent cells*. They proliferate and form *two major lineages of progenitor polypotent cells (half-stem cells, HSC)* – lymphoid cells (for lymphopoiesis) and myeloid cells (for other blood cells). From these, under the action of colony stimulating factors (CSF) *7 unipotent progenitor cells* are formed; they are called colony-forming units (CFU):

1) CFU-GM – gives progeny of CFU-M (monocytes) and CFU-Gn
(neutrophiles);
2) CFU-Eo (eosinophiles);
3) CFU-B (basophiles);
30
4) CFU-Meg (megakaryocytes);
5) CFU-E (erythrocytes);
6) pre-T- cell (T-lymphocyte);
7) pre-B-cell (B-lymphocyte).

Questions for self-control:

1. What main components of blood do you know?
2. What types of leukocytes do you know?
3. What are the functions of granulocytes?
4. What are the functions of agranulocytes?
5. What types of hematopoiesis do you know?
6. What is the basic of the hematopoiesis theory?

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Lecture 9
Blood 1
Introduction, Blood Types. Erythrocytes.
Outcomes:

1. describe the functions and major components of the circulatory system;
2. describe the components and physical properties of blood;
3. describe the composition of blood plasma;
4. explain the significance of blood viscosity and osmolarity;and
5. describe in general terms how blood is produced.
6. explain the function of leukocytes in general and the individual role of each leukocyte type;
7. describe the appearance and relative abundance of each type of leukocyte;
8. describe the formation and life history of leukocytes;
9. discuss the types, causes, and effects of leukocyte excesses and deficiencies.

The circulatory system consists of the heart, blood vessels, and blood. The term cardiovascular system refers only to the heart and vessels, which are the subject of the next two chapters. The study of blood, treated in this chapter, is called hematology. The fundamental purpose of the circulatory system is to transport substances from place to place in the body. Blood is the liquid medium in which these materials travel, blood vessels ensure the proper routing of blood to its destinations, and the heart is the pump that keeps the blood flowing.
More specifically, the functions of the circulatory system are as follows:

Transport

• Blood carries oxygen from the lungs to all of the body's tissues, while it picks up carbon dioxide from those tissues and carries it to the lungs to be removed from the body. • It picks up nutrients from the digestive tract and delivers them to all of the body's tissues. • It carries metabolic wastes to the kidneys for removal.

• It carries hormones from endocrine cells to their target organs.

• It transports a variety of stem cells from the bone marrow and other origins to the tissues where they lodge and mature.

Protection

• Blood plays several roles in inflammation, a mechanism for limiting the spread of infection. • White blood cells destroy microorganisms and cancer cells and remove debris from the tissues. • Antibodies and other blood proteins neutralize toxins and help to destroy pathogens. • Platelets secrete factors that initiate blood clotting and other processes for minimizing blood loss, and contribute to tissue growth and blood vessel maintenance.

Regulation

• By absorbing or giving off fluid under different conditions, the blood capillaries help to stabilize fluid distribution in the body.
• By buffering acids and bases, blood proteins help to stabilize the pH of the extracellular fluids. • Cutaneous blood flow is extremely important in dissipating metabolic heat from the body. Shifts in blood flow help to regulate body temperature by routing blood to the skin for heat loss or retaining it deeper in the body to conserve heat.

Erythrocytes, or red blood cells (RBCs), have two principal functions:
(1) to pick up oxygen from the lungs and deliver it to tissues elsewhere, and
(2) to pick up carbon dioxide from the tissues and unload it in the lungs.

RBCs are the most abundant formed elements of the blood and therefore the most obvious things one sees upon its microscopic examination. They are also the most critical to survival; a severe deficiency of leukocytes or platelets can be fatal within a few days, but a severe deficiency of RBCs can be fatal within mere minutes. It is the lack of life-giving oxygen, carried by erythrocytes, that leads rapidly to death in cases of major trauma or hemorrhage.

Leukocytes, or white blood cells (WBCs), are the least abundant formed elements, totaling only 5,000 to 10,000 WBCs/μL. Yet we cannot live long without them, because they afford protection against infection and other diseases. WBCs are easily recognized in stained blood films because they have conspicuous nuclei that stain from light violet to dark purple with the most common blood stains. They are much more abundant in the body than their low number in blood films would suggest, because they spend only a few hours in the bloodstream, then migrate into the connective tissues and spend the rest of their lives there. It's as if the bloodstream were merely the subway that the WBCs take to work; inblood films, we see only the ones on their way to work, not the WBCs already at work in the tissues.

Types of Leukocytes

- **granulocytes**
  - – neutrophils (60-70%)-polymorphonuclear leukocytes
    - • barely-visible granules in cytoplasm; 3 to 5 lobed nucleus
  - – eosinophils (2-4%)
    - • large rosy-orange granules; bilobed nucleus
  - – basophils (<1%)
    - • large, abundant, violet granules (obscure a large S-shaped nucleus)
- **agranulocytes**
  - – lymphocytes (25-33%)
    - • variable amounts of bluish cytoplasm (scanty to abundant); ovoid/round, uniform dark violet nucleus
  - – monocytes (3-8%)
    - • largest WBC; ovoid, kidney-, or horseshoe- shaped nucleus

Leukocyte Disorders

The total WBC count is normally 5,000 to 10,000 WBCs/μL. A count below this range, called leukopenia21 (LOO-co-PEE-neeuh), is seen in lead, arsenic, and mercury poisoning; radiation sickness; and such infectious diseases as measles, mumps, chickenpox, polio, influenza, typhoid fever, and AIDS. It can also be produced by glucocorticoids, anticancer drugs, and

immunosuppressant drugs given to organ-transplant patients. Since WBCs are protective cells, leukopenia presents an elevated risk of infection and cancer. A count above 10,000 WBCs/μL, called leukocytosis,22 usually indicates infection, allergy, or other diseases but can also occur in response to dehydration or emotional disturbances. More useful than a total WBC count is a differential WBC count, which identifies what percentage of the total WBC count consists of each type of leukocyte.

Questions for control

1. Describe the size, shape, and contents of an erythrocyte, and explain how it acquires its unusual shape.
2. What is the function of hemoglobin? What are its protein and nonprotein moieties called?
3. Define hematocrit, hemoglobin concentration, and RBC count and give the units of measurement in which each is expressed.
4. List the stages in the production of an RBC and describe how each stage differs from the previous one.
5. What is the role of erythropoietin in the regulation of RBC count? What is the role of gastroferritin?
6. What happens to each component of an RBC and its hemoglobin when it dies and disintegrates?
7. What are the three primary causes or categories of anemia?
8. What are its three primary consequences?
9. What is the overall function of leukocytes?
10. List the five kinds of leukocytes in order of abundance, identify whether each is a granulocyte or agranulocyte, and describe the functions of each one.
11. What does leukopoiesis have in common with erythropoiesis?
12. How does it differ?
13. What can cause an abnormally high or low WBC count?
14. Suppose myeloblasts began multiplying out of control, but their subsequent development remained normal.
15. What types of mature WBCs would be produced in excess?
16. What types would not?

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Lecture 10
Blood 2
Platelets and Hemostasis, The Control of Bleeding. Interpretation of blood test, coagulogram. Changes in blood system parameters

Outcomes:

1. describe the body's mechanisms for controlling bleeding;
2. list the functions of platelets;
3. describe two reaction pathways that produce blood clots;
4. explain what happens to blood clots when they are no longer needed;
5. explain what keeps blood from clotting in the absence of injury; and
6. describe some disorders of blood clotting.

Platelet Form and Function

Platelets are not cells but small fragments of marrow cells called megakaryocytes. They are the second most abundant formed elements, after erythrocytes; a normal platelet count in blood from a fingerstick ranges from 130,000 to 400,000 platelets/μL (averaging about 250,000). The platelet count can vary greatly, however, under different physiological conditions and in blood samples taken from various places in the body. In spite of their numbers, platelets are so small (2 to 4 μm in diameter) that they contribute even less than WBCs to the blood volume.

Platelets have a complex internal structure that includes lysosomes, mitochondria, microtubules and microfilaments; granules filled with platelet secretions; and a system of channels called the open canalicular system, which opens onto the platelet surface. They have no nucleus. When activated, they form pseudopods and are capable of ameboid movement.

Despite their small size, platelets have a greater variety of functions than any of the true blood cells:

• They secrete vasoconstrictors, chemicals that stimulate spasmodic constriction of broken vessels and thereby help to reduce blood loss.

• They stick together to form temporary platelet plugs that seal small breaks in injured blood vessels.

• They secrete procoagulants, or clotting factors, which promote blood clotting. • They initiate the formation of a clot-dissolving enzyme that dissolves blood clots that have outlasted their usefulness.

• They secrete chemicals that attract neutrophils and monocytes to sites of inflammation.

• They internalize and destroy bacteria.

• They secrete growth factors that stimulate mitosis in fibroblasts and smooth muscle and thereby help to maintain and repair blood vessels.

Questions for control

1. What are the three basic mechanisms of hemostasis?
2. How do the extrinsic and intrinsic mechanisms of coagulation differ? What do they have in common?
3. In what respect does blood clotting represent a negative feedback loop? What part of it is a positive feedback loop?
4. Describe some of the mechanisms that prevent clotting in undamaged vessels.
5. Describe a common source and effect of pulmonary embolism.

Basic literature:

1. Saladin, Kenneth S: Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education) на англ. яз.
2. Costanzo, Linda S.: BRS Physiology. Board Review Series.7 edition. -Wolters Kluwer Health, 2018.- 307p. - ISBN 1496367693, 9781496367693
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Lecture 11
Human Histology 5-6
Cardiovascular system. General features of the CVS. Blood vessels. Arteries and veins. Microcirculation stream. Arterioles. Capillaries. Venules.

LECTURE OUTLINE

·General features of the Circulatory system.
·General features of the Blood vessels.
·Comparison and classification of arteries, veins, blood capillaries.
·General features of the Heart.
·Cardiac skeleton, tunics.
·Cardiac muscle.

LEARNING OUTCOMES

1. name the 3 tunics that make up the walls of cardiovascular system components.
2. know the tissue type in each tunic in wall of blood vessels and heart.
3. list the features of cardiac muscle that distinguish it from other muscle tissues.
4. recognize the vessel types in a micrograph and identify their structural components.
5. distinguish between cardiac muscle and Purkinje fibers
6. identify the endocardium, myocardium, epicardium in micrographs of the heart.

The cardiovascular system consists of the heart, blood and lymphatic vessels. In the organs some portion of blood plasma leaves the vessels for tissues, provides them with nutrition, collects metabolic products and turns into the lymph. The lymph passes into lymphatic vessels, is cleared in the lymph nodes and returns to the blood. The vessels develop from the yolk sac mesenchyme at the 2nd–3rd week. Their formation is influenced by hemodynamic conditions, it est the vessel's function, blood pressure and the rate of blood flow. The arteries carry blood from the heart to organs; the pressure in them is high, and the blood flow is rapid. The microcirculation vessels (arterioles, capillaries, venules) are responsible for metabolism between the blood and tissues; the blood flow rate is slowed down, the pressure is low. The veins carry blood from organs to the heart; the pressure is still low, the blood flow rate is slow. All vessels are lined with inner endothelium. It is a continuous layer of squamous cells on the basal membrane. The ARTERIES are of the large, medium and small size. By structure they can be elastic, mixed, or muscular. The vessel walls have 3 concentric tunics: 1) the internal tunica intima of 3 layers – endothelium, subendothelial layer of the loose connective tissue and the internal elastic membrane, 2) the middle tunica media of smooth myocytes and elastic fibers, 3) the external tunica adventitia of the loose connective tissue with nerves and vessels, and the external elastic membrane. The VEINS can be small, medium and large; by structure they are muscular and non-muscular. The microcirculatory blood stream provides metabolism and protective reactions.

They include vessels less than 100 microns in diameter. They are arterioles, capillaries and venules. *Arterioles* are short, d=50–100 microns, and regulate the blood supply of organs. The wall structure is like that in arteries, but all sheaths are thin. In the tunica media myocyte bundles are circular. The adventitia has non-differentiated cells and labrocytes. *Capillaries* are from 4,5–7 to 20–40 microns in diameter. The HEART pumps blood and lymph like a pump. Its walls have 3 tunics: endocardium, myocardium, and epicardium. The myocardium and epicardium develop from the myoepicardial plate of the mesoderm visceral layer. The endocardium develops at the 3rd week from the mesenchyme, like a vessel. It consists of 4 layers: 1) the endothelium layer made of large cells on the thick basal membrane; 2) the subendothelial layer, like in the aorta, 3) the musculoelastic layer of smooth myocytes and elastic fibers; 4) the external connective tissue layer with fine vessels. The myocardium contains 3 types of cardiomyocytes: 1) contracting typical; 2)conductive atypical; 3) secretory endocrine.

Questions for self-control:

1. What organs belong to the cardiovascular system?
2. Name the tunics of the blood vessels wall.
3. What are the types of arteries by the size and structure of the wall?
4. What are the types of veins by the size and structure of the wall?
5. List the microvasculature vessels.
6. Name the heart tunics.
7. What are the types of cardiomyocytes?

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2. Victor P. Eroschenko, Atlas of Histology with Functional Correlations 13th Edition, LWW, 2017

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Lecture 12

Overview of the Cardiovascular System. Gross Anatomy of the heart

Outcomes:

1. define and distinguish between the pulmonary circuit and systemic circuit;
2. describe the general location, size, and shape of the heart; and
3. describe the pericardial sac that encloses the heart.
4. describe the three layers of the heart wall;
5. identify the four chambers of the heart;
6. identify the surface features of the heart and correlate them with its internal four chambered anatomy;
7. identify the four valves of the heart;
8. trace the flow of blood through the four chambers and valves of the heart and adjacent blood vessels; and
9. describe the arteries that nourish the myocardium and the veins that drain it.

The Pulmonary and Systemic Circuits

The cardiovascular system has two major divisions: a **pulmonary circuit,** which carries blood to the lungs for gas exchange and returns it to the heart, and a **systemic circuit,** which supplies blood to every organ of the body, including other parts of the lungs and the wall of the heart itself.

Position, Size, and Shape of the Heart

The heart lies within a thick partition called the **mediastinum** between the two lungs. It extends from a broad **base** at its uppermost end, where the great vessels are attached, to a bluntly pointed **apex** at the lower end, just above the diaphragm. It tilts toward the left from base to apex, so somewhat more than half the heart is to the left of the body's median plane. We can see this especially in a cross (horizontal) section through the thorax. The adult heart is about 9 cm (3.5 in.) wide at the base, 13 cm (5 in.) from base to apex, and 6 cm (2.5 in.) from anterior to posterior at its thickest point. Whatever one's body size, from child to adult, the heart is roughly the same size as the fist. It weighs about 300 g (10 ounces) in adults. The heart is enclosed in a double-walled sac called the **pericardium.** The outer wall, called the **pericardial sac (parietal pericardium),** has a tough, superficial *fibrous layer* of dense irregular connective tissue and a thin, deep *serous layer.* The serous layer turns inward at the base of the heart and forms the **visceral pericardium,** equivalent to the epicardium described shortly as part of the heart wall.

The Heart Wall

The heart wall consists of three layers: *epicardium, myocardium,* and *endocardium.* The

epicardium (visceral pericardium) is a serous membraneof the external heart surface. It consists mainly of a simple squamous epithelium overlying a thin layer of areolar tissue. In some places, it also includes a thick layer of adipose tissue muscle of the underlying myocardium shows through. The largest branches of the coronary blood vessels travel through the epicardium.
The **endocardium,** a similar layer, lines the interior of the heart chambers. Like the epicardium, this is a simple squamous epithelium overlying a thin areolar tissue layer; however, it has no adipose tissue. The endocardium covers the valve surfaces and is continuous with the endothelium of the blood vessels.
The **myocardium** between these two is composed of cardiac muscle. This is by far the thickest layer and performs the work of the heart. Its thickness is proportional to the workload on the individual chambers.

The heart contains 4 chambers that essentially make up 2 sides of 2 chamber (atrium and ventricle) circuits; the left side chambers supply the systemic circulation, and the right side chambers supply the pulmonary circulation. The chambers of each side are separated by an atrioventricular valve (A-V valve). The left-sided chambers are separated by the mitral (bicuspid) valve, and right-sided chambers are divided by the tricuspid valve. Blood flows through the heart in only one direction enforced by a valvular system that regulates opening and closure of valves based on pressure gradients

Questions for control

1. Distinguish between the pulmonary and systemic circuits and state which part of the heart supplies each one.
2. Predict the effect of a pericardial sac that fits too tightly around the heart. Predict the effect of a failure of the pericardial sac to secrete pericardial fluid.
3. Name the three layers of the heart and describe their structural differences.
4. What are the functions of the fibrous skeleton?
5. Trace the flow of blood through the heart, naming each chamber and valve in order.
6. What are the three principal branches of the left coronary artery? Where are they located on the heart surface? What are the branches of the right coronary artery, and where are they located?
7. What is the medical significance of anastomoses in the coronary arterial system?
8. Why do the coronary arteries carry a greater blood flow during ventricular relaxation than they do during ventricular contraction?
9. What are the three major veins that empty into the coronary sinus?

Basic literature:

1. Saladin, Kenneth S: Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Costanzo, Linda S.: BRS Physiology. Board Review Series.7 edition. -Wolters Kluwer Health, 2018.- 307p. - ISBN 1496367693, 9781496367693
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Lecture 13
Biophysics 2
Electrical and Contractile Activity of the Heart. ECG

LECTURE OUTLINE

1. Reason of the arising of biopotentials.
2. Structural scheme of the biopotentials registering, standard leads.
3. Main statements of the Einthoven theory.
4. Mechanism of forming of cardiogram.
5. Cardiograph, main blocks.
6. Input block of cardiograph: electrodes, cables of leads.
7. Amplification block: input and output parameters.
8. Registering devices: different types.

Learning outcomes:

• learn the theoretical basics of the method, principles of the work of cardiograph; • find out the functions of main blocks, mechanism of registering and principles of analysis of cardiogram.
• understand the principles of registering, to teach the main moments of decoding of cardiogram; • determination of time intervals, pulse, anatomic axis.

Electrocardiography is a transthoracic interpretation of the electrical_activity of the heart over a period of time, as detected by electrodes attached to the outer surface of the skin and recorded by a device external to the body. The recording produced by this noninvasive procedure is termed as **electrocardiogram**. An ECG test records the electrical activity of the heart.

ECG is used to measure the rate and regularity of heartbeats, as well as the size and position of the chambers, the presence of any damage to the heart, and the effects of drugs or devices used to regulate the heart, such as a pacemaker.

Most ECGs are performed for diagnostic or research purposes on human hearts, but may also be performed on animals, usually for diagnosis of heart abnormalities or research.

Function

An ECG is the best way to measure and diagnose abnormal rhythms of the heart, particularly abnormal rhythms caused by damage to the conductive tissue that carries electrical signals, or abnormal rhythms caused by electrolyte imbalances. In a myocardial infarction (MI), the ECG can identify if the heart muscle has been damaged in specific areas, though not all areas of the heart are covered. The ECG cannot reliably measure the pumping ability of the heart, for which ultrasound based (echocardiography) or nuclear medicine tests are used. It is possible for a human or other animal to be

in cardiac arrest, but still have a normal ECG signal (a condition known as pulseless electrical activity).

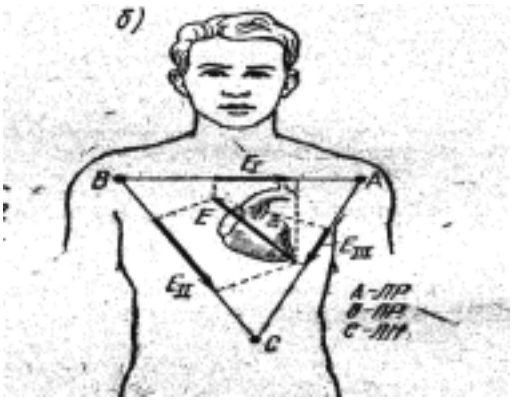
The ECG device detects and amplifies the tiny electrical changes on the skin that are caused when the heart muscle depolarizes during each heartbeat. At rest, each heart muscle cell has a negative charge, called the membrane potential, across its cell membrane. Decreasing this negative charge towards zero, via the influx of the positive cations, $Na^{+}$and Ca^{++}, is called depolarization, which activates the mechanisms in the cell that cause it to contract. During each heartbeat, a healthy heart will have an orderly progression of a wave of depolarisation that is triggered by the cells in the sinoatrial node, spreads out through the atrium, passes through the atrioventracular node and then spreads all over theventricles. This is detected as tiny rises and falls in the voltage between two electrodes placed either side of the heart which is displayed as a wavy line either on a screen or on paper. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle.

Leads

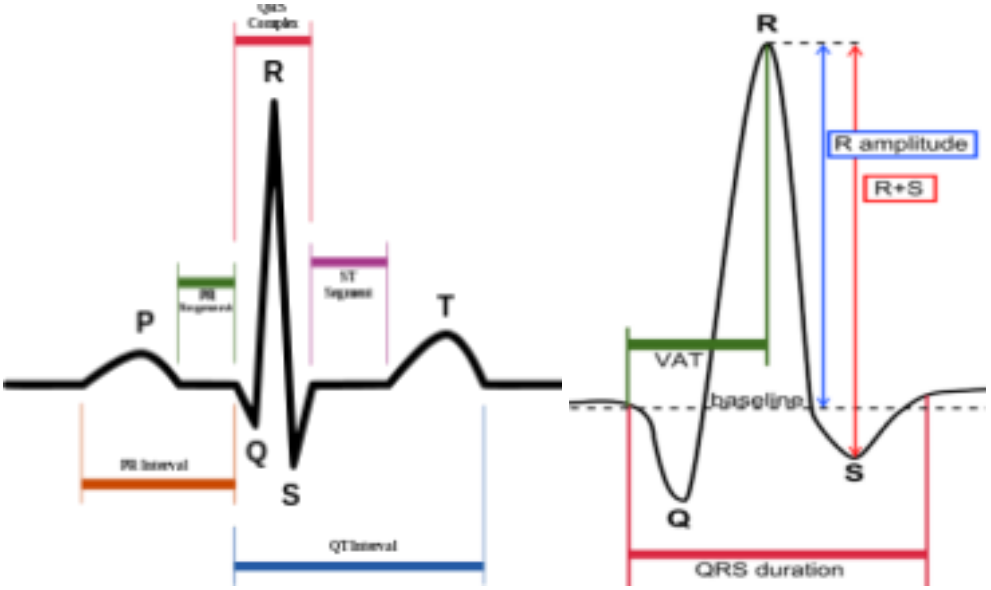
The term "lead" in electrocardiography causes much confusion because it is used to refer to two different things. In accordance with common parlance, the word lead may be used to refer to the electrical cable attaching the electrodes to the ECG recorder. As such, it may be acceptable to refer to the "left arm lead" as the electrode (and its cable) that should be attached at or near the left arm. Usually, 10 of these electrodes are standard in a "12-lead" ECG.

Alternatively (and some would say properly, in the context of electrocardiography), the word lead may refer to the tracing of the voltage difference between two of the electrodes and is what is actually produced by the ECG recorder. Each will have a specific name. For example "lead I" is the voltage between the right arm electrode and the left arm electrode, whereas "Lead II" is the voltage between the right arm and the feet. (This rapidly becomes more complex as one of the "electrodes" may in fact be a composite of the electrical signal from a combination of the other electrodes (see later). Twelve of this type of lead form a "12-lead" ECG.

To cause additional confusion, the term "limb leads" usually refers to the tracings from leads I, II and III rather than the electrodes attached to the limbs.



Waves and intervals



P.3. Schematic representation of normal ECG P.2. Detail of the QRS complex, showingventricular activation time (VAT) and amplitude

The questions for self - control:

1. Mechanism of arise the biological potentials in tissues and organs, essence of one or another biopotentials in living organism.
2. What is Einthoven theory? What does the cardiogram register and what dependence does it show?
3. How to determine the value of heart biopotentials in the different moments of heart cycle using cardiogram?
4. Symbols of the ECG intervals.
5. How the duration of time intervals is determined? What values does it have?
6. How to determine the heart rate (pulse) and position of the anatomic axis of the heart using ECG?

Recommended literature:

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Lecture 14

Cardiac Muscle and the Cardiac Conduction System. Blood flow, heart sounds and cardiac cycle

Output Outcomes:

1. explain why the SA node fires spontaneously and rhythmically;
2. explain how the SA node excites the myocardium;
3. describe the unusual action potentials of cardiac muscle and relate them to the contractile behavior of the heart;
4. interpret a normal electrocardiogram.

Contraction is called **systole** (SIS-toe-lee) and relaxation is **diastole.** These terms can refer to a specific part of the heart (for example, atrial systole), but if no particular chamber is specified, they usually refer to the more conspicuous and important ventricular action, which ejects blood from the heart.

The Cardiac Rhythm

The normal heartbeat triggered by the SA node is called the**sinus rhythm.** At rest, the adult heart typically beats about 70 to 80 times per minute, although heart rates from 60 to 100 bpm are not unusual. Any region of spontaneous firing other than the SA node is called an **ectopic**22 **focus.** If the SA node is damaged, an ectopic focus may take over the governance of the heart rhythm. The most common ectopic focus is the AV node, which produces a slower heartbeat of 40 to 50 bpm called a **nodal (junctional) rhythm.** If neither the SA nor AV node is functioning, other ectopic foci fire at rates of 20 to 40 bpm. The nodal rhythm is sufficient to sustain life, but a rate of 20 to 40 bpm provides too little flow to the brain to be survivable. This condition calls for an artificial pacemaker.

Pacemaker Physiology

Why does the SA node spontaneously fire at regular intervals? Unlike skeletal muscle or neurons, cells of the SA node do not have a stable resting membrane potential. Their membrane potential starts at about −60 mV and drifts upward, showing a gradual depolarization called the **pacemaker potential (prepotential)**. This results primarily from a slow inflow of Na+ without a compensating outflow of K+.When the pacemaker potential reaches a threshold of −40 mV, voltage-gated calcium channels open and Ca2+ flows in from the extracellular fluid. This produces the rising (depolarizing) phase of the action potential, which peaks slightly above 0 mV. At that point, K+ channels open and K+ leaves the cell. This makes the cytosol increasingly negative and creates the falling (repolarizing) phase of the action potential. When repolarization is complete, the K+ channels close and the pacemaker potential starts over, on its way to producing the next heartbeat. Each depolarization of the SA node sets off one heartbeat. When the

SA node fires, it excites the other components in the conduction system; thus, the SA node serves as the system's pacemaker. At rest, it typically fires every 0.8 second or so, creating a heart rate of about 75 bpm.

Questions for control

1. Define *systole* and *diastole.*
2. How does the pacemaker potential of the SA node differ from the resting membrane potential of a neuron? Why is this important in creating the heart rhythm?
3. Why is it important that the AV node slow down signal conduction to the ventricles?
4. How does excitation–contraction coupling in cardiac muscle resemble that of skeletal muscle? How is it different?
5. What produces the plateau in the action potentials of cardiomyocytes?
6. Why is this important to the pumping ability of the heart?
7. Identify the portion of the ECG that coincides with each of the following events: atrial depolarization, atrial systole, atrial repolarization, ventricular depolarization, ventricular systole, ventricular repolarization, ventricular diastole.

Basic literature:

1. Saladin, Kenneth S: Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education) на англ. яз.
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Lecture 15
Cardiac Output. General Anatomy of the Blood Vessels

Outcomes:

1. describe the structure of a blood vessel;
2. b. describe the types of arteries, capillaries, and veins;
3. c. trace the general route usually taken by the blood from
4. the heart and back again; and
5. d. describe some variations on this route.

There are three principal categories of blood vessels: arteries, veins, and capillaries (fig. 20.1). **Arteries** are the efferent vessels of the cardiovascular system—that is, vessels that carry blood away from the heart. **Veins** are the afferent vessels thatcarry blood back to the heart. **Capillaries** are microscopic, thin walled vessels that connect the smallest arteries to the smallest veins.

The Vessel Wall

Aside from their general location and direction of blood flow, the three categories of blood vessels also differ in the histological structure of their walls. The walls of arteries and veins are composed of three layers called *tunics*:

1. The **tunica interna (tunica intima)**
2. The **tunica media**
3. The **tunica externa (tunica adventitia**1)

Arteries

Arteries are sometimes called the *resistance vessels* of the cardiovascular system because they have a relatively strong, resilient tissue structure. Each beat of the heart creates a surge of pressure in the arteries as blood is ejected into them, and arteries are built to withstand these surges. Being more muscular than veins, they retain their round shape even when empty, and they appear relatively circular in tissue sections. They are divided into three classes by size, but of course there is a gradual transition from one class to the next.

1. **Conducting (elastic** or **large) arteries**
2. **Distributing (muscular** or **medium) arteries**
3. **Resistance (small) arteries**

Capillaries

For the blood to serve any purpose, materials such as nutrients, wastes, hormones, and leukocytes must pass between the blood and the tissue fluids, through the walls of the vessels. There are only two places in the circulation where this occurs—the capillaries and some venules.

We can think of these as the "business end" of the cardiovascular system, because all the rest of the system exists to serve the exchange processes that occur here. Since capillaries greatly outnumber venules, they are the more important of the two. Capillaries are sometimes called the *exchange vessels* of the cardiovascular system; the arterioles, capillaries, and venules are also called the **microvasculature (microcirculation).**Capillaries consist of only an endothelium and basal lamina. Their walls are as thin as 0.2 μm. They average about 5 μm in diameter at the proximal end (where they receive arterial blood), widen to about 9 μm at the distal end (where they empty into a small vein), and often branch along the way. Since erythrocytes are about 7.5 μm in diameter, they have to stretch into elongated shapes to squeeze through the smallest capillaries.

1. **Continuous capillaries**
2. **Fenestrated capillaries**
3. **Sinusoids (discontinuous capillaries**

Veins

Veins are regarded as the *capacitance vessels* of the cardiovascular system because they are relatively thin-walled and flaccid, and expand easily to accommodate an increased volume of blood; that is, they have a greater *capacity* for blood containment than arteries do. At rest, about 64% of the blood is found in the systemic veins as compared with only 13% in the systemic arteries. The reason that veins are so thin-walled and accommodating is that, being distant from the ventricles of the heart, they are subjected to relatively low blood pressure. In large arteries, blood pressure averages 90 to 100 mm Hg and surges to 120 mm Hg during systole, whereas in veins it averages about 10 mm Hg. Furthermore, the blood flow in the veins is steady, rather than pulsating with the heartbeat like the flow in the arteries. Veins therefore do not require thick, pressure-resistant walls. They collapse when empty and thus have relatively flattened, irregular shapes in histological sections

1. Postcapillary venules
2. Muscular venules
3. Medium veins
4. Venous sinuses
5. Large veins

Questions for control

1. Name the three tunics of a typical blood vessel and explain how they differ from each other.
2. Contrast the tunica media of a conducting artery, arteriole, and venule and explain how the histological differences are related to the functional differences between these vessels.
3. Describe the differences between a continuous capillary, a fenestrated capillary, and a sinusoid.
4. Describe two routes by which substances can escape the bloodstream and pass through a capillary wall into the tissue fluid.
5. Describe the differences between a medium vein and a medium (muscular) artery. State the functional reasons for these differences.
6. Contrast an anastomosis and a portal system with the more typical pathway of blood flow.

Basic literature:

1. Saladin, Kenneth S: Anatomy & Physiology. The Unity of Form and Function (2016,

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Lecture 16
Human Histology 7.
Cardiovascular system. Cardiac Muscle muscle tissue. Heart. Layers of the Heart Wall.

LECTURE OUTLINE

- ·General features of the Circulatory system.
- ·General features of the Blood vessels.
- ·Comparison and classification of arteries, veins, blood capillaries.
- ·General features of the Heart.
- ·Cardiac skeleton, tunics.
- ·Cardiac muscle.

LEARNING OUTCOMES

1. name the 3 tunics that make up the walls of cardiovascular system components.
2. know the tissue type in each tunic in wall of blood vessels and heart.
3. list the features of cardiac muscle that distinguish it from other muscle tissues.
4. recognize the vessel types in a micrograph and identify their structural components.
5. distinguish between cardiac muscle and Purkinje fibers
6. identify the endocardium, myocardium, epicardium in micrographs of the heart.

The cardiovascular system consists of the heart, blood and lymphatic vessels. In the organs some portion of blood plasma leaves the vessels for tissues provides them with nutrition, collects metabolic products and turns into the lymph. The lymph passes into lymphatic vessels, is cleared in the lymph nodes and returns to the blood. The vessels develop from the yolk sac mesenchyme at the 2nd–3rd week. Their formation is influenced by hemodynamic conditions, it est the vessel's function, blood pressure and the rate of blood flow. The arteries carry blood from the heart to organs; the pressure in them is high, and the blood flow is rapid. The microcirculation vessels (arterioles, capillaries, venules) are responsible for metabolism between the blood and tissues; the blood flow rate is slowed down, the pressure is low. The veins carry blood from organs to the heart; the pressure is still low, the blood flow rate is slow. All vessels are lined with inner endothelium. It is a continuous layer of squamous cells on the basal membrane. The ARTERIES are of the large, medium and small size. By structure they can be elastic, mixed, or muscular. The vessel walls have 3 concentric tunics: 1) the internal tunica intima of 3 layers – endothelium, subendothelial layer of the loose connective tissue and the internal elastic membrane, 2) the middle tunica media of smooth myocytes and elastic fibers, 3) the external tunica adventitia of the loose connective tissue with nerves and vessels, and the external elastic membrane. The VEINS can be small, medium and large; by structure they are muscular and non-muscular. The microcirculatory blood stream provides metabolism and protective reactions. They include vessels less than 100 microns in diameter. They are arterioles, capillaries and

venules. *Arterioles* are short, d=50–100 microns, and regulate the blood supply of organs. The wall structure is like that in arteries, but all sheaths are thin. In the tunica media myocyte bundles are circular. The adventitia has non-differentiated cells and labrocytes. *Capillaries* are from 4,5–7 to 20–40 microns in diameter. The HEART pumps blood and lymph like a pump. Its walls have 3 tunics: endocardium, myocardium, and epicardium. The myocardium and epicardium develop from the myoepicardial plate of the mesoderm visceral layer. The endocardium develops at the 3rd week from the mesenchyme, like a vessel. It consists of 4 layers: 1) the endothelium layer made of large cells on the thick basal membrane; 2) the subendothelial layer, like in the aorta, 3) the musculoelastic layer of smooth myocytes and elastic fibers; 4) the external connective tissue layer with fine vessels. The myocardium contains 3 types of cardiomyocytes: 1) contracting typical; 2)conductive atypical; 3) secretory endocrine.

Questions for self-control:

1. What organs belong to the cardiovascular system?
2. Name the tunics of the blood vessels wall.
3. What are the types of arteries by the size and structure of the wall?
4. What are the types of veins by the size and structure of the wall?
5. List the microvasculature vessels.
6. Name the heart tunics.
7. What are the types of cardiomyocytes?

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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE OMiF1214 Morphology and physiology of human body
Specialty "B086"
Educational program "General medicine")
Course – 1
Semester – 2
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Almaty 2022

Lecture 17
Biophysics 3
Blood pressure, resistance and flow

LECTURE OUTLINE

1. Hemodynamics
2. The mechanism of blood circulation. Functions of small and large circulation.
3. Hydrodynamic model of Frank. The pulse wave. Pulse wave propagation velocity in the vessels.
4. Simulation of the circulatory system using analog electrical circuits.

Learning outcomes:

- describe hemodynamic of blood circulation;
- describe functions of small and large circle of blood circulation;
- explain the pulse wave model of Frank;
- define the viscosity of the liquid using an Ostwald viscometer.

Hemodynamics is the area of biomechanics in which the movement of blood through the vascular system is studied. The main task of hemodynamics is to establish the relationship between the main hemodynamic parameters, as well as their dependence on the physical parameters of blood and blood vessels. The physical basis of hemodynamics is hydrodynamics. The blood flow depends both on the properties of the blood and on the properties of the blood vessels. The main hemodynamic indicators include pressure and blood flow velocity.

Pressure is the force exerted by the blood on the vessels per unit area: $P = F / S$.

Distinguish between volumetric and linear blood flow velocity.

Volumetric velocity Q is a quantity numerically equal to the volume of fluid flowing per unit time through a given pipe section: $Q = V / t$ [m^3/ s].

The linear velocity represents the path traveled by the particles per unit time: $V = l / t$ [m / s].

The linear velocity and volumetric rate are connected by a simple relation: $Q = V \cdot S$.

System of circulation organs includes the heart and blood vessels. The blood circulation in the human body in a closed cardiovascular system provides the rhythmic contractions of the heart, its central organ. The vessels that carry blood from the heart is carried to tissues and organs, called arteries, and those on which blood is delivered to the heart - veins. In the tissues and organs of the thin arteries (arterioles) and veins (venules) are connected by a dense network of the blood capillaries.

Sequential rhythmic contraction and relaxation of the atria and ventricles of the heart valves and activities provide one-way movement of blood from the atria to the ventricles and from the

ventricles into the small and large circles of blood circulation

During systole (contraction of the heart) blood is ejected from the left ventricle into the aorta and the branch from her the large arteries. During diastole (relaxation) of the ventricles aortic valve is closed and the flow of blood from the heart to the great vessels stopped. Stretched wall of the artery while reduced, providing the inflow of blood in the capillaries during diastole.The volume of blood ejected ventricle of the heart, for each systole is 50-70 ml. This value is called - stroke volume. The duration of the cardiac cycle = 0.8-1 seconds, which gives the heart rate (HR) in 60-75 per min. Hence, cardiac output (it is easy to count), 3-5L per min --- - cardiac output (ISO).

Large and small circles of blood circulation:

In the human body blood moves through the two circles of a circulation-large (trunk) and small (pulmonary). CCL starts in the left ventricle, from which arterial blood is thrown into the largest diameter artery-the aorta. Aorta makes the arc and then extends to the left along a backbone, branching into smaller arteries that carry blood to the organs.In the bodies the arteries branch off into smaller vessels, arterioles, which are pass into a network of capillaries. Venous blood through the veins collect into two large vessels --- upper and lower vena cava, which pour it in the right atrium.

Arterial system

Arteries have a powerful elastic shell, perform mainly a buffer role, smoothing the pressure fluctuations between systole and diastole. The walls of the arteries are elastic extensible, which allowthem to take the extra volume of blood "ejected" by heart systole..

During diastole, when the heart is not pumping anything, it is the elastic stretching of artery walls maintains the pressure of not letting it fall to zero, and thus ensure the continuity of blood flow.

The blood pressure in the arterial systemis pulsing. Normally, in human aorta at it highest power systole and 120 mm Hg. Art., the lowest moment in diastole is 80.Despite the lumpiness supply of blood in the artery, it continuously moves through the vessels due to the elasticity of the arteries and their ability to change the diameter of the lumen of blood vessels. Periodic jerky expansion of the walls of the arteries, synchronous with the contractions of the heart, called a pulse. Pulse can be determined on the arteries lying superficially on the bones (radiation, temporal artery).

The venous system

From the bodies the blood is returned through the post-capillary, venules and veins into the right atrium at the top and bottom hollow veins, and the coronary veins.

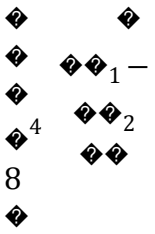
Venous return is carried out by several mechanisms. First of all blog differential pressure at the end of the capillary (25 mm Hg) and atrial (about 0). Secondly, it is important for skeletal muscle, that muscle contraction at external pressure exceeds the pressure in the vein so that the blood is "squeezed" out of the veins have reduced muscle. But the presence of venous valves determines the direction of the blood flow - from thearterial end to the venous. This mechanism is particularly important in the veins of the lower extremities, as is the blood in the veins rises, overcoming gravity.

Third part is the suction of the thorax During inspiration pressure in the thorax decreases below atmospheric pressure (which is set to 0). Which provides an additional mechanism for the return of blood.

Blood flow through the blood vessels in the physiology explained on the basis of known in physics laws of hydrodynamics (Bernoulli etc.).

The Basic Law of hemodynamics was proposed in the 50s of the 19th century French physiologist Poiseuille studying the flow of water in cylindrical tubes and blood in the capillaries, it showed that the volume of the flowing fluid is proportional to the pressure gradient, and inversely proportional to the viscosity of the fluid. (Poiseuille fomula)

$$\diamond\diamond \quad =$$



In 1899, a German physiologist O.FRANK created a simulation model that describes the temporal changes in pressure and flow rate of blood flow in the arteries.

The model of the vascular system, proposed by O.Frank allows to establish a connection between the pressure and flow rate of blood flow in large vessels with their elasticity. The model allows to calculate the change in time of hemodynamic parameters in a large vessel during the cardiac cycle. Basically, the pressure change is calculated at a certain point a major vessel.For the convenience of modeling identified two phase flow in the system, "the left ventricle of the heart, great vessels - small vessels" Phase 1 - Phase of blood flow into the aorta from the heart to the opening of the aortic valve to close it. At the time of blood flow from the heart of the walls of large blood vessels are stretched because of their flexibility, some of the blood is reserved in the large vessels, and the part takes place in the small vessels.

Phase 2 - Phase ejection of blood from the small to the large vessels of the aortic valve closing time, during this phase the walls of large vessels due to the elasticity back to the starting position by pushing the blood in microvessels. At this time in the left ventricle receives blood from the left atrium.

The movement of blood through the blood vessels in the physiology explained on the basis of the known laws in the physics fluid dynamics. According to the quantity of liquid Q, flowing through the vessel proportional to any difference in pressure and inversely proportional to the hydrodynamic resistance.

Under the arterial pulse understands rhythmic oscillations of the wall of the artery. These fluctuations occur during the discharge portion of the blood from the heart into the arteries: due to the elasticity of the vessel wall is stretched and comes back to its original state. A wave vibrations in the wall of the vessel - the pulse wave that propagates along it, ahead of the movement of blood. The pulse wave, which arose at the time of the expulsion of blood from the heart, is gradually fading in the periphery.

Distribution velocity of pulse wave depends on the properties of the vessel and blood:

$$= \frac{Eh}{r\rho} V_2$$

Where E- is Young's modulus of the material of the vessel wall, h - the thickness, r - radius of the lumen, p - the density of blood. (This formula was derived for the first time the famous British scientist T. Jung.)

Pulse wave propagation velocity measured experimentally, is Vpw = 6-8 m / s, which is 20-30 times greater than the particle velocity of blood V = 0.3-0.5 m / s. During the expulsion of blood from the ventricles (systole) tc = 0.3 s pulse wave has time to spread to the distance

$$L_{pw} = V_{pw} * t = 2 \text{ m},$$

that is cover all major blood vessels - the aorta and the arteries.

Blood flow regimes - are divided into laminar and turbulent. Laminar flow over an ordered liquid in which it is moved like layers parallel to the flow direction. In laminar flow velocity in

pipe section varies parabolically.

With increasing velocity, laminar flow becomes turbulent, wherein the intensive mixing of the liquid layers, present numerous vortexes of different sizes. Particles perform random motions on complex trajectories. For turbulent flow is characterized by an extremely irregular, erratic change of velocity with time at each point of the flow.While significantly changes flow properties, in particular the structure of the flow, velocity profile, resistance law. Profile high speed turbulent flow in pipes differ from the parabolic profile of laminar flow a more rapid increase in velocity at the walls and the curvature at the central part of the flow. Flow regime is characterized by the Reynolds number. For fluid flow in a circular pipe:

$$\mathrm{Re} = \frac{D}{\eta}$$

whereϑ _the average flow velocity, D-diameter pipes, fluid density, viscosity. When the value of Re is less than the critical Re=2300 (Re blood is normal for 2000), flow of a liquids laminar, if greater than the critical Re, the flow becomes turbulent. Typically the movement of blood through the vessels is laminar.

However, in some cases, may cause turbulence. Turbulent blood flow in the aorta can be caused primarily by turbulence of blood flow at the entrance of it. Vortices flow is initially present when blood ejected from the ventricle into the aorta that is observed on Doppler echocardiography. The flow can be turbulent and in the arteries branching points of vessels and increases blood flow velocity (in the vessels of the local constriction in the formation of blood clots)

State of health is determined by the nature of the physical-chemical, physiological processes occurring in the body**.** In ***its*** turn, these processes - temperature, pressure, and sugar ***component*** in urine, blood composition, viscosity ***of*** body fluid, etc. Blood relates to non Newtonian fluid, as it contains proteins and red blood cells, which are structured ***by*** polymer formation**.** The viscosity of human blood normally 4-5, and the pathology may vary from 1.7-3 and 6-22,9**.** Blood viscosity has diagnostic value. In some infectious diseases, the blood viscosity increases, and ***at*** tuberculosis, for example, decreases. Change in viscosity of blood - one of the reasons for changes in the erythrocyte sedimentation rate (ESR). In medicine, for determining the viscosity of the blood used medical viscometer**.**

During the flow of a real fluid the individual layers interact with each other with forces tangent to the fibers. This phenomenon is called an internal friction or viscosity. Consider the flow of viscous liquid between the two rigid plates (Figure 1), the bottom of which is fixed, while the upper moving with a velocity ϑ_6. Conventionally, liquid represented in the form of several layers 1, 2, 3, etc. Layer "stuck" to the bottom, motionless. With increasing distance from the bottom (bottom plate) liquid layers are all great velocity (...) ϑ_1 ϑ_2 ϑ_3, in a layer that "stuck" to the top of the plate will be the maximum speed. Layers affect each other. For example, the layer 3 tends to accelerate the movement of the layer 2, but the experiences with its braking side, and accelerates layer 4, etc. The strength of the internal friction is proportional to the square of interacting layers *S*and want more, more, their relative speed. Since layering conditionally, the force is usually expressed as a function of speed change, $d\vartheta$:

referred to the length in the direction perpendicular to the velocity, i.e., fromdx

$$F\vartheta$$
$$d$$

$$\frac{S}{dx} = \eta \quad (1)$$

X

V6
V5
V4

V3
V2
V1
V

This is Newton's equation. Here η - proportionality coefficient is called the coefficient of internal friction, dynamic viscosity (or viscosity). The viscosity depends on the molecular state and fluid properties.

The unit of viscosity is the pascal-second (Pa · s). Sometimes a viscosity expressed in poise (P):

$$1 \text{ Pa*s} = 10 \text{ P}.$$

For many fluids, such as water, the viscosity does not depend on $\frac{d\vartheta}{dx}$, such liquid obey the Newton equation (1) and are called Newtonian. Liquids do not obey the equation (1), referred to as non-Newtonian. Sometimes viscosity of Newtonian fluids referred to as a normal and non Newtonian - abnormal.

Liquids, consisting of a complex and large molecules, such as polymer solutions, and adhesion of molecules are formed due to particles or spatial structures are non-Newtonian. Blood is also a non-Newtonian fluid.

The instruments with which determine the viscosity, called viscometers. Ostwald capillary viscometer is shown in Figure 2. One knee of viscometer is a capillary tube. Liquids in the capillar move under the influence of hydrostatic pressure

$$\Delta p = \rho g h$$

where ρ - liquid density; h - the difference between liquid levels in the two tribes of viscometer.

The questions for self - control:

1. Newton's formula for a viscous fluid.
2. The physical meaning of the coefficient of viscosity and its units.
3. Newtonian and non-Newtonian fluids.
4. Hagen - Poiseuille formula.

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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body
Course – 1 Semester – 2
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Lecture 18
Capillary Exchange. Regulation of blood pressure and flow.

Outcomes:

1. describe the structure of a blood vessel;
2. describe the types of arteries, capillaries, and veins;
3. trace the general route usually taken by the blood from the heart and back again;
5. describe some variations on this route.

There are three principal categories of blood vessels: arteries, veins, and capillaries (fig. 20.1). **Arteries** are the efferent vessels of the cardiovascular system—that is, vessels that carry blood away from the heart. **Veins** are the afferent vessels thatcarry blood back to the heart. **Capillaries** are microscopic, thin walled vessels that connect the smallest arteries to the smallest veins.

The Vessel Wall

Aside from their general location and direction of blood flow, the three categories of blood vessels also differ in the histological structure of their walls. The walls of arteries and veins are composed of three layers called *tunics*:

1. The **tunica interna (tunica intima)**
2. The **tunica media**
3. The **tunica externa (tunica adventitia**1)

Arteries

Arteries are sometimes called the *resistance vessels* of the cardiovascular system because they have a relatively strong, resilient tissue structure. Each beat of the heart creates a surge of pressure in the arteries as blood is ejected into them, and arteries are built to withstand these surges. Being more muscular than veins, they retain their round shape even when empty, and they appear relatively circular in tissue sections. They are divided into three classes by size, but of course there is a gradual transition from one class to the next.

1. **Conducting (elastic** or **large) arteries**
2. **Distributing (muscular** or **medium) arteries**
3. **Resistance (small) arteries**

Capillaries

For the blood to serve any purpose, materials such as nutrients, wastes, hormones, and leukocytes must pass between the blood and the tissue fluids, through the walls of the vessels. There are only two places in the circulation where this occurs—the capillaries and some venules. We can think of these as the “business end” of the cardiovascular system, because all the rest of

the system exists to serve the exchange processes that occur here. Since capillaries greatly outnumber venules, they are the more important of the two. Capillaries are sometimes called the *exchange vessels* of the cardiovascular system; the arterioles, capillaries, and venules are also called the **microvasculature (microcirculation).**Capillaries consist of only an endothelium and basal lamina. Their walls are as thin as 0.2 μm. They average about 5 μm in diameter at the proximal end (where they receive arterial blood), widen to about 9 μm at the distal end (where they empty into a small vein), and often branch along the way. Since erythrocytes are about 7.5 μm in diameter, they have to stretch into elongated shapes to squeeze through the smallest capillaries.

1. **Continuous capillaries**
2. **Fenestrated capillaries**
3. **Sinusoids (discontinuous capillaries**

Veins

Veins are regarded as the *capacitance vessels* of the cardiovascular system because they are relatively thin-walled and flaccid, and expand easily to accommodate an increased volume of blood; that is, they have a greater *capacity* for blood containment than arteries do. At rest, about 64% of the blood is found in the systemic veins as compared with only 13% in the systemic arteries. The reason that veins are so thin-walled and accommodating is that, being distant from the ventricles of the heart, they are subjected to relatively low blood pressure. In large arteries, blood pressure averages 90 to 100 mm Hg and surges to 120 mm Hg during systole, whereas in veins it averages about 10 mm Hg. Furthermore, the blood flow in the veins is steady, rather than pulsating with the heartbeat like the flow in the arteries. Veins therefore do not require thick, pressure-resistant walls. They collapse when empty and thus have relatively flattened, irregular shapes in histological sections

1. Postcapillary venules
2. Muscular venules
3. Medium veins
4. Venous sinuses
5. Large veins

Questions for control

1. Name the three tunics of a typical blood vessel and explain how they differ from each other.
2. Contrast the tunica media of a conducting artery, arteriole, and venule and explain how the histological differences are related to the functional differences between these vessels.
3. Describe the differences between a continuous capillary, a fenestrated capillary, and a sinusoid.
4. Describe two routes by which substances can escape the bloodstream and pass through a capillary wall into the tissue fluid.
5. Describe the differences between a medium vein and a medium (muscular) artery. State the functional reasons for these differences.
6. Contrast an anastomosis and a portal system with the more typical pathway of blood flow.

Basic literature:

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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body
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Lecture 19

Venous Return and Circulatory Shock. Special Circulatory Routes. Anatomy of the Pulmonary Circuit

Outcomes:

1. explain how blood in the veins is returned to the heart;
2. discuss the importance of physical activity in venous return;
3. discuss several causes of circulatory shock; and
4. name and describe the stages of shock.

Mechanisms of Venous Return

The flow of blood back to the heart, called **venous return,** is achieved by five mechanisms:

1. **The pressure gradient.** Pressure generated by the heart is the most important force in venous flow, even though it is substantially weaker in the veins than in the arteries. Pressure in the venules ranges from 12 to 18 mm Hg, and pressure at the point where the venae cavae enter the heart, called **central venous pressure,** averages 4.6 mm Hg. Thus, there is a venous pressure gradient (ΔP) of about 7 to 13 mm Hg favoring the flow of blood toward the heart. The pressure gradient and venous return increase when blood volume increases. Venous return also increases in the event of generalized, widespread vasoconstriction because this reduces the volume of the circulatory system and raises blood pressure and flow.

2. **Gravity.** When you are sitting or standing, blood from your head and neck returns to the heart simply by flowing "downhill" through the large veins above the heart. Thus, the large veins of the neck are normally collapsed or nearly so, and their venous pressure is close to zero. The dural sinuses of the brain, however, have more rigid walls and cannot collapse. Their pressure is as low as −10 mm Hg, creating a risk of *air embolism* if they are punctured.

3. **The skeletal muscle pump.** In the limbs, the veins are surrounded and massaged by the muscles. Contracting muscles squeeze the blood out of the compressed part of a vein, and the valves ensure that this blood can go only toward the heart.

4. **The thoracic (respiratory) pump.** This mechanism aids the flow of venous blood from the abdominal to the thoracic cavity. When you inhale, your thoracic cavity expands and its internal pressure drops, while downward movement of the diaphragm raises the pressure in your abdominal cavity. The *inferior vena cava* (*IVC*), your largest vein, is a flexible tube passing through both of these cavities. If abdominal pressure on the IVC rises while thoracic pressure on it drops, then blood is squeezed upward toward the heart. It is not forced back into the lower limbs because the venous valves there prevent this. Because of the thoracic pump, central venous pressure fluctuates from 2 mm Hg when you inhale to 6 mm Hg when you exhale, and blood

flows faster when you inhale. This is what produces the slight fluctuations in blood pressure at the right end of the graph in figure 20.10.

5. **Cardiac suction.** During ventricular systole, the tendinous cords pull the AV valve cusps downward, slightly expanding the atrial space. This creates a slight suction that draws blood into the atria from the venae cavae and pulmonary veins.

Questions for control

1. Explain how respiration aids venous return.
2. Explain how muscular activity and venous valves aid venous return.
3. Define circulatory shock. What are some of the causes of low venous return shock?

Basic literature:

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Lecture 20

Human Histology 8-9 Lymphoid system. General features of the Lymphoid system. Thymus. Lymphoid system. Lymph Nodes. Spleen.

LECTURE OUTLINE

- General features of the Lymphoid System.
- Cells of the Lymphoid System. Lymphoid nodules.
- Thymus.
- Lymph nodes.
- Spleen

LEARNING OUTCOMES

1. define the distinguishing features of the lymphoid organs.
2. define the names, locations, functions of the cells, tissues, organs of the lymphoid system.
3. identify the structure of spleen, thymus and lymph nodes in a microscopic
4. specimen.
5. recognize the cells, tissues of the thymus in micrographs.
6. recognize the cells, tissues of the lymph nodes in micrographs.
7. recognize the cells, tissues of the spleen in micrographs.

The organs of immunogenesis have a reticular stroma of the connective tissue, or reticular epithelium, and perform three functions: 1) formation of blood cells, 2) blood or lymph depot, 3) protection (as the result of phagocytosis and the formation of immune cells). There are central and peripheral organs. Central organs are red bone marrow and thymus; they contain stem cells and continuously form blood cells. The peripheral organs are spleen, lymph nodes and lymphoid formations of the mucous membranes. They do not contain stem cells but they form mature lymphocytes and plasmocytes when an antigen appears in the body. Thymus (thymus gland, T) is responsible for the cellular immunity. It performs 2 functions: 1) hematopoietic – it forms T-helpers and T-suppressors; 2)endocrine – thymic stromal cells secrete thymic hormones. When the thymus is removed, the immune system is suppressed, an infection spreads rapidly, but a transplanted tissue does not die off. The thymus develops from the ectoderm of the pharyngeal section of the gut at the 4–5th week. At the 7th week it is

populated by lymphocytes. The thymus is covered with the connective tissue capsule and consists of lobes separated by the septa of interlobular connective tissue. Each lobe has a dark cortex and a light medulla. The stroma is composed of the squamous reticular epithelium. Its basal layer lies under the lobular capsule and the surface layers, in the center of the lobe. The epithelial cells with large processes are called oxyphils. The stromal epithelium secretes hormones: thymosins into the blood and thymopoietin into the thymic tissue. They activate the reproduction of lymphocytes and functions of mature lymphocytes. T-lymphocytes are called thymocytes. They lie between the stromal epithelial cells. Lymph nodes develop from mesenchyme during the 3rd month; they begin myelopoiesis. From the 4th month B-lymphocytes move into the nodes, form dark cortex and bright medulla. Then T-lymphocytes move into the nodes, myelopoiesis decreases, lymphopoiesis increases. A lymph node is bean-shaped, d=0,5–1 cm, located along the lymph vessels, covered with the connective tissue capsule, the trabeculae depart from it. There is a network of reticulum between lymph nodes. Lymphoid cells and macrophages are placed in the network hinges. Spleen performs five functions: 1) hematopoietic, 2) immune protection, 3)blood depot, 4) hemolytic, 5) absorbing iron from erythrocytes. At the 5th week of development the mesenchyme of the dorsal mesentery forms the spleen germ from the reticular tissue. Then at the 12th week macrophages and B-lymphocytes appear in the germ; they group and form follicles of the white pulp. By the 6th month the red pulp is formed between them. By the 5th month all blood cells have been formed in the spleen. After birth only lymphopoiesis takes place.

The spleen is covered with the mesothelium and has a connective tissue capsule and trabeculae with smooth muscle cells. It is a support-contractile apparatus through which the deposited blood is expelled into the general circulation. Between the trabeculae the stroma from the reticular tissue is placed. The stroma with lymphoid cells and erythrocytes forms the white and red pulp.

Questions for self-control:

1. What are the functions of the reticular stroma of haemopoietic organs?
2. What are the central and peripheral organs of haemopoiesis and immunogenesis?
3. What cells are formed in the red bone marrow?
4. What cells are formed in the thymus?
5. Name the T- and B-dependent zones in the peripheral haemopoietic organs.
6. What spleen functions do you know?
7. What zones has the spleen follicle?

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OMiF1214 Morphology and physiology of human body
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Lecture 21
The lymphatic and immune system.

Outcomes:

1. list the functions of the lymphatic system;
2. explain how lymph forms and returns to the bloodstream;
3. name the major cells of the lymphatic system and state their functions;
4. name and describe the types of lymphatic tissue; and
5. describe the structure and function of the red bone marrow, thymus, lymph nodes, tonsils, and spleen.

The **lymphatic system** consists of a network of vessels that penetrate nearly every tissue of the body, and a collection of tissues and organs that produce immune cells. These include the lymph nodes, spleen, thymus, tonsils, and red bone marrow.
The lymphatic system has three functions:

• **fluid recovery**
– fluid continually filters from the blood capillaries into the tissue spaces • blood capillaries reabsorb 85%
• 15% (2 – 4 L/day) of the water and about half of the plasma proteins enters lymphatic system and then returned to the blood

• **immunity**
– excess filtered fluid picks up foreign cells and chemicals from the tissues • passes through lymph nodes where immune cells stand guard against foreign matter
• activate a protective immune response

• **lipid absorption**
– **lacteals** in small intestine absorb dietary lipids that are not absorbed by the blood capillaries

Components of the Lymphatic System

• **lymph**
– the recovered fluid

• **lymphatic vessels**
– transport the lymph

• **lymphatic tissues**
– composed of aggregates of lymphocytes and macrophages that populate many organs in the body

• **lymphatic organs**
– defense cells are especially concentrated in these organs
– separated from surrounding organs by connective tissue capsules

Balance

• cellular function requires **a fluid medium** with a carefully controlled composition • **three types of homeostatic balance**
– **water balance**
• average daily water intake and loss are equal

– **electrolyte balance**
  • the amount of electrolytes absorbed by the small intestine balance with the amount lost from the body, usually in urine
– **acid-base balance**
  • the body rids itself of acid (hydrogen ion – H^+) at a rate that balances metabolic production

• balances maintained by the collective action of the urinary, respiratory, digestive, integumentary, endocrine, nervous, cardiovascular, and lymphatic systems **Body Water**
• newborn baby's body weight is about 75% water
• young men average 55% - 60%
• women average slightly less
• obese and elderly people as little as 45% by weight
• total body water (TBW) of a 70kg (150 lb) young make is about 40 liters

Fluid Compartments
• major fluid compartments of the body
– 65% intracellular fluid (ICF)
– 35% extracellular fluid (ECF)
  • 25% tissue (interstitial) fluid
  • 8% blood plasma and lymphatic fluid
  • 2% transcellular fluid 'catch-all' category
    – cerebrospinal, synovial, peritoneal, pleural, and pericardial fluids
    – vitreous and aqueous humors of the eye
    – bile, and fluids of the digestive, urinary, and reproductive tracts

Water Gain
• **fluid balance** - when daily gains and losses are equal (about **2,500 mL/day**) • **gains** come from **two sources:**
– **preformed water** (2,300 mL/day)
  • ingested in food (700 mL/day) and drink (1600 mL/day) – **metabolic water** (200 mL/day)
    • by-product of aerobic metabolism and dehydration synthesis
      – $C_6H_{12}O_6 + 6O_2\ 6CO_2 + 6H_2O$

Water Loss
• **sensible water loss** is observable
– 1,500 mL/ day is in urine
– 200 mL/day is in feces
– 100 mL/day is sweat in resting adult
• **insensible water loss** is unnoticed
– 300 mL/day in expired breath
– 400 mL/day is cutaneous transpiration
  • diffuses through epidermis and evaporates
    – does not come from sweat glands
– loss varies greatly with environment and activity
• **obligatory water loss** – output that is relatively unavoidable
expired air, cutaneous transpiration, sweat, fecal moisture, and urine output

Questions for control
1. List the primary functions of the lymphatic system. What do you think would be the most noticeable effect of clampingthe right lymphatic duct closed?

2. How does fluid get into the lymphatic system? What prevents it from draining back out? 3. What do NK, T, and B cells have in common? How do their functions differ?
4. List five major cell types of lymphatic tissues and state the function of each.
5. Predict the relative seriousness of removing the following organs from a 2-year-old child: (a) a lymph node, (b) the spleen, (c) the thymus, (d) the palatine tonsils.
6. List five routes of water loss. Which one accounts for the greatest loss? Which one is most controllable?
7. Explain why even a severely dehydrated person inevitably experiences further fluid loss.
8. Suppose there were no mechanisms to stop the sense of thirst until the blood became sufficiently hydrated. Explain why we would routinely suffer hypotonic hydration.
9. Summarize the effect of ADH on total body water and blood osmolarity.
10. Name and define the four types of fluid imbalance, and givean example of a situation that could produce each type.

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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE OMiF1214 Morphology and physiology of human

body
Specialty "B086"

Educational program “General medicine”)

Course – 1
Semester – 2
Number of credits – 8
Almaty 2022

Lecture 27
Human Histology 12 Histology of the nervous system
Central nervous system. Brain. Cortex. Cerebellum.
Overview of the meninges, ventricles, cerebrospinal fluid and blood supply

Plan of the Lecture
1. Bioelectric potentials.
2. Resting potential.
3. Total ion flux density.
4. Nernst formula.
5. Hodgkin's experiment.
6. Propagation of impulse along nerve fibers.

Learning outcomes:
• Learning the electrochemical potentials of biological membranes
• solving of standard and situational problems.

Resting potential

The relatively static membrane potential of quiescent cells is called the **resting membrane potential**, as opposed to the specific dynamic electrochemical phenomena called action potential and graded membrane potential.

Apart from the latter two, which occur in excitable cells (neurons, muscles, and some secretory cells in glands), membrane voltage in the majority of non-excitable cells can also undergo changes in response to environmental or intracellular stimuli [*citation needed*]. In principle, there is no difference between resting membrane potential and dynamic voltage changes like action potential from biophysical point of view: all these phenomena are caused by specific changes in membrane permeabilities for potassium, sodium, calcium, andchloride, which in turn result from concerted changes in functional activity of various ion channels, ion transporters, and exchangers. Conventionally, resting membrane potential can be defined as a relatively stable, ground value of transmembrane voltage in animal and plant cells.

Any voltage is a difference in electric potential between two points - for example, the separation of positive and negative electric charges on opposite sides of a resistive barrier. The typical resting membrane potential of a cell arises from the separation of potassium ions from intracellular,

relatively immobile anions across the membrane of the cell. Because the membrane permeability for potassium is much higher than that for other ions (disregarding voltage-gated channels at this stage), and because of the strong chemical gradient for potassium, potassium ions flow from the cytosol into the extracellular space carrying out positive charge, until their movement is balanced by build-up of negative charge on the inner surface of the membrane. Again, because of the high relative permeability for potassium, the resulting membrane potential is almost always close to the potassium reversal potential. But in order for this process to occur, a concentration gradient of potassium ions must first be set up. This work is done by the ion pumps/transporters and/or exchangers and generally is powered by ATP.

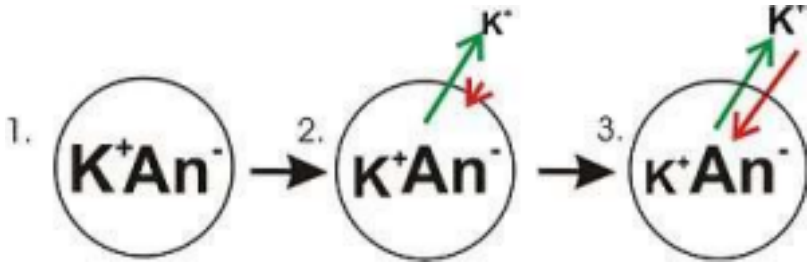
In the case of the resting membrane potential across an animal cell's plasma membrane, potassium (and sodium) gradients are established by the Na+/K+-ATPase (sodium-potassium pump) which transports 2 potassium ions inside and 3 sodium ions outside at the cost of 1 ATP molecule. In other cases, for example, a membrane potential may be established by acidification of the inside of a membranous compartment (such as the proton pump that generates membrane potential across synaptic vesiclemembranes)

Electroneutrality

In most quantitative treatments of membrane potential, such as the derivation of Goldman equation, **electroneutrality** is assumed; that is, that there is no measurable charge excess in any side of the membrane. So, although there is an electric potential across the membrane due to charge separation, there is no actual measurable difference in the global concentration of positive and negative ions across the membrane (as it is estimated below), that is, there is no actual measurable charge excess in either side. That occurs because the effect of charge on electrochemical potential is hugely greater than the effect of concentration so an undetectable change in concentration creates a great change on electric potential.

Generation of the resting potential

Cell membranes are typically permeable to only a subset of ions. These usually include potassium ions, chloride ions, bicarbonate ions, and others. To simplify the description of the ionic basis of the resting membrane potential, it is most useful to consider only one ioni222322№Пс species at first, and consider the others later. Since trans-plasma-membrane potentials are almost always determined primarily by potassium permeability, that is where to start.



A diagram showing the progression in the development of a membrane potential from a concentration gradient (for potassium). Green arrows indicate net movement of K^+down a concentration gradient. Red arrows indicate net movement of K^+due to the membrane potential. The

diagram is misleading in that while the concentration of potassium ions outside of the cell increases, only a small amount of K^+needs to cross the membrane in order to produce a membrane potential with a magnitude large enough to counter the tendency the potassium ions to move down the concentration gradient.

The resting voltage is the result of several ion-translocating enzymes (uniporters, cotransporters, and pumps) in the plasma membrane, steadily operating in parallel, whereby each ion-translocator has its characteristic electromotive force (= reversal potential = 'equilibrium voltage'), depending on the particular substrate concentrations inside and outside (internal ATP included in case of some pumps). H^+exporting ATPase render the membrane voltage in plants and fungi much more negative than in the more extensively investigated animal cells, where the resting voltage is mainly determined by selective ion channels.

In most neurons the resting potential has a value of approximately -70 mV. The resting potential is mostly determined by the concentrations of the ions in the fluids on both sides of the cell membrane and the ion transport proteins that are in the cell membrane. How the concentrations of ions and the membrane transport proteins influence the value of the resting potential is outlined below.

The resting potential of a cell can be most thoroughly understood by thinking of it in terms of equilibrium potentials. In the example diagram here, the model cell was given only one permeant ion (potassium). In this case, the resting potential of this cell would be the same as the equilibrium potential for potassium.

However, a real cell is more complicated, having permeabilities to many ions, each of which contributes to the resting potential. To understand better, consider a cell with only two permeant ions, potassium and sodium. Consider a case where these two ions have equal concentration gradients directed in opposite directions, and that the membrane permeabilities to both ions are equal. K^+leaving the cell will tend to drag the membrane potential toward E_K. Na^+entering the cell will tend to drag the membrane potential toward the reversal potential for sodium E_{Na}. Since the permeabilities to both ions were set to be equal, the membrane potential will, at the end of the Na^+/K^+tug-of-war, end up halfway between E_{Na} and E_K. As E_{Na} and E_K were equal but of opposite signs, halfway in between is zero, meaning that the membrane will rest at 0 mV.

Note that even though the membrane potential at 0 mV is stable, it is not an equilibrium condition because neither of the contributing ions are in equilibrium. Ions diffuse down their electrochemical gradients through ion channels, but the membrane potential is upheld by continual K^+influx and Na^+efflux via ion transporters. Such situation with similar permeabilities for counter-acting ions, like potassium and sodium in animal cells, can be extremely costly for the cell if these permeabilities are relatively large, as it takes a lot ofATP energy to pump the ions back. Because no real cell can afford such equal and large ionic permeabilities at rest, resting potential of animal cells is determined by predominant high permeability to potassium and adjusted to the required value by modulating sodium and chloride permeabilities and gradients.

In a healthy animal cell Na^+permeability is about 5% of the K permeability or even less, whereas the respective reversal potentials are +60 mV for sodium (E_{Na})and -80 mV for potassium (E_K). Thus the

membrane potential will not be right at E_K, but rather depolarized from E_K by an amount of approximately 5% of the 140 mV difference between E_K andE_{Na}. Thus, the cell's resting potential will be about −73 mV.

In a more formal notation, the membrane potential is the weighted average of each contributing ion's equilibrium potential (Goldman equation). The size of each weight is the relative permeability of each ion. In the normal case, where three ions contribute to the membrane potential:

$$E_m = \frac{P_{K^+}}{P_{tot}} E_{K^+} + \frac{P_{Na^+}}{P_{tot}} E_{Na^+} + \frac{P_{Cl^-}}{P_{tot}} E_{Cl^-},$$

where

- E_m is the membrane potential, measured in volts
- E_X is the equilibrium potential for ion X, also in volts
- P_X is the relative permeability of ion X in arbitrary units (e.g. siemens for electrical conductance)
- P_{tot} is the total permeability of all permeant ions, in this case $P_{K^+} + P_{Na^+} + P_{Cl^-}$

Membrane transport proteins

For determination of membrane potentials, the two most important types of membrane ion transport proteins are ion channels and ion transporters. Ion channel proteins create paths across cell membranes through which ions can passively diffuse without direct expenditure of metabolic energy. They have selectivity for certain ions, thus, there arepotassium-, chloride-, and sodium selective ion channels. Different cells and even different parts of one cell (dendrites, cell bodies, nodes of Ranvier) will have different amounts of various ion transport proteins. Typically, the amount of certain potassium channels is most important for control of the resting potential (see below). Some ion pumps such as theNa+/K+-ATPase are electrogenic, that is, they produce charge imbalance across the cell membrane and can also contribute directly to the membrane potential. Most pumps use metabolic energy (ATP) to function.

Equilibrium potentials

For most animal cells potassium ions (K^+) are the most important for the resting potential. Due to the active transport of potassium ions, the concentration of potassium is higher inside cells than outside. Most cells have potassium-selective ion channel proteins that remain open all the time. There will be net movement of positively-charged potassium ions through these potassium channels with a resulting accumulation of excess negative charge inside of the cell. The outward movement of positively-charged potassium ions is due to random molecular motion (diffusion) and continues until enough excess negative charge accumulates inside the cell to form a membrane potential which can balance the difference in concentration of potassium between inside and outside the cell. "Balance" means that the electrical force (potential) that results from the build-up of ionic charge, and which impedes outward diffusion, increases until it is equal in magnitude but opposite in direction to the tendency for outward diffusive movement of potassium. This balance point is an *equilibrium potential* as the net transmembrane flux (or current) of $K^+$is zero. The equilibrium potential for a given ion depends only upon the concentrations on either side of the membrane and the temperature. It can be calculated using the Nernst equation:

$$E_{eq,K^+} = \frac{RT}{zF} \ln \frac{[K^+]_o}{[K^+]_i}$$

where

▪ $E_{eq,K}{}^{+}$is the equilibrium potential for potassium, measured in volts

▪ R is the universal gas constant, equal to 8.314 joules·K^{-1}·mol^{-1}

▪ T is the absolute temperature, measured in kelvins (= K = degrees Celsius + 273.15) ▪ z is the number of elementary charges of the ion in question involved in the reaction ▪ F is the Faraday constant, equal to 96,485 coulombs·mol^{-1} or J·V^{-1}·mol^{-1} ▪ $[K^+]_o$ is the extracellular concentration of potassium, measured in mol·m^{-3} or mmol·l^{-1} ▪ $[K^+]_i$ is likewise the intracellular concentration of potassium

Summary of resting potential values in different types of cells

The resting membrane potential in different cell types are approximately:

▪ Skeletal muscle cells: –95 mV

▪ Smooth muscle cells: –60mV

▪ Astroglia: –80 to –90mV

▪ Neurons: –60 to –70mV

Electroencephalography - part of electrophysiology, studying patterns of the total electrical activity of the brain, as well as a method of recording such potentials. Electroencephalography enables qualitative and quantitative analysis of the functional state of the brain and its reaction by the action of stimuli. EEG is widely used in diagnostic and therapeutic work (especially common in epilepsy), in anesthesia , as well as in the study of brain activity associated with the implementation of functions such as perception, memory, adaptation, etc. The EEG recording is performed using the latest 32 channel electroencephalograph "Neuron -Spectrum -5 ". Multi-channel EEG recording allows simultaneous recording of the electrical activity of the entire surface of the brain, which makes it possible to carry out the most delicate of the study.

The questions for self - control:

1. The Goldman – Hodgkin – Katz equation.
2. Diagram of action potential and its phases.
3. Ratio of permeability coefficients at RP and AP.
4. The main types of electrical activity of pyramidal neurons.
5. What current models used in the EEG?
6. How important is the relationship of pyramidal neurons' electrical activity. 7.

What is the important condition of EEG genesis?

Recommended readings:

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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body
Specialty "B086"
Educational program "General medicine")
Course – 1
Semester – 2
Number of credits – 8
Almaty 2022

Lecture 23

Human Histology 10-11 Histology of the supporting cells of the nerve tissue (neuroglia). Histology of the Nervous System Peripheral Nervous System. Ganglia. Spinal cord

LECTURE OUTLINE

- nerve system general morphofunctional characteristic
- sources of origin
- structural and functional classification
- neuroglia – micro - and macroglia. gliocytes.
- peripheral nerve system. nerve truncs structure.
- dorsal root ganglion
- spinal cord

LEARNING OUTCOMES

1. Investigate the organs of nervous system in the specimens according to key features of structure.
2. Identify and classify the peripheral and central organs of nervous system.
3. Recognize the spinal ganglion in the specimens on the basis of key morphological features.
4. Determine the general structure of the peripheral nerve.
5. Identify the spinal cord and its horns in the specimen
6. Define the structural and functional significances of different nuclei.

The neuroglia consists of micro- and macroglia. The microgliais small macrophages with multibranch short processes. When the tissue is damaged they are involved, and the cells become ordinary macrophages (called granular spheres). The macroglia includes 3 kinds of cells:
1) ependymocytes cover the central canal of the spinal cord and brain ventricles. The cells have cilia in the apical part for the brain liquor circulation and long processes in the basal part to support the brain cells; 2) astrocytes are small cells with processes and a light nucleus, whose functions are supporting, trophic and protective. Plasmatic astrocytes are placed in the grey matter of the brain and have short branchy processes. Fibrous astrocytes are placed in the white matter and have long smooth processes. The astrocytes contact with the capillaries by processes and form thehemato-encephalon barrier possessing selective permeability; 3) oligodendrocytes form sheaths of neurons on the periphery. Satellite gliocytes form capsules around the neuron bodies in the ganglions. Lemmocytesform Schwann sheaths around the neuron processes in the nerves. These cells carry out 5 functions: trophic, protective, phagocytosis of disintegration products, participation in the transfer of the nerve impulse and in nerve regeneration. The nerve fiber is a neuron process (the axialone), surrounded withlemmocytes which form the Schwann sheath around the process. It acts as an electrical isolator and protects the process from damages. The Schwann sheath can be myelinated and

non-myelinated. Non-myelinated fibers are thin, 1–2 microns, the impulse passes slowly, 1–2 m/s. Lemmocytes cover the axial cylinder by means of their processes which close and form mesaxon (the dual membrane). Lemmocytes often form arope likethe fibers covering some axial cylinders which are separated only by a thin layer of the lemmocyte cytoplasm. So, the non-myelinated Schwann sheath does not create electrical isolation. Therefore, distribution of the nerve impulse on the neighboring fibers and its generalization are possible. The myelinated fiber is thick, up to 20 microns;there is only one axial cylinder. The lemmocyte processes grow, extend, and the mesaxon is wound spirally on the axial cylinder, forming the myelinated layer. The lemmocyte cytoplasm and thenucleus are pushed aside to the periphery forming the neurilemma. The axial cylinder and lemmocytes grow with different rates, and slanting fissures are visible in the myelinated layer. These are the sites of myelin stratification; they are called myelin clefts (Schmidt – Lantermann'sincisures). On impregnating with osmium myelin is black. The myelin layer has small parts lacking myelin where the lemmocytes connect witheach other; these parts are called Ranvier`s nodes (or nodal gaps). The myelin consists of fat (phospholipids) and creates good electrical isolation; the impulse is transferred precisely to destination. Under the myelin the acting potential cannot arise. The impulse arises only in Ranvier`s nodes jumping through the myelin. Therefore, the rate of its movement is high – 100 km/s. The structure of the nerve. The nerve consists of bundles of myelinated and non-myelinated nerve fibers. Large nerves unite many bundles of fibers and are covered with the epineurium made of the connective tissue with vessels. Each bundle of fibers is covered with dense perineurium. Inside the bundle thin fibers of theloose connective tissue with capillaries form the endoneurium. Under the perineurium there is a fissure with liquid called the perineural space. It communicates with the brain liquor and can be «the infectiongate» which can invade the brain. The spinal cord. It is developed from the body part of the neural tube and lies in the vertebral canal, connected with the periphery by 31 pairs of mixed spinal nerves. The spinal cord is a long white cord divided into two halves by the ventral median fissure and the dorsal white commissure (from pia mater and gliocytes). The ventral and dorsal roots go out from the surface of the spinal cord. The spinal cord is segmented. The segment is a part of the spinal cord with two pairs of roots. There is dark grey matter in the center (on the slice it is shaped like a butterfly). The grey matter consists of the neuron bodies forming the functional centers of the spinal cord called neural nuclei. The neuron processes form a light white matter around the grey matter. The grey matter forms short and massive anterior horns, thin and long posterior horns and an intermediate zone between them which has lateral horns in the interval between the 8th cervical and 2nd lumbar segments. The right and left halves of the grey matter are connected with the central canal lined with the ependima and containing the liquor by the grey commissure. The grey matter horns divide the white matter into 3 pairs of funiculi: ventral, lateral and dorsal.

Questions for self-control:

1. What are the nervous tissue components?
2. Describe the classification of the neuroglia.
3. What are the functions of the neuroglia?
4. What neuron types do you know?
5. What kinds of nerve fibers do you know?
6. What synapses kinds do you know?

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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body

Course – 1 Semester – 2
Number of credits – 8
Almaty 2022

Lecture 24
Overview of the Nervous System. Properties of Neurons. Supportive Cells (Neuroglia). Synapses. Neural Integration

Outcomes:

1. describe the overall function of the nervous system; and
2. describe its major anatomical and functional subdivisions.
3. describe three functional properties found in all neurons;
4. define the three most basic functional categories of neurons;
5. identify the parts of a neuron; and
6. explain how neurons transport materials between the cell body and tips of the axon.
7. name the six types of cells that aid neurons, and state their respective functions;
8. describe the myelin sheath that is found around certain nerve fibers, and explain its importance;
9. describe the relationship of unmyelinated nerve fibers to their supportive cells; and
10. explain how damaged nerve fibers regenerate.

The nervous system carries out its coordinating task in three basic steps:

- It receives information about changes in the body and external environment and transmits messages to the central nervous system (CNS).
- The CNS processes this information and determines what response, if any, is appropriate to the circumstances.
- The CNS issues commands primarily to muscle and gland cells to carry out such responses.

The peripheral nervous system is functionally divided into *sensory and motor* divisions, and each of these is further divided into *somatic and visceral* subdivisions.

The communicative role of the nervous system is carried out by nerve cells, or neurons. These cells have three fundamental physiological properties that enable them to communicate with other cells:
1. Excitability. All cells are excitable—that is, they respond to environmental changes (stimuli). Neurons exhibit this property to the highest degree.
2. Conductivity. Neurons respond to stimuli by producing electrical signals that are quickly conducted to other cells at distant locations.

3. Secretion. When the signal reaches the end of a nerve fiber, the neuron secretes a neurotransmitter that crosses the gap and stimulates the next cell.

There are three general classes of neurons corresponding to the three major aspects of nervous system function listed earlier:
1 Sensory (afferent) neurons are specialized to detect stimuli such as light, heat, pressure, and chemicals, and transmit information about them to the CNS. Such neurons begin in almost every organ of the body and end in the CNS; the word afferent refers to signal conduction toward the CNS. Some receptors, such as those for pain and smell, are themselves neurons. In other cases, such as taste and hearing, the receptor is a separate cell that communicates directly with a sensory neuron.
2 Interneurons lie entirely within the CNS. They receive signals from many other neurons and carry out the integrative function of the nervous system—that is, they process, store, and retrieve information and "make decisions" that determine how the body responds to stimuli. About 90% of our neurons are interneurons. The word interneuron refers to the fact that they lie between, and interconnect, the incoming sensory pathways and the outgoing motor pathways of the CNS.
3 Motor (efferent) neurons send signals predominantly to muscle and gland cells, the effectors. They are called motor neurons because most of them lead to muscle cells, and efferent neurons to signify signal conduction away from the CNS.

There are six kinds of neuroglia, each with a unique function. The first four types occur only in the central nervous system:
1. Oligodendrocytes
2. Ependymal cells
3. Microglia
4. Astrocytes
5. Schwann cells
6. Satellite cells

Questions for control:
1. What is a receptor? Give two examples of effectors.
2. Distinguish between the central and peripheral nervous systems, and between visceral and somatic divisions of the sensory and motor systems.
3. What is another name for the visceral motor nervous system? What are its two subdivisions? What are their functions?
4. Sketch a multipolar neuron and label its neurosoma, dendrites, axon, terminal arborization, axon terminals, and myelin sheath.
5. Explain the differences between a sensory neuron, motor neuron, and interneuron.
6. What is the functional difference between a dendrite and an axon?
7. How do proteins and other chemicals synthesized in the soma get to the axon terminals? By what process can a virus that invades a peripheral nerve fiber get to the soma of that neuron?

8. How is a glial cell different from a neuron? List the six types of glial cells and discuss their functions.
9. How is myelin produced? How does myelin production in the CNS differ from that in the PNS?
10. How can a severed peripheral nerve fiber find its way back to the cells it originally innervated?

Basic literature:

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EDUCATIONALAND METHODICAL COMPLEX OF DISCIPLINE

OMiF1214 Morphology and physiology of human body

Course – 1 Semester – 2

Number of credits – 8

Almaty 2022

Lecture 26

Spinal cord. Somatic reflexes.

Plan of the Lecture

1. Functions
2. Surface Anatomy
3. Meninges of the Spinal Cord
4. Cross-Sectional Anatomy
    a. Gray Matter
    b. White Matter
5. Spinal Tracts
    a. Ascending Tracts
    b. Descending Tracts
6. The Nature of Reflexes
7. The Muscle Spindle
8. The Stretch Reflex
9. The Flexor (Withdrawal) Reflex
10. The Crossed Extension Reflex
11. The Tendon Reflex

LEARNING OUTCOMES

1. state the three principal functions of the spinal cord;
2. describe its gross and microscopic structure;
3. trace the pathways followed by nerve signals traveling up and down the spinal cord.
4. define reflex and explain how reflexes differ from other motor actions; 5. describe the general components of a typical reflex arc;
6. explain how the basic types of somatic reflexes function.

The spinal cord serves four principal functions:

1. Conduction. It contains bundles of nerve fibers that conduct information up and down the cord, connecting different levels of the trunk with each other and with the brain. This enables sensory information to reach the brain, motor commands to reach the effectors, and input received at one level of the cord to affect output from another level.

2. Neural integration. Pools of spinal neurons receive input from multiple sources, integrate the information, and execute an appropriate output. For example, the spinal cord can integrate the stretch sensation from a full bladder with cerebral input concerning the appropriate time and

place to urinate and execute control of the bladder accordingly.

3. Locomotion. Walking involves repetitive, coordinated contractions of several muscle groups in the limbs. Motor neurons in the brain initiate walking and determine its speed, distance, and direction, but the simple repetitive muscle contractions that put one foot in front of another, over and over, are coordinated by groups of neurons called central pattern generators in the cord. These neural circuits produce the sequence of outputs to the extensor and flexor muscles that cause alternating movements of the lower limbs.
4. Reflexes. Spinal reflexes play vital roles in posture, motor coordination, and protective responses to pain or injury.

The spinal cord is a cylinder of nervous tissue that arises from the brainstem at the foramen magnum of the skull. It passes through the vertebral canal as far as the inferior margin of the first lumbar vertebra (L1) or slightly beyond. In adults, it averages about 45 cm long and 1.8 cm thick (about as thick as one's little finger). Early in fetal development, the cord extends for the full length of the vertebral column. However, the vertebral column grows faster than the spinal cord, so the cord extends only to L3 by the time of birth and to L1 in an adult. Thus, it occupies only the upper two-thirds of the vertebral canal; the lower one-third is described shortly.

The cord gives rise to 31 pairs of spinal nerves. Although the spinal cord is not visibly segmented, the part supplied by each pair of nerves is called a segment. The cord exhibits longitudinal grooves on its anterior and posterior sides—the anterior median fissure and posterior median sulcus, respectively. The spinal cord is divided into cervical, thoracic, lumbar, and sacral regions. It may seem odd that it has a sacral region when the cord itself ends well above the sacrum. These regions, however, are named for the level of the vertebral column from which the spinal nerves emerge, not for the vertebrae that contain the cord itself.

Meninges of the Spinal Cord. The spinal cord and brain are enclosed in three fibrous membranes called meninges. These membranes separate the soft tissue of the central nervous system from the bones of the vertebrae and skull. From superficial to deep, they are the dura mater, arachnoid mater, and pia mater. The dura mater forms a loose-fitting sleeve called the dural sheath around the spinal cord. It is a tough membrane about as thick as a rubber kitchen glove, composed of multiple layers of dense irregular connective tissue. The space between the sheath and vertebral bones, called the epidural space, is occupied by blood vessels, adipose tissue, and loose connective tissue. Anesthetics are sometimes introduced to this space to block pain signals during childbirth or surgery; this procedure is called epidural anesthesia. The spinal cord has a central core of gray matter that looks somewhat butterfly- or H shaped in cross sections. The core consists mainly of two posterior (dorsal) horns, which extend toward the posterolateral surfaces of the cord, and two thicker anterior (ventral) horns, which extend toward the anterolateral surfaces. The right and left sides of the gray matter are connected by a median bridge called the gray commissure. In the middle of the commissure is the central canal, which is collapsed in most areas of the adult spinal cord, but in some places (and in young children) remains open, lined with ependymal cells, and filled with CSF. Ascending tracts carry sensory signals up the spinal cord. Sensory signals typically travel across three neurons from their origin in the receptors to their destination in the brain: a first order neuron that detects a stimulus and transmits a signal to the spinal cord or brainstem; a second-order neuron that continues as far as a "gateway" called the
thalamus at the upper end of the brainstem; and a third-order neuron that carries the signal the rest of the way to the cerebral cortex. The axons of these neurons are called the first- through

third-order nerve fibers. Descending tracts carry motor signals down the brainstem and spinal cord. A descending motor pathway typically involves two neurons called the upper and lower motor neurons. The upper motor neuron begins with a soma in the cerebral cortex. or brainstem and has an axon that terminates on a lower motor neuron in the brainstem or spinal cord. The axon of the lower motor neuron then leads the rest of the way to the muscle or other target organ. The names of most descending tracts consist of a word root denoting the point of origin in the brain, followed by the suffix -spinal.

Reflexes are quick, involuntary, stereotyped reactions of glands or muscles to stimulation. This definition sums up four important properties: 1. Reflexes require stimulation—they are not spontaneous actions like muscle tics but responses to sensory input. 2. Reflexes are quick—they generally involve only a few
interneurons, or none, and minimum synaptic delay. 3. Reflexes are involuntary— they occur without intent, often without our awareness, and they are difficult to suppress. Given an adequate stimulus, the response is essentially automatic. You may become conscious of the stimulus that evoked a reflex, and this awareness may enable you to correct or avoid a potentially dangerous situation, but awareness is not a part of the reflex itself. It may come after the reflex action has been completed, and somatic reflexes can occur even if the spinal cord has been severed so that no stimuli reach the brain. 4. Reflexes are stereotyped—they occur in essentially the same way every time; the response is very predictable, unlike the variability of voluntary movement. A flexor reflex is the quick contraction of flexor muscles resulting in the withdrawal of a limb from an injurious stimulus. For example, suppose you are wading in a lake and step on a broken bottle with your right foot. In the preceding situation, if all you did was to quickly lift the injured leg from the lake bottom, you would fall over. To prevent this and maintain your balance, other reflexes shift your center of gravity over the leg that is still planted on the ground. The crossed extension reflex is the contraction of extensor muscles in the limb opposite from the one that is withdrawn. Tendon organs are proprioceptors located in a tendon near its junction with a muscle. A tendon organ is about 0.5 mm long. It consists of an encapsulated bundle of small, loose collagen fibers and one or more
nerve fibers that penetrate the capsule and end in flattened leaflike processes between the collagen fibers.

Check yourself! The questions for self-control

1. Name the four major regions and two enlargements of the spinal cord.
2. Describe the distal (inferior) end of the spinal cord and the contents of the vertebral canal from level L2 to S5.
3. Sketch a cross section of the spinal cord showing the anterior and posterior horns. Where are the gray and white matter? Where are the columns and tracts?
4. Give an anatomical explanation of why a stroke in the right cerebral hemisphere can paralyze the limbs on the left side of the body.
5. Identify each of the following spinal tracts—the gracile fasciculus and the lateral corticospinal, lateral reticulospinal, and spinothalamic tracts—with respect to whether it is ascending or descending; its origin and destination; and what sensory or motor purposes it serves.
6. Name five structural components of a typical somatic reflex arc. Which of these is absent from a monosynaptic arc?
7. State the function of each of the following in a muscle spindle: intrafusal fibers, gamma

motor neurons, and primary afferent fibers.
8. Explain how nerve fibers in a tendon sense the degree of tension in a muscle.
9. Why must the withdrawal reflex, but not the stretch reflex, involve a polysynaptic reflex arc?
10. Explain why the crossed extension reflex must accompany a withdrawal reflex of the leg

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company) 3. Richard L. Drake A. Wayne Vogl, Adam W. M. Mitchell - Gray's Atlas of Anatomy, Second Edition (2015, Churchill Livingstone Elsevier)
4. Dale Purves, David Fitzpatrick, George J. Augustine - Neuroscience (2018, Oxford University Press)

EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body
Specialty "B086"
Educational program “General medicine”)
Course – 1
Semester – 2
Number of credits – 8
Almaty 2022

Lecture 27

Human Histology 12 Histology of the nervous system Central nervous system. Brain. Cortex. Cerebellum. Overview of the meninges, ventricles, cerebrospinal fluid and blood supply

LECTURE OUTLINE

- Embrionic origin, structural and functional characteristics of the central nerve system.
- Cytoarchitecture and myeloarchitecture of cerebral cortex.
- Morphofunctional characteristic of cerebral cortex neurons.
- The agranular and granular types of cerebral cortex.
- The blood – brain barrier in terms of its structural correlates and its function.

LEARNING OUTCOMES

1. Identify the layers of the cerebellar cortex.
2. Recognise the cerebellum in the specimens and slides.
3. Explain the functional peculiarities of cerebellar cortex on the basis of cellular content and relationship with other organs of the nervous system.
4. Recognise the cerebral cortex.
5. Identify the layers of the cerebral cortex.
6. Interpret the cytoarchitecture of the cerebral cortex.
7. Explain the differences between sensory and motor cortex.
8. Describe the agranular and granular types of cerebral cortex.
9. Describe the blood – brain barrier in terms of its structural correlates and its function.

The brain consists of the trunk and the pallium (both the trunk and the pallium develop from 3 brain bubbles). The trunk consists of the medulla oblongata, the pons, the mesencephalon, the thalamus and the basal ganglia of the end brain. The grey matter is placed in the center as nuclei. The pallium is composed of the cerebral and cerebellar cortex. The cerebellum. It is the main center of balance and movement coordination. It has the form of two hemispheres. On their surface the most part of the grey matter forms the cerebellar cortex with sulci and gyri, the smaller part forms nuclei in the white matter in the middle of the cerebellum. The dentate nucleus transfers the information to the cerebral cortex and to the spinal cord; other nuclei transfer the impulse to the spinal cord. The cerebellar cortex has 3 layers. The external molecular layer is light, has inhibitory neurons and neuron processes of all layers. The middle ganglionic layer consists of one layer of large efferent neurons – piriform Purkinje neurons (the size is 35–60 microns). The internal granular layer is dark; it contains synaptic complexes «Cerebellum glomeruli» and 10 billion fine neurons. There are 3 groups of them: 1 – exciting cells-grains with a large dense nucleus and little cytoplasm, 2 –

inhibitory Golgi cells of the second type with a short axon, 3) associative neurons – horizontal and Golgi cells of the first type with a long axon, connect the cortex sites. 2 kinds of afferent tracts come to the cerebellum: the moss fibers from the cerebral cortex and the climbing fibers from the spinal cord and the organ of balance. The climbing fibers pass into the molecular layer, climb along the dendrites of the Purkinje cells and excite them. The moss fibers come into the granular layer and branchlike moss. They form exciting synapses with the dendrites of the cells-grains which branch like a bird's foot. These synapse complexes form «the cerebellum glomeruli». The axons of the cells-grains go from them into the molecular layer, divide like T and excite all cortex neurons. The excited inhibitory neurons take part in processing the information and inhibit the piriform Purkinje neurons. The Purkinje cells collect the information and transfer it to the cerebellum nuclei. The inhibitory neurons are of 4 kinds. 3 kinds of them lie in the molecular layer: 1 – basket neurons which form baskets around the bodies of the Purkinje cells; 2, 3 – fine and large stellate neurons which form inhibitory synapses with their dendrites. In the granular layer the 4th kind of the inhibitory neurons lies. It is Golgi cells of the 2nd type, their short axons enter the cerebellum glomeruli and inhibit the transfer of impulses from the moss fibers onto the cells-grains. Thus, they can inhibit the excitation of the Purkinje cells. Each Purkinje`s cell forms up to 60 thousand synapses. The inhibitory neurons can strengthen or block the exciting impulses, that leads to the inhibition or counter inhibition of the Purkinje cells. An intense impulse inhibits the Purkinje cells, blocks their inhibiting influence on the dentate nucleus. The nucleus neurons become excited and inhibit the pyramids of the cerebral cortex that leads to the counter inhibition of the motor neurons of the spinal cord, and a movement is made. And on the contrary, a weak impulse disinhibits the Purkinje cells, and a movement is not made. By the same principle the majority of reflexes work including the higher nervous activity. The cerebral cortex. The thickness of the cerebral cortex is 3 to 5 mm, it contains 14 to 17 billion neurons, all of them are multipolar, have different forms, pyramids prevail. They have the top and lateral dendrites, the axon passes from the basis of the cell. The pyramids can be small – 10 to 12 microns, middlesized – 20 to 30 microns, greater – 40 to 80 microns, and huge – 120 microns. New synapses are formed on the process terminals in the form of thorns and swellings, in nutritional disorder they die, but they remain near the perikaryon, that is why old men have long-term memory but no short-term memory.

THE STRUCTURE. The cerebral cortex has cell- and myeloarchitectonics, or the certain arrangement of fibers and cells forming the cortical areas – the centers of the higher nervous activity. The cortical neurons lie in 6 layers: 1 – the molecular layer, external, contains fine neurons and many processes of neurons from all layers forming the tangential plexus; 2 – the external granular layer composed of fine inhibitory neurons; 3 – the pyramidal layer, the widest, pyramids are of different size. The top dendrite goes into the molecular layer, the lateral dendrites branch in their own layer and form a plexus – external Bajarge's strip, the axons form radial rays and make up the cortico-cortical and pyramidal tracts; 4 – the internal granular layer contains echinate stellate neurons, accepting excitation from the thalamo-cortical tracts; 5 – the ganglionar layer composed of huge pyramids – Besth's cells (120 microns). Their axons form the pyramidal tracts, and the lateral dendrites form the internal Bajarge's strip in the same layer; 6 – the layer of polymorphic cells, their axons compose the pyramidal ways. There are 2 types of cortex zones: 1 – granular type with well developed granular layers – the sensory zones where the higher analysis of information is performed; 2 – agranular type where pyramidal layers are well developed – these are motor zones.

Questions for self-control:

1. What functional parts does the nervous system have?
2. What organs does the central nervous system include?
3. What organs does the peripheral nervous system include?
4. What is the grey and white matter of the spinal cord?
5. What components make up the spinal ganglion?

6. Name the layers of the cerebellar cortex.
7. Name the layers of the cerebral cortex.
8. What is a structural and functional unit of the cortex?

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1.Leslie P. Gartner: Color Atlas and Text of Histology. - 7th Edition. - Wolters Kluwer, 2017.
2. Victor P. Eroschenko, Atlas of Histology with Functional Correlations 13th Edition, LWW, 2017

EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body

Course – 1 Semester – 2
Number of credits – 8
Almaty 2022

Lecture 28
Spinal Nerves

Plan of the Lecture

1. General Anatomy of Nerves and Ganglia
2. Spinal Nerves
a. Proximal Branches
b. Distal Branches
3. Nerve Plexuses
4. Cutaneous Innervation and Dermatomes

LEARNING OUTCOMES

1. describe the anatomy of nerves and ganglia in general;
2. describe the attachments of a spinal nerve to the spinal cord;
3. trace the branches of a spinal nerve distal to its attachments;
4. name the five plexuses of spinal nerves and describe their general anatomy;
5. name some major nerves that arise from each plexus;
6. explain the relationship of dermatomes to the spinal nerves.

The spinal cord communicates with the rest of the body by way of the spinal nerves. Before we discuss those specific nerves, however, it is necessary to be familiar with the structure of nerves and ganglia in general. A nerve is a cordlike organ composed of numerous nerve fibers (axons) bound together by connective tissue. If we compare a nerve fiber to a wire carrying an electrical current in one direction, a nerve would be comparable to an electrical cable composed of thousands of wires carrying currents in opposite directions. A nerve contains anywhere from a few nerve fibers to (in the optic nerve) a million. Nerves usually have a pearly white color and resemble frayed string as they divide into smaller and smaller branches. As we move away from the spinal nerves proper, the smaller branches are called peripheral nerves.

There are 31 pairs of spinal nerves: 8 cervical (C1–C8), 12 thoracic (T1–T12), 5 lumbar (L1–L5), 5 sacral (S1–S5), and 1 coccygeal (Co1) (fig. 13.10). The first cervical nerve emerges between the skull and atlas, and the others emerge through intervertebral foramina, including the anterior and posterior foramina of the sacrum and the sacral hiatus.

Each spinal nerve arises from two points of attachment to the spinal cord. In each segment of the cord, six to eight nerve rootlets emerge from the anterior surface and converge to form the anterior (ventral) root of the spinal nerve. Another six to eight rootlets emerge from the posterior surface and converge to form the posterior (dorsal) root. Distal to the vertebrae, the branches of a spinal nerve are more complex. Immediately after emerging from the intervertebral foramen, the nerve divides into an anterior ramus, posterior ramus, and a small meningeal branch. Thus, each

spinal nerve branches on both ends—into anterior and posterior roots approaching the spinal cord, and anterior and posterior rami leading away from the vertebral column. Except in the thoracic region, the anterior rami branch and anastomose (merge) repeatedly to form five webs called nerve plexuses: the small cervical plexus in the neck, the brachial plexus near the shoulder, the lumbar plexus of the lower back, the sacral plexus immediately inferior to this, and finally, the tiny coccygeal plexus adjacent to the lower sacrum and coccyx.

The nerves tabulated here have somatosensory and motor functions. Somatosensory means that they carry sensory signals from bones, joints, muscles, and the skin, in contrast to sensory input from the viscera or from special sense organs such as the eyes and ears. Somatosensory signals are for touch, heat, cold, stretch, pressure, pain, and other sensations. One of the most important sensory roles of these nerves is proprioception, in which the brain receives information about body position and movements from nerve endings in the muscles, tendons, and joints. The brain uses this information to adjust muscle actions and thereby maintain equilibrium (balance) and coordination.

The cervical plexus receives fibers from the anterior rami of nerves C1 to C5 and gives rise to the nerves listed below, in order from superior to inferior. The most important of these are the phrenic nerves, which travel down each side of the mediastinum, innervate the diaphragm, and play an essential role in breathing. In addition to the major nerves listed here, there are several motor branches that innervate the geniohyoid, thyrohyoid, scalene, levator scapulae, trapezius, and sternocleidomastoid muscles. The brachial plexus (figs. 13.15 and 13.16) is formed predominantly by the anterior rami of nerves C5 to T1 (C4 and T2 make small contributions).

It passes over the first rib into the axilla and innervates the upper limb and some muscles of the neck and shoulder. This plexus is well known for its conspicuous M or W shape seen in cadaver dissections. The subdivisions of this plexus are called roots, trunks, divisions, and cords. The five roots are the anterior rami of C5 through T1. Roots C5 and C6 converge to form the upper trunk; C7 continues as the middle trunk; and C8 and T1 converge to form the lower trunk. Each trunk divides into an anterior and posterior division. As the body is dissected from the anterior surface of the shoulder inward, the posterior divisions are found behind the anterior ones. Finally, the six divisions merge to form three large fiber bundles—the lateral, posterior, and medial cords. From these cords arise the following major nerves, listed in order of the illustration from superior to inferior. The sacral plexus is formed from the anterior rami of nerves L4, L5, and S1 through S4. It has six roots and anterior and posterior divisions. Since it is connected to the lumbar plexus by fibers that run through the lumbosacral trunk, the two plexuses are sometimes referred to collectively as the lumbosacral plexus. The coccygeal plexus is a tiny plexus formed from the anterior rami of S4, S5, and Co1. The tibial and common fibular nerves travel together through a connective tissue sheath; they are referred to collectively as the sciatic nerve. The sciatic nerve passes through the greater sciatic notch of the pelvis, extends for the length of the thigh, and ends at the popliteal fossa. Here, the tibial and common fibular nerves diverge and follow their separate paths into the leg. The tibial nerve descends through the leg and then gives rise to the medial and plantar nerves in the foot.

Check yourself! The questions for self-control

1. What is meant by the anterior and posterior roots of a spinal nerve? Which of these is sensory and which is motor?
2. Where are the neurosomas of the posterior root located? Where are the neurosomas of the anterior root?

3. List the five plexuses of spinal nerves and state where each one is located.
4. State which plexus gives rise to each of the following nerves: axillary, ilioinguinal, obturator, phrenic, pudendal, radial, and sciatic.
5. Name five structural components of a typical somatic reflex arc. Which of these is absent from a monosynaptic arc?
6. State the function of each of the following in a muscle spindle: intrafusal fibers, gamma motor neurons, and primary afferent fibers.
7. Explain how nerve fibers in a tendon sense the degree of tension in a muscle.
8. Why must the withdrawal reflex, but not the stretch reflex, involve a polysynaptic reflex arc?
9. Explain why the crossed extension reflex must accompany a withdrawal reflex of the leg

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)
3. Richard L. Drake A. Wayne Vogl, Adam W. M. Mitchell - Gray's Atlas of Anatomy, Second Edition (2015, Churchill Livingstone Elsevier)
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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body

Course – 1 Semester – 2
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Almaty 2022

Lecture 29
Overview of the meninges, ventricles, cerebrospinal fluid and blood supply. Midbrain.

Plan of the Lecture

1. Major Landmarks
2. Gray and White Matter
3. Embryonic Development
4. Meninges
5. Ventricles and Cerebrospinal Fluid
6. Blood Supply and the Brain Barrier System
7. Midbrain.

LEARNING OUTCOMES
1. describe the major subdivisions and anatomical landmarks of the brain;
2. describe the locations of its gray and white matter;
3. describe the embryonic development of the CNS and relate this to adult brain anatomy.
4. describe the meninges of the brain;
5. describe the fluid-filled chambers within the brain;
6. discuss the production, circulation, and function of the cerebrospinal fluid that fills these chambers;
7. explain the significance of the brain barrier system.

In the evolution of the central nervous system from the simplest vertebrates to humans, the spinal cord changed very little while the brain changed a great deal. In fishes and amphibians, the brain weighs about the same as the spinal cord, but in humans, it weighs 55 times as much. It averages about 1,600 g (3.5 lb) in men and 1,450 g in women. The difference between the sexes is proportional to body size, not intelligence. through a more detailed study.

Two directional terms used in descriptions of CNS anatomy are rostral and caudal. Rostral1 means "toward the nose" and caudal means "toward the tail." These are apt descriptions for an animal such as a laboratory rat, on which so much brain research has been done. The terms are retained for human neuroanatomy as well, but in references to the brain, rostral means "toward the forehead" and caudal means "toward the spinal cord." In the spinal cord and brainstem, which are vertically oriented, rostral means "higher" and caudal means "lower." Gray matter—the seat of the neurosomas, dendrites, and synapses—forms a surface layer called the cortex over the cerebrum and cerebellum, and deeper masses called nuclei surrounded by white matter. White matter lies deep to the cortical gray matter in most of the brain, opposite from the relationship of gray and white matter in the spinal cord. As in the
spinal cord, white matter is composed of tracts, or bundles of axons, which here connect one part

of the brain to another and to the spinal cord.

The nervous system develops from ectoderm, the outermost tissue layer of an embryo. Within the first 3 weeks, a neural plate forms along the dorsal midline of the embryo and sinks into the tissues to form a neural groove, with a raised neural fold along what like a closing zipper, beginning in the cervical region and progressing both caudally and rostrally. By day 26, this process creates a hollow channel called the neural tube. Following closure, the neural tube separates from the overlying ectoderm, sinks a little deeper, and grows lateral processes that later form motor nerve fibers. The lumen of the neural tube becomes a fluid-filled space that later constitutes the central canal of the spinal cord and ventricles of the brain. As the neural tube develops, some ectodermal cells that originally lay along the margin of the groove separate from the rest and form a longitudinal column on each side called the neural crest. Neural crest cells give rise to the two inner meninges (arachnoid mater and pia mater); most of the peripheral nervous system, including the sensory and autonomic nerves and ganglia and Schwann cells; and some other structures of the skeletal, integumentary, and endocrine systems.

The brain is enveloped in three membranes, the meninges, which lie between the nervous tissue and bone. They protect the brain and provide a structural framework for its arteries and veins. As in the spinal cord, these are the dura mater, arachnoid mater, and pia mater. The brain has four internal chambers called ventricles. The largest and most rostral ones are the two lateral ventricles, which form an arc in each cerebral hemisphere. Through a tiny pore called the interventricular foramen, each lateral ventricle is connected to the third ventricle, a narrow median space inferior to the corpus callosum. From here, a canal called the cerebral aqueduct passes down the core of the midbrain and leads to the fourth ventricle, a small triangular chamber between the pons and cerebellum. Caudally, this space narrows and forms a central canal that extends through the medulla oblongata into the spinal cord. On the floor or wall of each ventricle is a spongy mass of blood capillaries called a choroid plexus, named for its histological resemblance to a fetal membrane called the chorion. Ependyma, a type of neuroglia that resembles a cuboidal epithelium, lines the ventricles and canals and covers the choroid plexuses. It produces cerebrospinal fluid. Cerebrospinal fluid (CSF) is a clear, colorless liquid that fills the ventricles and canals of the CNS and bathes its external surface. The brain produces about 500 mL of CSF per day, but the fluid is constantly reabsorbed at the same rate and only 100 to 160 mL is normally present at one time.

Despite its critical importance to the brain, blood is also a source of antibodies, macrophages, bacterial toxins, and other potentially harmful agents. Damaged brain tissue is essentially irreplaceable, and the brain therefore must be well protected. Consequently, there is a brain barrier system (BBS) that strictly regulates what can
get from the bloodstream into the tissue fluid of the brain. The BBS is highly permeable to water, glucose, and lipidsoluble substances such as oxygen, carbon dioxide, alcohol, caffeine, nicotine, and anesthetics. It is slightly permeable to sodium, potassium, chloride, and the waste products urea and creatinine. While the BBS is an important protective device, it is an obstacle to the delivery of medications such as antibiotics and cancer drugs, and thus complicates the treatment of brain diseases.

Check yourself! The questions for self-control

1. List the three major parts of the brain and describe their locations.

2. Define gyrus and sulcus.
3. Contrast the composition and locations of gray and white matter in the brain.
4. Explain how the five secondary brain vesicles arise from the neural tube.
5. Name the three meninges from superficial to deep. How does the dura mater of the brain differ from that of the spinal cord?
6. Describe three functions of the cerebrospinal fluid.
7. Where does the CSF originate and what route does it take through and around the CNS?
8. Name the two components of the brain barrier system and explain the importance of this system.

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)
3. Richard L. Drake A. Wayne Vogl, Adam W. M. Mitchell - Gray's Atlas of Anatomy, Second Edition (2015, Churchill Livingstone Elsevier)
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EDUCATIONALAND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body

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Lecture 30
Hindbrain. Forebrain.

Plan of the Lecture

1. The Hindbrain
a. The Medulla Oblongata
b. The Pons
c. The Reticular Formation
d. The Cerebellum
2. The Forebrain
a. The Diencephalon
i. The Thalamus
ii. The Hypothalamus
iii. The Epithalamus
b. The Cerebrum
i. Gross Anatomy
ii. The Cerebral White Matter
iii. The Cerebral Cortex
iv. The Limbic System
v. The Basal Nuclei

LEARNING OUTCOMES
1. list the components of the hindbrain and their functions;
2. describe the location and functions of the reticular formation.
3. name the three major components of the diencephalon and describe their locations and functions;
4. identify the five lobes of the cerebrum and their functions;
5. describe the three types of tracts in the cerebral white matter;
6. describe the distinctive cell types and histological arrangement of the cerebral cortex;
7. describe the location and functions of the basal nuclei and limbic system.

The medulla begins at the foramen magnum of the skull and extends for about 3 cm rostrally, ending at a transverse groove between the medulla and pons. It looks superficially like an extension of the spinal cord, but slightly wider. Significant differences are apparent, however, on closer inspection of its gross and microscopic
anatomy. Externally, the anterior surface features a pair of ridges called the pyramids. Resembling side-by-side baseball bats, these are wider at the rostral end, taper caudally, and are separated by a longitudinal groove, the anterior median fissure, continuous with that of the spinal cord. Lateral to each pyramid is a prominent bulge called the olive. Posteriorly, the gracile and cuneate fasciculi of the spinal cord continue as two pairs of ridges on the medulla. The pons measures about 2.5 cm long. Most of it appears as a broad anterior bulge rostral to the medulla.

Cranial nerves V to VIII begin or end in the pons. The other three emerge from the groove between the pons and medulla. The functions of these four nerves, include sensory roles in hearing, equilibrium, and taste; facial sensations such as touch and pain; and motor roles in eye movement, facial expressions, chewing, swallowing, urination, and the secretion of saliva and tears. The reticular formation in the pons contains additional nuclei concerned with sleep, respiration, and posture.

The part of the midbrain posterior to the cerebral aqueduct is a rooflike tectum. It exhibits four bulges, the corpora quadrigemina. The upper pair, called the superior colliculi, functions in visual attention; visually tracking moving objects; such reflexes as blinking, focusing, pupillary dilation and constriction; and turning the eyes and head in response to a visual stimulus. The lower pair, called the inferior colliculi, receives signals from the inner ear and relays them to other parts of the brain, especially the thalamus. Among other functions, they mediate the reflexive turning of the head in response to a sound, and one's tendency to jump when startled by a sudden noise.

The reticular formation is a loose web of gray matter that runs vertically through all levels of the brainstem. It occupies much of the space between the white fiber tracts and the more anatomically distinct brainstem nuclei, and has connections with many areas of the cerebrum. It consists of more than 100 small neural networks defined less by anatomical boundaries than by their use of different neurotransmitters. The functions of these networks include the following: Somatic motor control, Cardiovascular control, Pain modulation, Sleep and consciousness, Habituation.

The cerebellum is the largest part of the hindbrain and second largest part of the brain as a whole. It consists of right and left cerebellar hemispheres connected by a narrow wormlike bridge called the vermis. Each hemisphere exhibits slender, transverse, parallel folds called folia separated by shallow sulci. The cerebellum has a surface cortex of gray matter and a deeper layer of white matter. In a sagittal section, the white matter exhibits a branching, fernlike pattern called the arbor vitae. Each hemisphere has four masses of gray matter called deep nuclei embedded in the white matter. All input to the cerebellum goes to the cortex and all of its output comes from the deep nuclei.

Each side of the brain has a thalamus, an ovoid mass perched at the superior end of the brainstem beneath the cerebral hemisphere. The two thalami form about four fifths of the diencephalon. Laterally, they protrude into the lateral ventricles. Medially, they protrude into the third ventricle and are joined to each other by a narrow intermediate mass in about 70% of people.
The hypothalamus is the major control center of the endocrine and autonomic nervous systems. It plays an essential role in the homeostatic regulation of nearly all organs of the body. Its nuclei include centers concerned with a wide variety of visceral functions: Hormone secretion, Autonomic effects, Thermoregulation, Food and water intake, Sleep and circadian rhythms, Memory, Emotional behavior and sexual response.

The cerebrum so dwarfs and conceals the other structures that people often think of "cerebrum" and "brain" as synonymous. Its major anatomical landmarks were described at the beginning of this chapter and should be reviewed if necessary; most important are the two cerebral hemispheres, separated by the longitudinal fissure but connected by a prominent fiber tract, the corpus callosum; and the conspicuous wrinkles, or gyri, of each hemisphere, separated by grooves called sulci. The folding of the cerebral surface into gyri allows a greater amount of cortex to fit in the cranial cavity.

Neural integration is carried out in the gray matter of the cerebrum, which is found in three places: the cerebral cortex, basal nuclei, and limbic system. We begin with the cerebral cortex, a layer covering the surface of the hemispheres. Even though it is only 2 to 3 mm thick, the cortex constitutes about 40% of the mass of the brain and contains 14 to 16 billion neurons. It possesses two principal types of neurons called stellate cells and pyramidal cells.

The limbic system is an important center of emotion and learning. It is a ring of cortex on the medial side of each hemisphere, encircling the corpus callosum and thalamus. Its most anatomically prominent components are the cingulate gyrus, which arches over the top of the corpus callosum in the frontal and parietal lobes; the hippocampus in the medial temporal lobe; and the amygdala.

The basal nuclei are masses of cerebral gray matter buried deep in the white matter, lateral to the thalamus. They are often called basal ganglia, but the word ganglion is best restricted to clusters of neurons outside the CNS. Neuroanatomists disagree on how many brain centers to classify as basal nuclei, but agree on at least three: the caudate nucleus, putamen, and globus pallidus.

Check yourself! The questions for self-control

1. List several visceral functions controlled by nuclei of the medulla. What general function would be lost if the pyramids of the medulla were severed?

2. List several sensory and motor functions of the pons.
3. What functions are served by the superior and inferior colliculi? To what portion of the brainstem do they belong?
4. Where is the reticular formation found? Define reticular formation in a single sentence.
5. List several functions of the cerebellum.
6. What are the three major components of the diencephalon? Which ventricle does the diencephalon enclose?
7. What is the role of the thalamus in sensory function?
8. List at least six functions of the hypothalamus.
9. Name the five lobes of the cerebrum and describe their locations, boundaries, and principal functions.
10.Distinguish between commissural, association, and projection tracts of the cerebrum.
11. Where is the limbic system located? What component of it is involved in emotion? What component is involved in memory?
12. Where are the basal nuclei located? What is their general function?

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company) 3. Richard L. Drake A. Wayne Vogl, Adam W. M. Mitchell - Gray's Atlas of Anatomy, Second Edition (2015, Churchill Livingstone Elsevier)
4. Dale Purves, David Fitzpatrick, George J. Augustine - Neuroscience (2018, Oxford University Press)

EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE

OMiF1214 Morphology and physiology of human body

Course – 2 Semester – 3

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Almaty 2022

Lecture 31

Integrative functions of the brain

Plan of the Lecture

1. The Electroencephalogram
2. Sleep
3. Cognition
4. Memory
5. Emotion
6. Sensation
a. The Special Senses
b. The General Senses
7. Motor Control
8. Language
9. Cerebral Lateralization

LEARNING OUTCOMES

1. list the types of brain waves and discuss their relationship to mental states; 2. describe the stages of sleep, their relationship to the brain waves, and the neural mechanisms of sleep;
3. identify the brain regions concerned with consciousness and thought, memory, emotion, sensation, motor control, and language;
4. discuss the functional differences between the right and left cerebral hemispheres.

For research and clinical purposes, it is common to monitor electrical activity called brain waves. Recorded with electrodes on the scalp, these are rhythmic voltage changes resulting predominantly from synchronized postsynaptic potentials (not action potentials) in the superficial layers of the cerebral cortex. The recording, called an electroencephalogram (EEG), is useful in studying normal brain functions such as sleep and consciousness, and in diagnosing degenerative brain diseases, metabolic abnormalities, brain tumors, trauma, and so forth.

Sleep can be defined as a temporary state of unconsciousness from which (in contrast to coma) one can awaken when stimulated. It is one of many bodily functions that occur in cycles called circadian rhythms, so named because they are marked by events that reoccur at intervals of about 24 hours. Sleep is characterized by a stereotyped posture (usually lying down with the eyes closed) and inhibition of muscular activity (sleep paralysis). It superficially resembles other states of prolonged unconsciousness such as coma and animal hibernation, except that

individuals cannot be aroused from those states by sensory stimulation.
Sleep occurs in distinct stages recognizable from changes in the EEG. In the first 30 to 45 minutes, the EEG waves drop in frequency but increase in amplitude as one passes through four sleep stages.

Cognition is the range of mental processes by which we acquire and use knowledge—sensory perception, thought, reasoning, judgment, memory, imagination, and intuition. Such functions are widely distributed over regions of cerebral cortex called association areas, which constitute about 75% of all brain tissue. This is the most difficult area of brain research and the most incompletely understood aspect of cerebral function. Much of what we know about it has come from studies of patients with brain lesions—areas of tissue destruction resulting from cancer, stroke, and trauma.

Memory is one of the cognitive functions, but warrants special attention. Our subject is really a little broader than memory per se. Information management by the brain entails learning (acquiring new information), memory proper (information storage and retrieval), and forgetting (eliminating trivial information). Brain-injured people are sometimes unable to recall things they once knew (retrograde amnesia) or unable to store new information (anterograde amnesia).

Emotional feelings and memories are not exclusively cerebral functions, but result from an interaction between areas of the prefrontal cortex and diencephalon. Emotional control centers of the brain have been identified by studying people with brain lesions and by such techniques as surgical removal, ablation (destruction) of small regions with electrodes, and stimulation with electrodes and chemical implants, especially in experimental animals. Changes in behavior following such procedures give clues to the functions that a region performs. However, interpretation of the results is difficult and controversial because of the complex connections between the emotional brain and other regions.

The special senses are limited to the head, and some employ relatively complex sense organs. They are vision, hearing, equilibrium, taste, and smell. The general (somatosensory, somesthetic, or somatic) senses are distributed over the entire body and employ relatively simple receptors. They include such senses as touch, pressure, stretch, movement, heat, cold, and pain. Coming from the head, such signals reach the brain by way of certain cranial nerves, especially the trigeminal nerve; from the rest of the body, they ascend sensory tracts of the spinal cord such as the spinothalamic tract. In both routes, they decussate to the contralateral thalamus.

The intention to contract a skeletal muscle begins in the motor association (premotor) area of the frontal lobes. This is where we plan our behavior—where neurons compile a program for the degree and sequence of muscle contractions required for an action such as dancing, typing, or speaking. The program is then transmitted to neurons of the precentral gyrus (primary motor area), which is the
most posterior gyrus of the frontal lobe, immediately anterior to the central sulcus. Neurons here send signals to the brainstem and spinal cord, which ultimately results in muscle contractions.

Language includes several abilities—reading, writing, speaking, sign language, and understanding words—assigned to different regions of cerebral cortex. The Wernicke area is responsible for the recognition of spoken and written language. It lies just posterior to the lateral sulcus, usually in the left hemisphere, at the crossroad between visual, auditory, and somatosensory areas of cortex, receiving input from all these neighboring regions. The angular gyrus, part of the parietal lobe just caudal and superior to the Wernicke area, is important in the

ability to read and write. When we intend to speak, the Wernicke area formulates phrases according to learned rules of grammar and transmits a plan of speech to the Broca56 area, located in the inferior prefrontal cortex of the same hemisphere.

The two cerebral hemispheres look identical at a glance, but close examination reveals a number of differences. For example, in many women the left temporal lobe is longer than the right. In left-handed people, the left frontal, parietal, and occipital lobes are usually wider than those on the right. The two hemispheres also differ in some of their functions. Neither hemisphere is "dominant," but each is specialized for certain tasks. This difference in function is called cerebral lateralization. The idea, however, that some people are "left-brained" (such as a mathematician or scientist) and others "right-brained" (such as a musician or artist) is only a discredited popular myth. Everyone uses the two hemispheres about equally.

Check yourself! The questions for self-control

1. Suppose you are reading a novel and gradually fall asleep and begin to dream. How would your brain waves change during this sequence of events?
2. Describe the locations and functions of the somatosensory, visual, auditory, and frontal association areas.
3. Describe the somatotopy of the primary motor area and primary sensory area.
4. What are the roles of the Wernicke area, Broca area, and precentral gyrus in language?
5. Name the five lobes of the cerebrum and describe their locations, boundaries, and principal functions.
6. Distinguish between commissural, association, and projection tracts of the cerebrum.
7. Where is the limbic system located? What component of it is involved in emotion? What component is involved in memory?
8. Where are the basal nuclei located? What is their general function?

Recommended readings:

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4. Dale Purves, David Fitzpatrick, George J. Augustine - Neuroscience (2018, Oxford University Press)

Lecture 38

The Cranial Nerves

Plan of the Lecture

1. Cranial Nerve Pathways
2. Cranial Nerve Classification
3. Cranial Nerve Survey
4. Composition, Function, Origin, Termination, Cranial, Passage, Effect of Damage, Clinical Test of I, II, III, IV, V, VI, VII, IX, X, XI, XII cranial nerves

LEARNING OUTCOMES

1. List the 12 cranial nerves by name and number;
2. Identify where each cranial nerve originates and terminates in the model and picture;
3. State the functions of each cranial nerve.

To be functional, the brain must communicate with the rest of the body. Most of its input and output travels by way of the spinal cord, but it also communicates by way of 12 pairs of cranial nerves.

These arise primarily from the base of the brain, exit the cranium through its foramina, and lead to muscles and sense organs located mainly in the head and neck. The cranial nerves are numbered I to XII starting with the most rostral pair. Each nerve also has a descriptive name such as optic nerve and vagus nerve.

Most motor fibers of the cranial nerves begin in the nuclei of the brainstem and lead to glands and muscles. The sensory fibers begin in receptors located mainly in the head and neck and lead mainly to the brainstem. These include the special senses such as vision and hearing, as well as general senses such as touch and proprioception.

Sensory fibers for proprioception begin in the muscles innervated by motor fibers of the cranial nerves, but they often travel to the brain in a different nerve than the one that supplies the motor innervation.

Most cranial nerves carry fibers between the brainstem and ipsilateral receptors and effectors. Thus, a lesion in one side of the brainstem causes a sensory or motor deficit on the same side of the head. This contrasts with lesions of the motor and somatosensory cortex of the cerebrum, which, as we saw earlier, cause sensory and motor deficits on the contralateral side of the body. The exceptions are the optic nerve (II), where half the fibers decussate to the opposite side of the brain, and the trochlear nerve (IV), in which all efferent fibers lead to a muscle of the contralateral eye.

Cranial nerves are traditionally classified as sensory (I, II, VIII), motor (III, IV, VI, XI, XII), or mixed (V, VII, IX, X). In reality, only cranial nerves I and II (for smell and vision) are purely sensory, whereas all of the rest contain both afferent and efferent fibers and are therefore mixed nerves. Those traditionally classified as motor not only stimulate muscle contractions but also contain sensory fibers of proprioception, which provide the brain with feedback for controlling muscle action and make one aware of such things as the position of the tongue and orientation of the head. Cranial nerve VIII, concerned with hearing and equilibrium, is traditionally classified as sensory, but it also has motor fibers that return signals to the inner ear and tune it to sharpen the sense of hearing. The nerves traditionally classified as mixed have sensory functions quite unrelated to their motor functions. For

example, the facial nerve (VII) has a sensory role in taste and a motor role in controlling facial expressions.

Check yourself! The questions for self-control

1. Names and numbers of the 12 pairs of cranial nerves, and their relationships to the brainstem and skull foramina
2. Which cranial nerves are purely sensory, which are mixed, which have traditionally been regarded as motor, and why it is not entirely accurate to simply call them motor nerves
3. For each cranial nerve, its location, functions, origin, termination, passage through the skull
4. Effects of damage to each cranial nerve, and clinical methods of testing for damage

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
3. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)
4. Stefan Silbernagl, Agamemnon Despopoulos - Color Atlas of Physiology (Thieme, 2009)