МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
КАФЕДРА НОРМАЛЬНОЙ ФИЗИОЛОГИИ

А. И. КУБАРКО, Т. Г. СЕВЕРИНА

НОРМАЛЬНАЯ ФИЗИОЛОГИЯ

NORMAL PHYSIOLOGY

Практикум
для иностранных студентов 2-го года обучения

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Р е ц е н з е н т ы: зав. каф. патологической физиологии Белорусского государственного медицинского университета, д-р мед. наук, проф., чл.-корр. Национальной академии наук Беларуси Ф. И. Висмонт; зав. каф. анатомии, физиологии и валеологии Белорусского государственного педагогического университета им. М. Танка, д-р мед. наук Ю. М. Досин

Кубарко, А. И.

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Представлены вопросы к практическим занятиям по нормальной физиологии, а также описания лабораторных работ и протоколы их оформления.

Предназначено для иностранных студентов 2-го курса.

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Introduction

The Practical Part is intended to assist students in their preparation for the lessons and recording practical works in Normal Physiology. It meets the requirements of the program "NORMAL PHYSIOLOGY" for students of higher educational establishments and is approved by the Health Ministry of the Republic of Belarus in 2005. The character of practical classes is constantly changing due to the improvement of new equipment supply associated with the possibility to model many classical physiological experiments on virtual animals as the practical part is aimed at studying the status of physiological function of a healthy human organism. The practical part includes works using computer techniques for teaching and monitoring students' knowledge, modeling known physiological phenomena. There has been presented the research technique of some human functions status by modern methods of clinical examination of blood, gases analysis, electroencephalography, investigation of the cardio-respiratory system reserves, etc.

The teaching and monitoring programs are available in the computer class of the Department for every practical work, and the students can use them while getting ready for current and concluding sessions; while working off missed classes as well as during preparation for exams.

At the end of Physiology classes provided that the student has acquired practical skills and sufficient amount of theoretical knowledge of performed works and discussed questions as well as observed academic discipline and safety rules, the teacher puts his signature (credit test is passed).

It is recommended to read the present publication while preparing every practical work. Along with the textbooks the lectures of the Normal Physiology department and adjoining disciplines should be used. Teaching materials for every lesson as well as teaching computer programs are available in the computer class.

The authors will be grateful for recommendations and remarks contributing to further improvement of the given Practical Part.

PHYSIOLOGY OF THE BLOOD

Lesson 1. INTRODUCTION. SAFETY PROVISIONS IN PRACTICAL CLASSES AND LABORATORIES OF THE DEPARTMENT. THE SUBJECT AND TASKS OF NORMAL PHYSIOLOGY. PHYSICAL AND CHEMICAL PROPERTIES OF THE BLOOD

Basic questions:

1. Safety provisions while performing practical works.
2. Physiological concept of homeostasis as the constancy of internal environment and functions of the organism as well as the mechanisms regulating them.
3. Basic homeostasis constants of the blood, cardiovascular, respiratory and other systems of the organism. The concept of their relative constancy at rest and changes when the organism is exposed to various effects.
4. The role of water for vital functions. The content and distribution of water in the organism; peculiarities associated with age. Fluid media of the organism.
5. The blood. The blood system concept. The amount, content, basic physical and chemical properties of the blood. Functions of the blood.
6. Osmotic and colloid osmotic (oncotic) blood pressure, their role in water and electrolyte exchange between the blood and tissues. Hyper- and hypohydration of tissues.
7. Hemolysis and its types, plasmolysis. Concept of hypo-, hyper- and isotonic solutions.
8. Acid-base balance of the internal environment of the organism. The concept of acidosis and alkalosis.

Self check:

1. What is the total blood volume of a young human organism?
2. What is the normal value of blood plasma osmolarity?
3. Arrange the following osmotically active substances according their contribution to the plasma osmotic pressure in descending order: proteins, glucose, sodium, potassium, chlorine, bicarbonate.
4. Why is the 0,9 % solution of NaCl isotonic?
5. What is the value of colloid osmotic (oncotic) blood plasma pressure?
6. What protein components (globulins or albumins) and why it is this blood protein type that mainly determine the oncotic pressure level?
7. What consequences may have hypoproteinemia for the fluid distribution in the organism? The infusion of what solutions into the bloodstream may correct these consequences?

INSTRUCTIONS ON SAFETY PROVISIONS

The teaching program at the Normal Physiology department envisages practical works performed by the students, mastering their practical skills of operating some electric devices, computer techniques, research equipment, laboratory dishes, chemical reagents and biological fluids.

Besides, the students may carry out research work in the department laboratories during their out-of-classes hours.

General requirements

The student should put on a gown before entering an academic room.

A student on duty is appointed in every group to observe the order, rules and requirements of safety provisions while working in academic rooms. The student on duty should receive various materials necessary for carrying out practical works. At the end of practical classes the student on duty should return the received materials and check the state of the room for practical classes — if the water and electricity are switched off.

Safety provisions in operating electric equipment

Cases of electric trauma and fires may occur while working with electric equipment. They may be caused by:

- working with defective electric equipment (knife-switches, sockets, etc.);
- absence of electric appliances grounding;
- breaking rule of operating electric devices;
- touching current-carrying elements with hands and metal objects.

In case of revealing a defect of the electric device or electric equipment it is necessary to inform the teacher about it. While operating the electric equipment and electric devices it is strictly forbidden to:

- check the presence of electric voltage with fingers and touch current-carrying parts;
- operate ungrounded electric equipment and devices if not allowed by the device instruction;
- use defected electric equipment and electric wiring;
- leave an electric circuit under tension without supervision.

Actions taken in case of fire

In case of fire one should immediately switch off the power, call in the assistance and start extinguishing the fire. There are fire extinguishers in rooms 104, 131, 135 and 138. First of all, before you start extinguishing the fire, it is necessary to de-energize the room power. Then use the fire extinguisher. For extinguishing the fire one can also use available fire hoses: unreel the hose and open the hydrant. The fire hydrants with hoses are at the end of the corridor next to room 136, in the niche between rooms 139 and 140, 133 and 132 as well as opposite room 104.

General rules of giving the first aid

The first aid to victims should be given immediately and properly. It may affect the life, consequences of injuries, burns and poisonings. You'll get acquainted with specific rules of rendering it at clinical departments.

In case of serious injuries, burns due to electric trauma an ambulance should be called in. If the injuries are mild, the victims should be given the first aid and directed

to a medical care institution. It should be kept in mind that rendering aid to a person under electric current you shouldn't touch him with bare hands. First of all, the setting (device), which the victim touches, should be switched off. If it is impossible to switch off the whole setting, you should separate the victim from current-carrying parts using sticks, boards and other dry objects not conducting electric current or cut off wires by an axe with a dry axe handle.

In all cases it is necessary to call in a laboratory assistant on duty from room 131 or a teacher of the Department.

PRACTICAL WORKS

Work 1.1. LEARNING METHODS OF WORKING IN THE COMPUTER ROOM

The computer room of the Department allows to monitor the degree of learning the educational material by the students as well as to visually present the information for learning the discipline. Using computer programs allowing modeling a response of organs and systems to various effects makes it easier to learn and understand the educational material.

During the introductory lesson the students get acquainted with working rules in the room, kinds of educational materials offered for studies and, in particular, with the content of the introductory and the following classes.

Work 1.2. ACQUAINTANCE WITH BASIC FACTORS OF BLOOD HOMEOSTASIS, CARDIO-VASCULAR AND RESPIRATORY SYSTEMS OF THE ORGANISM

Table 1

Some most important factors of homeostasis

Factor	Range of normal values	Measurement units
Blood		
Blood volume	_____	liters
Blood viscosity	_____	relative units
Content of blood cells:	_____	
Red blood cells (Erythrocytes)	_____	cells/l of blood
White blood cells (Leukocytes)	_____	cells/l of blood
Platelets (Thrombocytes)	_____	cells/l of blood
Hematocrit	_____	–
Osmotic blood pressure	_____	mosm/kg
Oncotic blood pressure	_____	mm Hg
Blood pH	_____	–
Blood glucose content	_____	mmol/l
Blood protein content	_____	g/l
Cardiovascular system		
Heart rate (HR) at rest	_____	Beats/min
Stroke volume (SV) at rest	_____	ml
Cardiac output (CO) at rest	_____	l/min

Ending of the table 1

Factor	Range of normal values	Measurement units
Respiratory system		
Respiration rate (RR) at rest	_____	per minute
Tidal volume (TV) at rest	_____	ml
Minute ventilation (MV) at rest	_____	l/min
Alveolar ventilation (AV) at rest	_____	l/min

Work 1.3. HEMOLYSIS AND ITS TYPES (DEMONSTRATION)

Hemolysis is the red blood cell membrane destruction resulting in the appearance of hemoglobin in the blood. Depending on etiology hemolysis can be osmotic, mechanic, thermal, chemical and biological. Physiological hemolysis is the result of ageing and destruction of red blood cells.

Materials and equipment: 0,9 % solution of NaCl; ammonium chloride; alcohol; iodine; distilled water; 3 test-tubes; scarificators in sterilizers; cotton wool; rubber gloves; masks; 3 % solution of chloramine.

Accomplishment. 2 ml of 0,9 % solution of NaCl are applied into one test-tube, 2 ml of 0,9 % solution of NaCl and 5 drops of ammonium chloride into the second test-tube and 2 ml of distilled water into the third test-tube. Then 2 drops of blood are added into every test-tube and the content is stirred. The result is evaluated in 45 min.

PROTOCOL		
Test-tubes	**Presence of red blood cells sediment**	**Color of the solution**
0,9 % NaCI		
0,9 % NaCI + NH_4OH		
Distilled water		
Conclusion:	**Presence or absence of hemolysis**	**Type of hemolysis (if there is any)**
0,9 % NaCI		
0,9 % NaCI + NH_4OH		
Distilled water		

Work 1.4. VALUATION OF BLOOD PLASMA OSMOTIC PRESSURE (demonstration)

Blood plasma osmotic pressure depends on the amount (total concentration) of molecules of all dissolved substances (electrolytes and non-electrolytes). Osmotic pressure is one of strict homeostatic constants and determines water distribution between the internal environment and the cells of the organism. The value of **blood plasma osmotic pressure** in a healthy individual comprises on an average **290 ± 10 mosmol/kg** (7,3 atm or 5600 mm Hg or 745 kPa).

Evaluation of osmotic pressure in biological fluids (blood, lymph, cerebrospinal fluid, etc.) is performed by a cryoscopic method. It is known that the higher is the total concentration of small ions and molecules, the lower is the freezing temperature of the fluid. The blood freezing temperature in humans is 0,56–0,59 ºC below zero, and the freezing temperature of blood plasma is 0,54 ºC below zero.

Accomplishment. Demonstration of a teaching video. The device "OSMOMETER MO 801" allows evaluating osmolarity of a biological fluid (osmol/kg) in the volume of 0,05 ml. The results received in the video are to be recorded into the Protocol.

PROTOCOL

1. Received results: osmotic pressure in the tested sample of blood plasma = _____ osmol/kg, or _____ mosmol/kg.

2. Conclusion: osmotic pressure in the tested sample of blood sample: _____.
(in norm, decreased or elevated)

Lesson 2. BASES OF INFORMATION EXCHANGE OF THE CELL WITH THE ENVIRONMENT: CHEMICAL SIGNALING. HEMOPOESIS

Basic questions:

1. Information exchange between the cell and the environment. Concepts: information, signal. Types of signals.
2. Chemical signaling. Basic ways of intercellular communication involving signal molecules, their characteristics.
3. Classification of molecular receptors. Types of signal molecules (ligands).
4. Ligand-receptor interactions. Basic ways of signal transmission involving membrane receptors. Second messengers, their function. Ligands acting through membrane receptors.
5. Signal transmission involving intracellular receptors. Ligands acting through intracellular receptors.
6. Basic physiological effects of ligand-receptor interaction at a cellular level.
7. The concept of a stem cell, the role of microenvironment of a stem cell. The concept of signal molecules important for regulation of blood formation (cytokines, hormones, neurotransmitters and etc.).
8. Needs of the organism in indispensable nutrients, vitamins and trace elements for maintaining normal blood formation. A general concept of blood formation disturbances in deficiency of these substances.

9. Blood volume. The concept of the most important cellular receptors and mechanisms controlling the blood volume.

Self check:

1. What types of receptors do lipophilic and hydrophilic ligands bind with?
2. What substances are classic second messengers? What substances play a role of the first messengers?
3. What enzymes are activated by second messengers cAMP, cGMP and diacylglycerol?
4. What function does the second messenger inositol triphosphate (IP_3) perform?
5. Why do the effects of thyroid and corticoid hormones develop slowly as compared to the effects of protein and peptide hormones?

PRACTICAL WORKS

Work 2.1. STUDYING THE RECEPTOR MECHANISM OF THE EFFECT OF ADRENALIN ON THE HEART RATE

The work is accomplished using the program "**PHYSIOL 2**".

Fill in the table and make a conclusion regarding the receptor mechanism of the effect of adrenalin on HR having compared its effect during the action of the antagonist of β-adrenoreceptors propranolol with the initial effect.

	Effects	**Heart rate**
Rat 1	Initial value	
	Injection of adrenalin, 5 μg/kg	
Rat 2	Initial value	
	Injection of propranolol, 100 μg/kg	
	Injection of adrenalin, 5 μg/kg	
CONCLUSION: Adrenalin increases heart rate by stimulating _____ (α- or β-) adrenoreceptors. They are located on cell membranes (in particular, of myocardial cells) and are attributed to the _____ family of membrane receptors. The second messenger of adrenalin action on the heart is _____.		

Work 2.2. STUDYING REGULATION MECHANISMS OF HEMOPOESIS AND BLOOD VOLUME ON SLIDES AND DIAGRAMS; STUDYING THE NEEDS IN VITAMINS, TRACE ELEMENTS AND INDISPENSABLE COMPONENTS OF FOOD FOR NORMAL HEMOPOESIS (is done independently)

1. Fill in the blanks in answers to questions on the most important signal mechanisms controlling the blood volume in the organism.

_____ receptors response to a decrease of the blood volume. _____ receptors of _____ cells response to changes of the osmotic blood pressure. The activity increase of these receptors in case of _____ (↓ or ↑) of circulating blood volume and _____ (↓ or ↑) of osmotic pressure stimulates the formation and secretion of _____ hormone interacting with _____ receptors of the _____ cells and causing _____ (↓ or ↑) water reabsorption.

2. Fill in tables 2 and 3.

Table 2

Daily need in vitamins

Name	Daily norm	Function
Vitamin B_2 (riboflavin)		For normal oxidation-reduction reactions. In its deficiency anemia of a hyporegenerative type may develop.
Vitamin B_6 (pyridoxine)		For heme formation in red blood cells. In its deficiency anemia develops due to the abnormality of hemoglobin formation.
Vitamin B_9 (folic acid)		For DNA synthesis in bone marrow cells; it supplies one of nucleotides. In its deficiency acceleration of red blood cells destruction and anemia development are noted.
Vitamin B_{12} (cyanocobalamin)		For synthesis of nucleoproteins, maturation and division of cells. In deficiency of this vitamin in bone marrow megaloblasts are formed — large slowly maturating cells; short-living large red blood cells (megalocytes) are formed of them. Due to a retarded transition of red blood cells into the blood and their fast destruction vitamin B_{12} dependent anemia develops.
VitaminC		For normal erythropoesis at its basic stages. It promotes iron absorption from the gastrointestinal tract, its mobilization from the depot; metabolism of folic acid.
Витамин Е (α-tocopherol)		Jointly with selenium protects cell membranes from the action of peroxidation products. In its deficiency the probability of red blood cells hemolysis increases.
Vitamin PP (nicotinic acid)		Protects red blood cell membrane and hemoglobin from oxidation. Is contained in NAD and NADP.

Table 3

Daily need in trace elements

Name	Daily norm	Purpose
Iron		To form hemo- and myoglobin; enzymes in an electron transport chain in mitochondria; DNA synthesis; cell division; efficiency of detoxification mechanisms involving cytochrome P450.
Cobalt		To synthesize hemoglobin; stimulates iron utilization. To stimulate synthesis and excretion of erythropoietin in kidneys. In cobalt insufficiency anemia develops.

Ending of the table 3

Name	Daily norm	Purpose
Copper		To absorb iron in the gastrointestinal tract, mobilization of its reserves from the liver and reticular cells.
Zinc		To provide functions of enzyme carbonic anhydrase. In zinc insufficiency leucopenia develops.
Selenium		To protect cell membranes (including blood cells) from the action of peroxidation products and to prevent red blood cells hemolysis; it is contained in enzymes metabolizing thyroid hormones.

Lesson 3. PHYSIOLOGICAL FUNCTIONS OF RED BLOOD CELLS AND PLATELETS. ERYTHROPOESIS, THROMBOCYTOPOESIS. HEMOSTASIS

Basic questions:

1. Measures to prevent infection while working with blood and other biological fluids.
2. Red blood cells (erythrocytes). Peculiarities of the structure and properties of red blood cells providing their functioning. Methods of red blood cells count. Erythrocytosis and erythrocytopenia. Reticulocytes. The red blood cells distribution curve.
3. Hemoglobin. Peculiarities of the structure and properties of hemoglobin providing its functioning. Types of hemoglobin. Normal hemoglobin amount, evaluation methods.
4. Color index and red blood cells indices (MCH, MCHC, MCV, RDV), their calculation. Its significance in diagnosing anemias.
5. Erythropoesis and erythrocyte destruction. Red blood cells destruction products.
6. Neurohumoral mechanisms of erythropoesis regulation. The origin, role and application of erythropoietin in clinical practice.
7. Erythrocyte sedimentation rate (ESR), main factors affecting it, and methods of determination. Diagnostic significance of ESR.
8. Platelets, their count, structure and functions. Count methods. Thrombocytosis and thrombocytopenia. Thrombocytopoesis and its regulation.
9. The concept of the hemostasis system and its mechanisms. Primary (vascular-thrombocyte) and secondary (plasma-coagulation) hemostasis: significance, evaluation methods. Concept of anticoagulants.

Self check:

1. What is the main factor that determines red blood cells count?
2. Why the red blood cells count and hemoglobin content is higher in men than in women?

3. Proceeding from red blood cells life span and red blood cells count calculate a daily amount of formed and destroyed red blood cells in the organism.

4. Why are there oxygen carriers necessary in the blood if oxygen is consumed from the blood in its freely soluble form?

5. What does the color index of blood characterize, what is it calculated for?

6. What common cause may explain an increase of erythropoesis intensity in blood loss, massive hemolysis, respiration at low atmospheric pressure?

7. What trace elements and vitamins are most important for erythropoesis?

8. Which of the listed factors and laboratory samples (bandage test, prothrombin time, bleeding time, fibrinogen content, platelets count) characterize the primary hemostasis and which ones — the secondary hemostasis?

PRACTICAL WORKS

Work 3.1. METHODS OF TAKING CAPILLARY BLOOD (demonstration). MEASURES TO PREVENT INFECTION

Total clinical blood test is one of the most common laboratory examinations. Capillary blood is often used for this purpose.

Working with blood one should remember that blood can be virulent (HIV, hepatitis, etc.) and doctors and laboratory assistants performing serological and clinical tests are at risk of getting infected. That is why while making blood tests one should follow orders of the Health Ministry of the Republic of Belarus № 66 of 2.04.1993 and № 351 of 16.12.1998 on prophylaxis of viral hepatitis and AIDS in medical workers engaged in taking and analyzing blood.

While performing laboratory tests of the blood and other biological fluids one should use individual protective means: a medical gown and rubber gloves, spectacles, a mask (or a shield).

Any injury of the skin, mucous membranes, getting blood or other biological fluid of the patient there should be qualified as a possible contact with the material containing HIV or other infected agent.

If the contact with blood or other biological fluid was associated with integument lesions (puncture, cut) the victim should:

– quickly take off the gloves with the working surface inside;
– squeeze out some blood from the wound immediately;
– rinse the injured site with one of disinfectors (70 % alcohol, 5 % iodine in cuts, 3 % peroxide solution in punctures, etc.);
– wash the hands with soap under running water and then rinse with alcohol;
– apply a plaster onto the wound.

In case of contamination with blood or other biological fluid without cutaneous lesions:

– rinse the skin with alcohol or other disinfectors if it is absent;

– wash the contaminated site with water and soap and rinse it with alcohol again.

When biological material has got on mucous membranes of:

– the oral cavity: rinse the mouth with 70 % alcohol;

– the nasal cavity: drop in 30 % solution of albucid from a tube-dropper;

– eyes: wash with water (with clean hands), drop in 30 % solution of albucid from a tube-dropper. In case 30 % solution of albucid is absent one can use 0,05 % solution of potassium permanganate for rinsing mucous membranes of the nose and eyes.

When biomaterial gets on the gown or clothes, this site should be immediately treated with one of disinfectors.

Materials and equipment: scarificators in sterilizers, cotton wool, alcohol, iodine, rubber gloves, masks, 3 % solution of chloramines.

Accomplishment. Taking capillary blood from the patient should be done as follows:

1. The patient should sit opposite the doctor, the patient's hand (better non-working) should be on the table.

2. Taking blood is done from the 4^{th} finger, as its synovial sheath is isolated preventing the spread of an inflammatory process to the wrist in case of infecting the site of puncture.

3. The finger skin is disinfected with alcohol.

4. The scarificator is taken from the sterilizer by the middle with pincers, then with the hand by the end opposite to a puncturing one. The scarificator point should be kept upward to prevent a water drop getting to a cutting edge.

5. A skin puncture is done in the central point of the finger-cushion, the scarificator being thrust to a full depth of a cutting surface.

6. The first blood drop is wiped away with dry cotton wool (to remove tissue fluid), the finger is carefully wiped out (the skin should be dry).

7. The next blood drop should have a convex meniscus and not spread about the finger, this drop and the next ones are taken for analysis.

8. Having taken the blood the puncture site is treated with alcohol or iodine.

Answer to the questions:

Why isn't the first blood drop recommended to be used for analysis:

_____

_____

Why is the blood usually taken from the 4^{th} finger of a non-working hand?

_____

_____

With safety provisions while performing practical works with blood and other biological fluids as well as with tissues has been acquainted and instructed _____

(signature)

Work 3.2. APPEARANCE OF RED BLOOD CELLS AND PLATELETES UNDER THE MICROSCOPE (demonstration)

Observe on the screen the shape, sizes, color and intercellular organelles of reticulocytes; those of plateletes.

PROTOCOL

A paler color of red blood cells in the center as compared to the periphery is due to their shape of _____.

The normal count of reticulocytes in the blood is _____% of the red blood count. An increase of reticulocytes in the blood reveals the _____ (↑ or ↓) erythropoesis.

The cells forming platelets are called _____.

Work 3.3. RED BLOOD CELLS COUNT IN THE COUNTING CHAMBER UNDER THE MICROSCOPE (demonstration)

To enhance prevention of infecting with HIV, viral hepatitis and other infections transmitted through blood the work is conducted as demonstration.

To count blood cells the blood is diluted in special mixers to create an optimal concentration of cells for their count. On counting red blood cells the hypotonic **3 % solution of NaCl** is used as a diluter where red blood cells get contracted.

The counting chamber is a thick glass, the middle part of which has **Goryaev's net**. This middle part of the glass is 0.1 mm lower than the lateral areas. In placing the cover glass the space of 0.1 mm is formed over the net.

Goryaev's net of the counting chamber is divided into small squares that in turn are divided into 16 small squares. A side of a small square is 1/20 mm, the area — 1/20 × 1/20 = 1/400 mm^2; thus the space volume over a small square is 1/400 × 1/10 = 1/4000 mm^3.

The red blood cells count is done by a fragment photograph of the counting chamber with red blood cells mixture. The red blood cells count is done in **5 large squares** located along the diagonal. The cells are counted according to **Egorov's rule**: this square includes all red blood cells inside as well as on its *left* and *upper* border.

Let's presume that 5 large squares (80 small squares) are found to contain the total count of red blood cells equal to E. The red blood cells count in the space volume (1/4000 mm^3) over one small square will be E/80. To evaluate it for 1 mm^3 of blood, E/80 is multiplied by 4000 and again by 200 as the blood was diluted 200-fold. To evaluate the red blood cells count in 1l of blood, the received red blood cells count in 1 mcl (1 $мм^3$) is multiplied by 10^6.

Directions for recording the protocol:

Calculate the total red blood cells count in 5 large squares located along the diagonal of the photograph. Calculate the content of red blood cells in 1 liter of blood by the formula. Evaluate the received result versus the norm.

PROTOCOL

1. Red blood cells count in large squares: in 1 __; in 2 __; in 3 __; in 4 __; in 5 __.
The total red blood cells count (E) in 5 large squares is equal to _____ cells.

2. The red blood cells count in 1 liter of blood (X) is calculated by the formula:

$$X = \frac{E \times 4000 \times 200}{80} \times 10^6 = E \times 10^{10}. \qquad X = \_\_\_\_\_ \times 10^{12} / l.$$

3. Conclusion:

Work 3.4. EVALUATION OF THE AMOUNT OF HEMOGLOBIN BY SALI'S METHOD (demonstration)

The hemoglobin content in the blood of a healthy person is: in men — 130–170 g/l; in women — 120–150 g/l.

The blood hemoglobin content is evaluated by measuring the amount of the reaction product formed in the interaction of hemoglobin and various reagents. Such measurement is conducted by a spectrophotometric or photoelectrocolorimetric method.

The simplest method is a colorimetric method, based on the formation of muriatic hematin (hematin chloride) — the substance giving the solution a brown color, when hemoglobin interacts with hydrochloric acid. For this purpose Sali's hemometer is used. It consists of a stand, the back wall of which is made of frosted glass, and 3 test-tubes. The center test-tube is graduated; it is designed for performing tests, while the lateral ones, soldered, contain the standard solution of hematin chloride. The blood used for preparing the standard contains 16,7 g% or 167 g/l of hemoglobin.

To evaluate the content of hemoglobin **0.1 N solution of HCl** is added to the central test-tube, then 20 mcl of blood taken from the finger. The content of the test-tube is stirred and it is placed to the stand for 5–10 minutes. During this time ***muriatic hematin*** will be formed and the solution will become dark-brown. Then distilled water is added to the test-tube till the solution color becomes as light-brown as the color of the standard in both lateral test-tubes (the solution is stirred with a glass stick on every addition of distilled water).

The hemoglobin content is determined by the graduation on the test-tube. The digits at the level of a lower solution meniscus show the hemoglobin content in grams per 100 ml of blood (g%). For example, the tested blood contains 15,5 g% of hemoglobin, so the hemoglobin content in 1 liter is 155 g/l.

Directions for recording the protocol:

Draw Sali's hemometer. Calculate the content of hemoglobin in the tested blood. Evaluate the received result versus the norm.

1. Sali's hemometer	**PROTOCOL** **2. Hemoglobin content in tested blood = _____g/%, or ____g/l.** **3. Conclusion: hemoglobin content in tested blood** **_____** **(normal, increased or decreased)**

Work 3.5. EVALUATION OF A COLOR INDEX

To evaluate an ***absolute*** content of hemoglobin in every erythrocyte the MCH (Mean Corpuscular Hemoglobin) index is used. It is approximately equal to 30 pg (normal range 25,4–34,6). Its value is obtained by division of the hemoglobin content in 1 liter by red blood cells count in 1 liter.

The **color index** (CI) is a ***relative*** value of hemoglobin content in red blood cells. CI is calculated by division of the hemoglobin content in g/l (Hb) by the number of the first three digits of red blood cells amount in 1 liter of blood with multiplication of the received value by 3. The calculation can be presented by the following formula: $\mathrm{CI} = \frac{3 \times Hb(g/l)}{\text{Red Blood Cells} \times 10^{-10}}$.

For example, the blood hemoglobin content is 152 g/l, the erythrocyte count is $4{,}56 \times 10^{12}$/l; then CI is equal to $3 \times 152 : 456 = 1.00$.

CI of a healthy person is **0,8–1,05** (**normochromia**). In decreased hemoglobin content in red blood cells CI **is less than 0,8** (**hypochromia** that usually occurs in iron deficiency in the organism), in increased — **over 1,05** (**hyperchromia** which is noted in insufficiency of vitamin B_{12} and/or folic acid in the organism).

Directions for recording the Protocol:

1. Calculate CI of the tested blood using the data of works 3.3 and 3.4.
2. Evaluate the obtained result (normo-, hypo- or hyperchromia).

PROTOCOL

1. Hemoglobin content in tested blood is equal to _____ g/l.
Red blood cells count in tested blood is equal to _____ × 10^{12}/l.
CI = 3 × (_____ : _____) = _____

2. Conclusion: _____.
(normo-, hypo- or hyperchromia)

Work 3.6. EVALUATION AND PHYSIOLOGICAL ASSESSMENT OF PRIMARY HEMOSTASIS INDICES

The term *hemostasis* means a complex of reactions to stop bleeding in vascular injuries and maintenance of blood liquid state in vessels. Since bleeding and thrombus formation in vessels of various sizes have different courses, there are two basic mechanisms of hemostasis:

1) *microcirculatory,* **vascular-thrombocyte** or **primary** mechanism of hemostasis. It starts reactions of hemostasis in capillaries, venous and arterial vessels up to 200 μm in diameter. This process involves platelets and endothelium of vessels. Almost 80 % of bleedings and 95 % of thrombus formations are associated with the impairment of this mechanism.

2) *macrocirculatory,* **hemocoagulatory** or **secondary** mechanism starts as a rule on the basis of the primary one and follows it. It is accomplished by the **blood coagulation** system. Due to the secondary hemostasis a red thrombus is formed, it consists mainly of fibrin and blood cells. It provides a final stop to bleeding from injured macrovessels (over 200 μm in diameter).

Primary (vascular-thrombocyte, microcirculatory) hemostasis means fast (within several minutes) formation of **platelet plug** at the site of vessel injury what is very important for stopping bleeding **from small vessels with low blood pressure**. The components of the primary hemostasis are vascular wall, platelets and their special factors. The primary hemostasis stages are:

1) **spasm of vessels;**

2) **platelets adhesion** (involving Willebrand's factor), their activation and secretion of platelets granules (involving thromboxan A_2 through a phospholipase mechanism), as well as platelets **aggregation** (at first it is reversible and then irreversible due to the action of thrombin and fibrin traces) with the formation of a **platelets plug**;

3) **retraction** (constriction and consolidation) of the **platelets plug**. The most important screening indices characterizing the primary hemostasis are: bandage test, platelets amount, bleeding time.

A. Bandage test (evaluation of a vascular component of the primary hemostasis)

The method is based on the fact that dosed mechanic action (pressure) on skin capillaries of a healthy person does not cause any substantial changes. When the normal state of a capillary wall is impaired, increased vascular fragility occurs and after mechanic action at the site of the pressure multiple petechiae or hemorrhage appear manifesting the impairment of a vascular component of hemostasis.

Materials and equipment: a tonometer, a stop-watch, a circle of dense card-board 2,5 cm in diameter, a pen or a pencil.

Accomplishment. The test is done on the forearm. A circle 2,5 cm in diameter is outlined 1,5–2,0 cm from the ulnar pit. To do a test one should check if there are any hemorrhages in this circle (and their number if there are any). The blood pressure cuff is applied and the pressure of 80 mm Hg is created. The pressure is sustained at this level for 5 minutes pumping the air if necessary. The arm of the examined person should be relaxed and lie freely. All petechiae that appeared in the outlined circle are counted in 10–15 minutes (taking into consideration those present before). In healthy persons petechiae are not formed or their number does not exceed 10 in the circle and their sizes are not more than 1 mm in diameter (negative bandage test). An increase of the petechiae number over 10 and petechiae sizes over 1 mm in diameter or the presence of a hemorrhage (positive bandage test) evidence the following: wall defects of microvessels due to endocrine changes (menstrual period); infectious-toxic effect (sepsis etc.); insufficiency of vitamin C; the impairment of Willebrand's factor formation, etc.; the presence of thrombocytopenia or thrombocytopathia etc.

PROTOCOL

1. Petechiae number in the circle before the test_____(no, 1, 2, 3,…)
Petechiae number in the circle in 10-15 minutes after the test _____ (no, 1, 2, 3,…).
If petechiae are present, indicate their diameter _____ (below 1 mm or over 1 mm).
2. Conclusion: bandage test _____.
(negative or positive)

B. Time of bleeding by Duke — *demonstration*.

The time of bleeding evaluated by Duke's method gives a general idea, if the primary hemostasis function is normal (and first of all it allows evaluating the function of platelets, their ability for adhesion or aggregation). An increase of bleeding time evidences the impairment of the primary hemostasis due to thrombocytopenias, thrombocytopathias, vascular wall injuries or a combination of these factors. Reducing the bleeding time evidences only an enhanced spastic ability of peripheral vessels.

Materials and methods: a stop-watch, sterile filter paper, scarificators in sterilizers, cotton wool, alcohol, iodine, rubber gloves, masks, 3 % solution of chloramine.

Accomplishment. Puncture the 4th finger-cushion to the depth of 3 mm. If this is done properly, the blood is discharged spontaneously without pressure. Having made a puncture, switch on the stop-watch. Touch the first appearing blood drop with a strip of sterile filter paper that absorbs the blood. Then take off further blood drops with sterile filter paper every 30 sec. Avoid touching the skin with filter paper, as it stimulates premature stop of bleeding. Continue till blood traces are absent on the filter paper. In norm the bleeding time by **Duke** is **2–4 min**.

PROTOCOL

1. Bleeding time is _____ min _____ sec.
2. Conclusion: Bleeding time _____.
(norm, increased, reduced)

Lesson 4. PHYSIOLOGICAL FUNCTIONS OF WHITE BLOOD CELLS. LEUKOPOESIS. NON-SPECIFIC AND SPECIFIC RESISTANCE OF THE ORGANISM. PHYSIOLOGIC ASSESSMENT OF THE BLOOD TEST

Basic questions:

1. White blood cells, their types. Leukogram (leucocyte formula).
2. Granulocytes, their types. Functions and properties of granular leukocytes. Granulocytopoesis.
3. Monocytes and tissue macrophages. Monocytopoesis. Peculiarities of the structure and properties providing their functioning. Mechanisms of phagocytosis. Concept of the complement system.
4. Concept of T- and B-lymphocytes, peculiarities of their maturation and functions. Lymphocytopoesis. Null and plasmatic cells.
5. Concept of cellular and humoral immunity; immune response. Classes and functions of immunoglobulines.
6. Basic indices included into the total blood test. Physiological assessment of the total blood test results. Diagnostic significance of the total blood test.
7. The concept of age associated norms of total blood test basic indices.

Self check:

1. The count of what blood cells (erythrocytes or leukocytes) is maintained at a more constant level in blood and why?
2. What indices of the total blood test characterize the respiratory function of the blood?
3. What is a leukogram (leukocyte formula)? Normal values of the leukocyte formula of a healthy adult person.
4. What is the leukocyte formula's *shift to the left*?
5. What is the difference between physiologic and reactive leukocytosis? Causes of physiologic and reactive leukocytosis.
6. Make a conclusion for the blood test of a woman of 20 years: red blood cells — 5×10^{12}/l; hemoglobin — 160 g/l; color index — *calculate*; white blood cells — 11×10^{9}/l (basophils — 1 %; eosinophils — 1 %; young neutrophils — 2%; band neutrophils — 9 %; segmented neutrophils — 58 %; lymphocytes — 20 %; monocytes — 9 %); ESR — 30 mm/h.

7. Make a conclusion for the blood test of a woman of 35 years: red blood cells — 4,2 × 10^{12}/l; hemoglobin — 100 g/l; color index — *calculate*; white blood cells — 4 × 10^9/l (basophils — 1 %; eosinophils — 5 %; young neutrophils — 0%; band neutrophils — 1 %; segmented neutrophils — 64 %; lymphocytes — 20 %; monocytes — 9 %); ESR — 5 mm/h.

8. Make a conclusion for the blood test of a man of 40 years: red blood cells — 2,9 × 10^{12}/l; hemoglobin — 90 g/l; color index — *calculate*; white blood cells — 5 × 10^9/l; platelets — 80 × 10^9/l; ESR — 10 mm/h.

PRACTICAL WORKS

Work 4.1. WHITE BLOOD CELLS COUNT IN THE COUNTING CHAMBER UNDER THE MICROSCOPE (demonstration)

The white blood cells content in the blood in norm is (4–9) × 10^9/l.

Materials and equipment: a mixer for white blood cells, a counting chamber, 5 % solution of acetic acid, scarificators in sterilizers, cotton wool, alcohol, iodine, rubber gloves, masks, 3 % solution of chloramine.

For white blood cells counting blood is diluted in special mixers. The blood is applied into the mixer to mark 0,5 and then 5 % solution of acetic acid stained with methylene blue to mark 11 (20-fold dilution of the blood) is added. The acetic acid hemolyzes plasmatic membranes of all blood cells, while methylene blue stains nuclei of white blood cells. The mixer is shaken for 1–2 min. The chamber is filled in from the mixer ampoule. Count the white blood cells (white blood cells nuclei) in small magnification in 25 large squares.

Directions for recording the Protocol:

1. Draw a mixer for leukocytes.
2. Calculate the total count of leukocytes in 25 large squares.
3. Calculate the leukocyte count in 1l by the formula.
4. Assess the obtained result versus the norm.

1. Fig. Mixer for leukocytes	**PROTOCOL** **2. White blood cells count (WBC) in 25 large squares is equal to _____cells.** **3. Leukocyte count (X) in 1 l of blood is calculated by the formula:** $$X = \frac{L \times 4000 \times 20}{400} \times 10^6 = 2L \times 10^8 \text{ /l}$$ $$X = \_\_\_\_\_ \times 10^9 \text{ /l}$$ **4. Conclusion:** _____.

Work 4.2. PERCENTAGE CALCULATION OF DIFFERENT TYPES OF WHITE BLOOD CELLS IN A BLOOD SMEAR (LEUKOCYTE FORMULA)

Accomplishment. Calculate the proportion of various types of white blood cells (per 100 cells) in a stained blood smear by its photograph presented on the monitor screen on the basis of the following features: size of cells, shape of the nucleus, character of the nucleus and cytoplasm staining, presence or absence of granules in the cytoplasm and type of their staining.

Directions for recording the Protocol:

1. Fill in the table with obtained count data of various forms of white blood cells (WBC).
2. Insert the data of % WBC of small sizes (W-SCR; % lymphocytes) and large sizes (W-LCR; % other WBC) into the table.
3. Assess the obtained result versus the norm.

PROTOCOL

Content of white blood cells of various types in the blood of an adult

Factors	Total WBC	Basophils	Eosino-phils	All types of Neutrophils	Monocytes	Lympho-cytes
Per 1 ml	4000–9000	0–90	40–350	2000–5800	80–600	1200–3500
%	100	0–1	1–5	46–76	2–9	18–40
In a blood smear	100					

CONCLUSION. Leukocyte formula _____ (in norm; baso-, eosino-, neutrophilia (or –penia); lymphocytosis; monocytopenia, lymphocytopenia).

Work 4.3. ESR EVALUATION BY PANCHENKOV'S METHOD (demonstration)

Unless the blood is not coagulated, red blood cells sediment to the test-tube bottom as their specific weight (1,096 g/ml) is higher than that of plasma (1,027 g/ml). Normal values of **ESR** in healthy people are: **in men 1–10 mm/h; in women 2–15 mm/h**. The most important factors affecting ESR are the proportion of various kinds of blood plasma proteins as well as red blood cells content. An increase of large plasma proteins, globulins and fibrinogen, and/or decrease of albumins in plasma as well as decrease of red blood cells is associated with an increase of ESR. An increase of red blood cells in the blood as well as an increase of albumin and bile pigments results in a decrease of ESR. A higher value of the ESR norm in women is associated with a less red blood cells content.

Under physiological conditions an increased ESR is noted during pregnancy, in eating dry food and fasting, after vaccination (due to an increase of globulins and fibrinogens in plasma). Delayed ESR can be noted in blood thickening due to enhanced perspiration (for example, in high external temperature)

or enhanced formation and content of erythrocytes in blood (for example, in Alpine residents and mountaineers).

Many diseases are accompanied by ESR changes. Thus, an increased ESR is noted in the majority of infectious, inflammatory and autoimmune diseases (due to hyperglobulinemia and/or hyperfibrinogenemia), kidney diseases with nephrotic syndrome (due to a loss of albumins with urine and development of hypoalbuminemia), malignant tumors and hemoblastoses (due to an increased content of large-molecular proteins in the blood and/or depression of erythropoesis and development of anemia), endocrine diseases (thyrotoxicosis and diabetes mellitus) and anemia of different genesis. A decreased ESR, up to a complete stop of sedimentation, occurs in erythrocytosis.

Materials and equipment: Panchenkov's device, a watch glass, scarificators in sterilizers, rubber gloves, masks, cotton wool, alcohol, iodine, 3 % solution of chloramine, 5 % solution of sodium citrate.

Accomplishment. Panchenkov's device is used to evaluate ESR. A pipette (capillary) of the device is washed with 5 % solution of sodium citrate. The taken blood is carefully stirred with sodium citrate on the watch glass. The mixture is drawn into the pipette to mark 0. The pipette is placed into the stand for 1 hour in a strictly vertical position. The result is assessed by a decrease of a red column of red blood cells in the capillary from point 0 (in millimeters).

While evaluating ESR this should be followed strictly: the proportion of sodium citrate and blood 1:4; verticality of the pipette in the stand; the temperature in the room — 18–22 ºC (in lower temperature ESR decreases and in higher — increases).

Directions for recording the Protocol:

Fill in the protocol. Assess the obtained result versus the norm.

PROTOCOL

1. **ESR of tested blood = _____ mm/h.**
2. **ESR normal values: in men _____ mm/h; in women _____ mm/h;**
3. **While evaluating ESR the blood is mixed with 5% solution of Na citrate with the aim _____.**
4. **Conclusion: ESR is _____(in norm, increased or decreased)**

Work 4.4. PHYSIOLOGICAL ASSESSMENT OF THE TOTAL BLOOD TEST

Total clinical blood test is one of the most common laboratory examinations. It includes evaluation of the following indices:

1) hemoglobin content (g/l);
2) red blood cells count per 1 liter of blood;
3) calculation of color index;

4) white blood cells count per 1 liter of blood;
5) leukocyte formula;
6) erythrocyte sedimentation rate (ESR).

Additional examinations include: evaluation of platelets in 1 liter of blood, count of reticulocyte percentage and some other indices. Modern hematologic analyzers allow additional evaluation of: the hematocrit, mean volumes of red blood cells, white blood cells and platelets; mean hemoglobin content in red blood cell, etc.

Using total blood test indices the doctor may assess the respiratory function of the blood (by the hemoglobin content, red blood cells count); erythropoesis intensity (by the reticulocyte count); suggest the presence of infectious, inflammatory and autoimmune processes in the organism (by the white blood cells count, shift of the leukocyte formula to the left and ESR changes) etc.

Directions for recording the Protocol:

Fill in the table of the total blood test indices with the results of works 3.3, 3.4, 3.5, 4.2, 4.3. Make a conclusion about the obtained results.

PROTOCOL

Factor	Norm	Obtained result
1. Red Blood Cells (RBC)	(**3,9–5,1**) × 10^{12}/l, men (**3,7–4,9**) × 10^{12}/l, women	
2. Hemoglobin (Hb)	**130–170** g/l, men **120–150** g/l, women	
3.Color index	**0,8–1,05**	
4. ESR	**1–10** mm/h, men **2–15** mm/h, women	
5. White Blood Cells (WBC)	(**4–9**) × 10^{9}/l	
6.Leukocyte formula	Per 100 cells (100 %)	
6.1. Basophils	**0–1 %**	
6.2. Eosinophils	**1–5 %**	
6.3. Neutrophils: myelocytes young neutrophils band neutrophils segmentonuclear	 **0 %** **0–1 %** **1–5 %** **46–68 %**	
6.4. Monocytes	**2–9 %**	
6.5. Lymphocytes	**18–40 %**	

Additional factors:

Shift index*	**0,05–0,1**	
Reticulocytes	**0,5–1,2 %**	
Platelets	(**150–450**) × 10^{9}/l	

Shift index (***regeneration index***) is the ratio of the sum of myelocytes, young and band neutrophils to segmentonuclear cells

Conclusion:

Lesson 5. BLOOD GROUPS. ABO SYSTEM. RHESUS (Rh) SYSTEM. PHYSIOLOGICAL BASES OF BLOOD MATCHING FOR THE TRANSFUSION

Basic questions:

1. Antigens of blood cells. Basic systems of red blood cells antigens: ABO and Rh system.
2. Blood groups in the ABO system. Antigens (agglutinogens) and antibodies (agglutinins) of blood groups.
3. Incompatibility reactions of blood groups in improper transfusion. Consequences of mismatched blood transfusion in ABO system.
4. Blood typing in the ABO system. Standard serums. Monoclonal serums.
5. The Rh system of antigens (Rh). Consequences of mismatched blood transfusion in the Rhesus system.
6. Other systems of blood groups. The system of HLA leukocyte antigens, its significance.
7. Basic principles of blood matching. Risk factors for the recipient. Prevention of infecting the recipient during transfusion of donor blood or its preparations.
8. Donor blood and its preparations. Blood substitutes, their requirements.

Self check:

1. What are the main differences between the ABO and Rh system?
2. Determine the blood group by the results of blood typing:

Standard serums:	I	II	III
Presence of agglutination:	+	+	+

3. Determine the blood group by the results of blood typing:

Monoclonal serums:	Anti-A	Anti-B
Presence of agglutination:	–	+

4. What are the reasons of rhesus incompatibility of the blood?
5. What consequences may result from mismatched blood transfusion in ABO system?
6. What is the difference between the methods of ABO system blood group typing using standard serums and monoclonal serums?

PRACTICAL WORKS

Work 5.1. BLOOD TYPING IN THE ABO SYSTEM USING STANDARD SERUMS (demonstration)

The ABO system blood group is determined by the presence of agglutinogens in red blood cells which is revealed by the hemagglutination reaction using

standard serums. The interaction between red blood cells antigens of the tested blood and a corresponding antibodies (agglutinins) of the standard serum underlies the bases of such reaction. As antibodies contained in standard serums are known, red blood cells antigens of the tested blood and consequently the blood group in the ABO system are determined by the presence or absence of agglutination.

Materials and equipment: standard serums of 0αβ(I), Aβ(II), Bα(III) and AB0(IV) groups of two various series; pipettes for them; special plate; glass sticks; isotonic (0,9 %) solution of NaCl; scarificators in sterilizers; cotton wool; alcohol; iodine; rubber gloves; masks; 3 % chloramine solution.

Accomplishment. Blood typing should be done in the room with sufficient illumination and at the temperature of 15–25 ºC.

Determination is done on special plate. 0,1 ml (1 large drop) of every standard serum of two series is applied to appropriate sockets of the plate. The blood for the test is taken from the finger in compliance with all necessary rules. The first blood drop is taken off with a gauze ball. Then the blood is added with glass sticks (5–10-fold less than the serum) to every drop of the serum and carefully stirred. The obtained mixture is mixed again by rocking the plate. The reaction is observed during 5 minutes. Usually the agglutination reaction starts during the first 10–30 seconds, however agglutination may be late, e. g. with red blood cells of A_2β(II) group. As agglutination occurs, but not earlier than in 3 minutes, per 1 drop of NaCl isotonic solution are added into those drops, where agglutination has already occurred, and observation is continued followed by rocking the plate for 5 minutes, and only then the final result is assessed.

The reaction in every drop may be either positive or negative. In a positive reaction there appear small red granules (agglutinates) seen with naked eye in the mixture; they consist of glued red blood cells. Step-by-step they cluster and form larger granules or flakes of irregular shape. Meanwhile the serum becomes completely or partially decolorized. In case of a negative reaction the content of drops stays regularly stained in red, and agglutinates are not revealed there. The results of the reaction in both serum series should be identical.

Four different combinations of the reaction are possible:

1) Agglutinins of standard serums of all 3 groups did not cause agglutination, and all drops stayed regularly stained in red. In this case the blood belonged to group 0αβ(I) (**type O**).

2) Agglutinins of standard serums of groups 0αβ (I) and Bα (III) caused a positive reaction of agglutination, and serums of group Aβ (II) — a negative one. The tested blood belongs to group Aβ (II) (**type A**).

3) Agglutinins of standard serums of groups 0αβ (I) и Aβ (II) caused a positive reaction of agglutination, while serums of group Bα (III) — a negative one. The tested blood belongs to group Bα (III) (**type B**).

4) Agglutinins of standard serums of all three groups caused a positive reaction of agglutination. The tested blood belongs to AB0(IV) group (**type AB**). In this case, before giving such a conclusion, to exclude non-specific agglutination, it is necessary to do an additional control test with the standard serum of AB0(IV) group by the same technique. The absence of agglutination in this test allows to consider the former reactions specific and refer the tested blood to AB0(IV) group. The presence of agglutination with the serum of AB0(IV) group reveals non-specific agglutination. In this case the test should be repeated with washed red blood cells.

Revealing other combinations of agglutination reactions testifies to improper blood typing.

Errors while determining blood groups are possible in situations, when agglutination is not revealed or a false agglutination occurs.

The absence of agglutination may be due to the following causes: 1) retardation of this reaction at high temperature of the environment >25 ºC (blood typing should be done only at the room temperature of 15–25 ºC); 2) addition of an excess of tested blood to standard serums resulting in a decrease of agglutinin titer in their content (remember that a drop of the applied blood should be 5–10 times less than that of the serum); 3) weak activity of the standard serum or low agglutinin ability of red blood cells.

Revealing false agglutination in its real absence may be due to drying of a serum drop and formation of red blood cells "monetary columns" (nummiform red cells aggregation) or appearance of cold agglutination at the temperature less than 15 ºC. The addition of a drop of isotonic NaCl solution to the tested mixture of serum and blood and performing the test at the temperature higher than 15 ºC allow to avoid the mentioned errors.

N o t e. In case of a doubtful or unclear result during the first determination of blood group a repeated test of the blood group of the same blood with standard serums of other series should be done. If the results remain still unclear, the blood group should be determined by a cross-method using standard serums and standard red blood cells or monoclonal antibodies (see the supplement).

Directions for recording the Protocol:

1. Fill in tables 4 and 5. Indicate in table 5, when agglutination occurs (+) and when doesn't (-).
2. Draw a diagram of the ABO system blood typing for the blood tested during the lesson.
3. Make a conclusion, what is the ABO system type of the tested blood.

PROTOCOL

Table 4

Blood groups	Serum agglutinins	Red blood cells agglutinogens
0αβ (I)		
Aβ (II)		
Bα (III)		
AB_0 (IV)		

Table 5

Blood groups	Standard serums			
	0αβ (I)	Aβ (II)	Bα (III)	ABO (IV)
0αβ (I)				
Aβ (II)				
Bα (III)				
AB_0 (IV)				

2. Fig. Test diagram of ABO system blood typing

3. Conclusion:the tested blood is type _____ of ABO system, as its red blood cells _____ (contain/don't contain) agglutinogen(s) _____ (A, B).

Work 5.2. BLOOD TYPING IN RHESUS SYSTEM (demonstration)

Determination of rhesus system blood types uses the same principle as ABO system blood typing. The tested whole blood (or red blood cells suspension) is mixed with the universal anti-rhesus serum containing antibodies to a rhesus-antigen. In case agglutination occurs the blood is considered Rh-positive. The rhesus system, unlike ABO system, has no natural agglutinins, but they may appear in immunization of the organism with rhesus-incompatible blood.

Materials and equipment: a universal anti-rhesus reagent for the express-method; a pipette to it; a test-tube; 0,9 % solution of NaCl; scarificators in sterilizers; cotton wool; alcohol; iodine; rubber gloves, masks, 3 % chloramine solution.

Accomplishment. One drop of the universal anti-rhesus serum and one drop of the tested blood are applied to the bottom of the test-tube. The test-tube content is mixed by shaking up and then the tube is slowly bent almost to its horizontal position so that its content spreads about the walls — it makes the reaction more marked. As a rule, agglutination occurs within 1 minute, but to form a stable antigen-antibody complexes and clear agglutination and considering the possibility of retarded reaction in case of weak agglutination ability of red blood cells, the contact of blood with the reagent should be made by turning the test-tube in its horizontal position no less than 3 minutes. Then, to exclude non-specific red blood cells agglutination, 2–3 ml of NaCl isotonic solution are added into the test-tube and stirred, without shaking up, by 2–3-fold turning over the test-tube. The assessment is done visually.

Simultaneously with testing the whole blood a control test of standard rhesus-positive red blood cells of the same group or group I(0) in ABO system and standard rhesus-negative red blood cells of the same blood group in ABO system as the tested blood, is done.

Agglutination presence manifested by flakes of red blood cells on the background of the cleared up fluid indicates that the tested blood is rhesus-positive (Rh^+). Agglutination absence indicates that the tested blood is rhesus-negative (Rh^-).

The result is considered authentic after checking up the control samples, i. e. in agglutination with standard rhesus-positive red blood cells and agglutination absence with standard rhesus-negative red blood cells belonging to the same blood group in ABO system as the tested blood.

Directions for recording the Protocol:

1. Draw a test diagram of blood typing in Rhesus system.
2. Make a conclusion about Rhesus system blood type of the tested blood (Rh^+ or Rh^-).

1. Fig. Test diagram of rhesus system blood typing	**2. The tested blood is _____ (Rh^+ or Rh^-), as when it is mixed with the universal anti-rhesus reagent in the test-tube, agglutination _____ (is or is not observed)**

MONOCLONAL SERUMS:

APPLICATION OF MONOCLONAL ANTIBODIES IN BLOOD TYPING

At present ABO-typing reagents produced from the human or animal serum with antibodies to red blood cells agglutinogens are still often used. These antibodies are the result of a polyclonal immune response, i. e. they come from various clones of antibody-forming cells and are the mix of immunoglobulins of various classes. To get such serums a great amount of donor blood is needed. Besides, the titer of natural antibodies in the human blood is usually low, that is why produced serums have low activity and one has to use serums obtained from specially immunized people.

Antibody-producing technology based on the fusion of a malignant myeloma cell and an antibody-forming lymphocyte of mice, becomes more and more widespread. As a result of fusion a hybrid cell (hybridoma) is formed inheriting basic properties of its parents: immortality and the ability to constant

growth — from a tumor cell, and the ability to produce antibodies — from a B-lymphocyte.

Antibodies secreted by cells-descendants of such hybrids are monoclonal, i. e. they come from one cellular clone, belong to one class of immunoglobulins, are aimed at one antigen, are standard and able to grow both in culture and in the mouse's organism as an ascite tumor producing antibodies in high concentrations, up to some tens of grams per liter.

To obtain ABO-typing monoclonal reagents it is enough to make a washout of tissue culture or take some ascite fluid and dilute these fluids as the titer of antibodies in them is very large (often for dilution 0.3 M solution of NaCl is used). At present ABO monoclonal reagents are commercially produced in many countries.

The benefits of monoclonal reagents are their high activity, standardization, reliability of revealing appropriate antigens, absence of false-positive reactions that is due, first of all, to the absence of antibodies of other specificity. Monoclonal reagents are not products of human cells that it excludes the possibility of transmitting viruses of hepatitis and AIDS.

Two types of monoclonal reagents are necessary for blood typing — anti-A and anti-B that are produced by two different hybridomas and contain correspondingly α- and β-agglutinins.

Blood typing in the ABO system using monoclonal serums

Per one large drop of anti-A and anti-B reagents is applied on a special plate or a porcelain dish under corresponding signs "anti-A" and "anti-B". Next to reagent drops small drops of the tested blood are applied (proportion 10:1). The reagent is carefully mixed with the blood with glass sticks. Observation of the course of the reaction is done by rocking the plate for 1–2,5 minutes.

Agglutination with monoclonal reagents usually occurs within the first 3–5 sec. But the observation should be continued for 2,5 min due to a possibility of late agglutination with red blood cells containing weak types of antigens A and B. The assessment of agglutination results is presented in table 6.

Table 6

Blood group	Reaction of tested red blood cells with monoclonal reagents	
	anti-A	anti-B
0 (I)	–	–
A (II)	+	–
B (III)	–	+
AB (IV)	+	+

BLOOD SUBSTITUTING SOLUTIONS

Blood substituting solutions are preparations that being intravenously injected into the patient's organism substitute to some degree one or several blood functions. They are used for transfusion therapy of various pathologic states.

Classification of blood substituting solutions

The most important is the classification of blood substituting solutions by their functional properties. The basic therapeutic functions of blood substitutes are:

1) filling in the blood stream that provides restoration and maintaining of arterial blood pressure at a constant normal level after blood loss or a shock;
2) toxins elimination in case of poisoning with toxic substances;
3) supply of nutritious protein substances to the tissues of the organism.

A series of preparations are developed that can substitute at least one of blood functions. Correspondingly three main groups of blood substituting solutions are singled out:

– ***hemodynamic*** (anti-shock): polyglukin, rheopolyglukin, jellatinol are used for treating the blood loss, shock, in traumas, burns, operations for restoration of hemodynamics including microcirculation, for hemodilution (**1**st group);

– ***detoxication*** (hemodesis, polydesis, etc.) — for treating intoxications of various genesis, toxemias, burn and radiation diseases, toxic forms of dysentery, hemolytic disease of newborns, diseases of the liver and kidneys (**2**nd group);

– preparations for ***parenteral*** protein nutrition: protein hydrolyzates, hydrolyzin, aminopeptide, mixtures of amino acids, etc. used for treating protein insufficiency developing in various severe diseases and in post-operation period (**3**rd group).

Modern blood substituting solutions of directed action can substitute the plasma by their therapeutic properties, their efficiency being often even higher than that of plasma.

Similar to blood substituting solutions are regulators of water-saline exchange and acid-base state; ***osmodiuretic*** substances producing dehydration action as well as correcting the blood content (solutions of polyatomic alcohols: mannitol and sorbitol) (**4**th group).

One more group of blood substitutes are ***hemocorrectors*** modeling a respiratory function of the blood being gas carriers of the blood (**5**th group).

At present the solutions are being developed that combine various therapeutic properties of the blood. These are complex ***polyfunctional blood substitutes*** having an expanded range of action (**6**th group): solutions of hemodynamic and detoxication action, solutions of hemodynamic and hemopoetic action, solutions of hemodynamic and rheological action.

Basic requirements to blood substituting solutions:

1. Osmolarity, pH, viscosity and other physical and chemical properties must be close to blood plasma.

2. Blood substituting solutions must be completely eliminated from the organism without injury of the tissue and impairment of the function of organs, or be metabolized by enzyme systems of the organism.

3. Blood substituting solutions must not cause sensibilization of the organism in repeated injections.

4. Blood substituting solutions must not be toxic, pyrogenic, must tolerate sterilization, and be stable in storage.

Abbreviations used for hematologic factors

1. WBC (white blood cells) — total leukocyte number.
2. RBC (red blood cells) — erythrocyte number.
3. HGB (hemoglobin) hemoglobin content.
4. HCT (hematocrit) — hematocrit factor.
5. MCV (mean corpuscular volume) — mean red blood cells volume.
6. MCH (mean corpuscular hemoglobin) — mean hemoglobin content in a red blood cell.
7. MCHC (mean corpuscular hemoglobin concentration) — hemoglobin content in 100 ml of red blood cells (hemoglobin concentration in one red blood cell).
8. PLT (platelets) — thrombocytes number.
9. W-SCR — percentage of small leukocytes, i. e. lymphocytes.
10. W-LCR — percentage of large leukocytes, i. e. total percentage of neutrophils + monocytes + basophils + eosinophils.
11. W-SCC — or LYMPH — absolute number of small leukocytes, i. e. lymphocytes.
12. W-LCC — or MO + GR — absolute number of large cells, i. e. total count of neutrophils + monocytes + basophils + eosinophils.
13. RDW (red cell distribution width) — distribution width of red blood cells by the volume.
14. PDW (platelet distribution width) — distribution width of platelets by the volume.
15. MPV (mean platelet volume) — mean thrombocyte volume.

BASIC PHYSIOLOGIC INDICES OF HUMAN BODY FLUID MEDIA

1. The blood.

1.1. The amount of blood is **6–8 %** of the body mass.

1.2 Hematocrit (blood cells share in the total blood volume):

40–49 % in men

36–42 % in women.

Plasma volume: 51–64 % of the total blood volume.

1.3. Blood plasma osmotic pressure **290 ± 10** mosmol/kg
(7,3 atm or 5600 mm Hg, or 745 kPa).
1.4. Blood plasma oncotic pressure: **25–30 mm Hg**.
1.5 Arterial blood pH: **7,34–7,44**.
1.6. Blood viscosity: **4,5–5,0** (versus water viscosity, taken for 1,0).
Plasma viscosity: **1,8–2,2** (versus water viscosity taken for 1,0).
1.7. Relative blood density: 1,050–1,062 g/ml.
Relative plasma density: 1,029–1,032 g/ml.
1.8. Indices of RBC in adults.

Table 7

Group	Total red blood cells count × 10^{12}/л	Reticulo-cytes, %	Hemoglobin, g/l	Mean RBC volume, fl (MCV)	Mean hemoglobin content in one RBC, pg (MCH)
Adult men	3,9–5,1	0,5–1,2	130–170	80–100	25,4–34,6
Adult women	3,7–4,9	0,5–1,2	120–150	79–98	25,4–34,6

1.9. **Leukocyte formula** (% proportion of different types of leukocytes).

Table 8

Granulocytes					Agranulocytes	
Neutrophils			Basophils	Eosinophils	Lymphocytes	Monocytes
Young	Band neutrophil	Segmentonuclear				
0–1 %	1–5 %	46–68 %	0–1 %	1–5 %	18–40 %	2–9 %

SHIFT TO THE LEFT (increase of immature neutrophils)

←

SHIFT TO THE RIGHT (increase of mature segmentonuclear neutrophils)

→

1.10. Platelets count in peripheral blood:
(150–450) × 10^9/l.
1.11. Osmotic resistance of red blood cells:
Minimal – **0,46–0,48 %** NaCl.
maximal – **0,32–0,34 %** NaCl.
1.12. Prothrombin index of capillary blood: 93–107 %.
1.13. Plasma protein content: **60–85 g/l.**
Albumin content: 38–50 g/l.
Globulin content: 20–36 g/l.
Fibrinogen content: 2–4 g/l.
1.14. Plasma glucose content: **3,33–5,55 mmol/l.**

TOPICS OF THE SECTION LESSONS ARE PASSED _____

Teacher's signature

GENERAL PHYSIOLOGY

Lesson 6. ELECTRIC SIGNALING. RESPONSE LAWS OF EXCITABLE TISSUES. BIOLOGICAL POTENTIALS. EXCITABILITY CHANGES IN EXCITATION

Basic questions:

1. Electric signaling. The concept of irritability, excitability and excitation. Basic manifestations of excitation. Types of electric signals, their physiological significance.
2. Stimulus parameters necessary for tissue response (thresholds of force and time, minimal gradient). The "force-duration" curve. Chronaxia, chronaximetry.
3. Response laws of excitable tissues to the stimulus action.
4. The concept of sensory receptors. Classification, structure and functions of sensory receptors.
5. The membrane resting potential. Basic mechanisms of maintaining the resting potential.
6. The receptor potential, the mechanism of its origin and characteristic.
7. The action potential (AP) as a carrier of information in the organism. Phases and ion mechanisms of AP generation.
8. Excitability modification in the process of excitation.
9. Comparative characteristics of the receptor potential, local response and AP.

Self check:

1. What factor allows comparing excitability of various cells? Compare the excitability of the nervous and striated muscle tissue.
2. The excitability of what tissue is checked in conducting chronaximetry in a healthy man and why of this particular tissue?
3. Why does the cardiac muscle response to the stimulus action by the "all-or-none" law, and a skeletal muscle — by the law of force?
4. How and why will the resting potential value change in increasing extracellular potassium ions concentration?
5. When the myocardial blood supply is impaired, the potassium ions concentration in the interstitial fluid increases. In what way will this affect the AP generation in myocardial fibers?

PRACTICAL WORKS

Work 6.1. THE EFFECT OF Na^+ AND K^+ IONS ON THE MEMBRANE RESTING POTENTIAL AND ACTION POTENTIAL

The work is done within the program "Neuromuscular junction" (**NMJ**).

Accomplishment. Choose the commands **Stimulate**, **nerve** in the upper line.

The initial parameters of obtained potentials: membrane potential — -85 mV; action potential peak —— +45 mV; action potential amplitude — 130 mV.

The effect of K^+ (Potassium): in normal extracellular concentration of K^+ (5 mM) a normal potential is recorded. To change K^+concentration choose the commands **Ions, Potassium**, then enter new concentration values and stimulate the nerve.

9 mM — hyperkalemia (hyperkalehistia): the membrane potential changes towards depolarization (-70 mV), i. e. muscle excitability increases; the action potential does not change.

2 mM — hypokalemia: the membrane potential changes towards hyperpolarization up to -109 mV, i. e. muscle excitability decreases; the action potential does not change.

Thus, K^+ concentration produces effect first of all on the **resting potential**.

The effect of Na^+ (Sodium): 120 mM is a normal extracellular concentration of sodium. Changes of sodium concentration, e. g.:

160 mM — hypernatremia: the resting potential does not change;

the action potential peak reaches +55 mV (the norm is +45 mV).

80 mM — hyponatremia: the resting potential does not change;

The action potential peak decreases to +40 mV.

Thus, the concentration of Na^+ ions determines the amplitude of action potential upstroke (depolarization phase).

Direction for recording the Protocol:

1. Fill in tables 9 and 10.
2. Make conclusions about the dependence of resting and action potentials on Na^+ and K^+ concentration outside the cell as well as on the concentration difference of these ions inside and outside the cell.

PROTOCOL

Table 9

Effect of K^+ on the membrane potential

K^+ concentration, mM	**Membrane potential, mV**	**Excitability change versus the initial value**
5 mM (norm)		
9 mM		
2 mM		

Таблица 10

Effect of Na^+ on the action potential

Na^+ concentration, mM	**Change of membrane potential**	**Action potential peak, mV**
120 mM (norm)		
160 mM		
80 mM		

Conclusions: _____
_____
_____

Lesson 7. EXCITATION CONDUCTION BY NERVE FIBERS. SYNAPTIC TRANSMISSION

Basic questions:

1. Coding of the information on the quality, force and place of action of a stimulus in sensory receptors. Peculiarities of information coding in receptors with different adaptation ability. The concept of analog and discrete coding.
2. The physiologic role of nerve fiber structural elements. Classification of nerve fibers.
3. Mechanisms and laws of conducting excitation by myelinated and unmyelinated nerve fibers. Excitation conduction velocity.
4. Classification of synapses, their physiologic role. The structure of synapses.
5. Modern concepts of excitation conduction mechanisms in synapses taking a neuromuscular junction as an example. An end plate potential (EPP), its transformation into an action potential. The processes providing restoration of the synapse readiness to conduct the next impulse.
6. Functional properties of synapses.
7. The possibilities of pharmacological influence on the process of signal transmission at synapses.

Self check:

1. In what way do local anesthetics discontinue excitation conduction by a nerve fiber?
2. What advantages have myelinated fibers as compared to unmyelinated ones?
3. What potential is generated on the postsynaptic membrane?
4. Is it possible to conduct a signal through the synapse in calcium-free medium?
5. Why does the organism die of oxygen insufficiency in poisoning with curare, a poison blocking neuromuscular junctions?
6. In what way will the signal transmission change under the influence of substances with anticholinesterase action at a neuromuscular synapse?

PRACTICAL WORKS

Work 7.1. DEMONSTRATION OF THE DEVELOPMENT OF LOCAL ANESTHETICS EFFECT DEPENDING OF THE TIME OF ACTION

The mechanism of local anesthetics action means blocking of voltage-gated sodium channels of afferent nerve fibers. As a result the action potential on a nerve fiber membrane is not generated. Impulses from pain receptors do not reach the central nervous system and pain perception is not formed. Blocking of sodium channels is a process that requires some time (usually some minutes). The time for the effect development depends on the dose of anesthetics and individual sensitivity.

The program **"NERVE"** allows following the time dynamics of local anesthetics action.

Accomplishment. Open the program "**Nerve**". Then choose **Nerve Physiology → Menu →** 7.**The effect of procaine**. The screen shows records of action potentials produced in the experiment by direct electric stimulation of a peripheral nerve. Consequential pressing the knobs with time indication in seconds produces records of the action potential on the screen, they being obtained directly after injection of procaine (0 s), in 1 min (60 s), 1,5 min (90 s), 2 min (120 s), 4 min (240 s) and 6 min (360 s).

Direction for recording the Protocol:

1. Observe changing of the summarized action potential amplitude of nerve fibers contained in the whole nerve, and of the depolarization velocity, fill in the protocol.

2. Make a conclusion of how many minutes it took in this case to reach the effect of local anesthesia.

PROTOCOL

1. Amplitude of the total AP as anesthesia developed _____ (↑, ↓), depolarization velocity _____ (↑, ↓).

2. Conclusion: it took _____ min to reach the effect of local anesthesia.

Table 11

Ways of affecting the synaptic transmission at a neuromuscular synapse

Types of influence	Result	Substance example
Blocking of acetylcholine (ACh) **release**	Complete blockade of synaptic transmission, muscle paralysis	Botulinum toxin
Blocking of postsynaptic membrane **receptors**	Blockade of synaptic transmission, muscle paralysis	Curare and curare-like substances (myorelaxants)
Inhibition of	***Reversible inhibitors:***	Anticholinesterase

acetylcholinesterase	Enhancement and prolongation of ACh action, **facilitation** of impulses conduction through a synapse	substances (proserin, neostigmin, etc.)
	Irreversible inhibitors: **Blockade** of synaptic transmission, muscle paralysis	Organophosphorous compounds — insecticides and battle chemical agents
Blocking of choline **reuptake** to presynaptic terminal	Depletion of ACh stores in a presynaptic terminal	Hemicholinium

Lesson 8. PHYSIOLOGY OF MUSCLES

Basic questions:

1. Physiologic properties of skeletal muscles. The structure of muscle fibers. Sarcomere.
2. Mechanisms of contraction and relaxations of a single muscle fiber and a whole muscle.
3. Types and contraction regimen of skeletal muscles. Muscular tone. Force and work of skeletal muscles. Muscle fatigue.
4. Physiologic properties and peculiarities of smooth muscles.
5. Contraction and relaxation mechanism of smooth muscles. Smooth muscle tone.

Self control:

1. The duration of muscle shortening in one contraction is 0,03 s, while the relaxation period is 0,04 s. Determine the type of this muscle contraction when the contraction frequency is 10 Hz.
2. The solution of $CaCl_2$ (10 %) should be injected only intravenously. Is it possible to inject this solution intramuscularly? What consequences will it cause?
3. What is the difference between the processes taking place in a skeletal muscle for its tone maintenance and during its contraction?
4. What is the stimulus for skeletal muscle contraction? What factors may cause the contraction of a smooth muscle?
5. What is the source of calcium ions for the contraction of a skeletal and smooth muscle?
6. What are the basic types of calcium channels of smooth muscle cell membrane (1, 2, 3) and its endoplasmic reticulum (ER) (1, 2)?

PRACTICAL WORKS

Work 8.1. DYNAMOMETRY OF HANDS AND BACK MUSCLES

Accomplishment. The strength of a right and left hand is determined by a manual dynamometer. The dynamometer is held on a stretched hand. The measurement is repeated several times and the maximum value of muscle strength is chosen (in kg). The hand strength index (HSI) is calculated by the formula:

$$\frac{\text{Muscle strength in kg} \times 100}{\text{Body mass in kg}}$$

Satisfactory HSI for men is 55 units, for women — 50 units.

The back muscles dynamometry allows evaluating the extensors strength of the back. The back muscle strength is also determined several times and the maximum value is chosen. To evaluate the back strength index (BSI) the ratio of the back extensors strength to the mass of a tested person is used: BSI = back extensors strength / body mass in kg.

Satisfactory back extensors strength for men is 2, for women — 1,5.

Directions for recording the Protocol:

1. Put down the obtained data into the Protocol.
2. Evaluate muscle strength of the tested person and indicate what it depends on.

PROTOCOL

Muscle strength of the left hand (kg): _____ of the right hand (kg): _____

Left hand strength index (units): _____ Right hand: _____

Strength of back extensors (kg):_____ Back strength index: _____

Conclusion: _____

_____

Work 8.2. CONTRACTION OF MOTOR UNITS AND OF A WHOLE MUSCLE

The work is done using the computer program "**Muscular**". Sections "Contraction of motor units", 5, and "Contraction of Whole muscle", 6.

Summary. Factors that affect muscle tension:

The frequency of stimulation: increasing of frequency provides temporal summation and increased muscular tension.

***The number of motor units recruited*:** stimulation of more motor units produces increased muscle tension.

***The starting length of the muscle*:** optimal stretch permits maximum binding of cross bridges for maximum muscle tension.

Lesson 9. THE ROLE AND FUNCTIONS OF THE NERVOUS SYSTEM AND ITS STRUCTURAL ELEMENTS. INHIBITION IN CNS. GENERAL PRINCIPLES OF CNS ACTIVITY COORDINATION

Basic questions:

1. Functions of the nervous system, its role in ensuring the vital activity of the organism and its interrelations with the environment.
2. Morphological and biophysical peculiarities of neurons ensuring their functions (perception, transmission of information, integration).
3. Integration of neurons into neuron chains. Types and functions of neuron chains. The concept of conduction pathways and their functions.
4. Morphologic and functional peculiarities of central synapses as compared to neuromuscular junctions. Neurotransmitters of central synapses. The concept of neurotransmitter systems of the brain.
5. Reflex principle of the nervous system functioning. A reflex arch, its components. Types of reflexes. Multilevel organization of a reflex.
6. The structure and functions of nerve centers and nuclei. Properties of nerve centers; their tone.
7. Inhibition processes in the nervous system. Manifestation forms of inhibition. Inhibitory neurotransmitters. Mechanisms of inhibitory synapses functioning (e. g. GABA-ergic inhibitory synapse).
8. Interaction of excitation and inhibition processes. The concept of neuron integrative function. Modern concepts of central inhibition mechanisms.
9. Physiologic principles and mechanisms of coordination in CNS.
10. Neuroglia functions. Blood-brain barrier, peculiarities of blood-brain barrier in different parts of CNS.
11. Cerebospinal fluid, its formation, composition and properties.
12. Peculiarities of the brain metabolism and its provision with blood supply by the cerebral circulation system. Life span of neurons under anoxia. Possibilities of functional restoration of the brain. Reanimation time.

Self check:

1. What is the similarity and difference between of an anatomic and physiologic concept of the nervous center?
2. In what way and why will the functional activity (tone) of the nervous center change: in decrease of afferent nerve impulses; under hypoxia; under action of toxic substances depressing metabolism; increase of afferent input?
3. Why is it in the brain that the extracellular potassium concentration may considerably increase in high neuronal activity? What consequences may it result in and what mechanism prevents these consequences in physiological conditions?
4. What are the basic functional differences between neuromuscular junctions and neuronal synapses?
5. What is the difference between the primary and secondary inhibition?

6. Why is the time of a tendon reflex the shortest as compared to the time of other reflexes?

WORK 9.1. STUDYING OF A KNEE AND AN ANKLE REFLEXES

Tendon reflexes participate in regulation of muscle tone and support of the body posture. In clinical practice tendon reflexes are studied to determine the functional state of different parts of the reflex arch and for the topic diagnosis of some CNS diseases.

Materials and equipment. A percussion hammer.

Accomplishment.

A. A knee jerk reflex.

The examined person should sit down on the chair and put one his leg on the other. Hit the tendon of a quadriceps muscle of the hip below the patella with the percussion hammer. Observe the extension movement of the leg in the knee joint. Compare the reflex reaction on both extremities.

B. An ankle (Achilles) reflex

The examined person should stand with his knees on the chair so that his feet are hanging freely. Hit the heel tendon with the percussion hammer. Observe the foot sole bending. Compare the reflex reaction on both extremities.

Directions for recording the Protocol:

1. Evaluate the expression degree of the reflexes, their symmetry.
2. Make a conclusion about the state of reflex reaction.

PROTOCOL

1. Knee and ankle reflexes _____ (are marked, absent) on _____ (one or both extremities).

2. Conclusion: the reflex reaction is _____ (in norm, asymmetric, absent)

Work 9.2. DETERMINATION OF THE ANKLE REFLEX TIME

Materials and equipment. Electromyoreflexometer.

Accomplishment. To record an electromyogram electrodes are applied on the patient's skin in the region of his calf muscle. The reflex time is determined from the moment of stimulation to the appearance of a bioelectric response component of motor reaction.

Switching on the reflexometer's millisecondmeter is accomplished by locking the contacts during hitting of a heel tendon with the percussion hammer, switching off – when reflex induced biopotentials appear in the muscle.

The reflex time measurement is conducted 3 times and a mean value is determined.

Directions for recording the Protocol:

1. Indicate a mean value of the ankle reflex time.

2. Explain why the ankle reflex time is the shortest as compared to that of other reflexes.

3. Indicate the levels of knee and ankle reflex arches in the spinal cord.

PROTOCOL

1. Mean value of the ankle reflex time is equal to _____ msec.
2. The ankle reflex time is the shortest because _____
_____
3. Spinal levels of a knee reflex motor neurons in the spinal cord are _____,
of an ankle reflex — _____.

Work 9.3. ELECTROMYOGRAPHY

Electromyography is a recording method of total bioelectric activity of the muscle. Electromyogram (EMG) reflects the tone state of the muscle at rest and its functional activity during contraction.

An electromyogram is made, when a person is awake and at rest, it having the character of continuous frequent oscillations with a very low amplitude (from 5 to 10 mcV). When the contraction and tension are weak, an increase of electric activity is observed reaching its maximum in voluntary contraction (oscillation amplitude may reach 1000–2000 mcV, oscillation frequency — 100 Hz). Electromyographic studies are used in clinical practice, physiology of labor and sport.

Materials and equipment: superficial (cutaneous) electrodes, an electromyograph or an electroencephalograph for EMG recording; a set of weighs from 0.5 to 2 kg.

Accomplishment. Electrodes (bipolar) are applied to the arm skin of the examined in the region of biceps and they are attached to the electromyograph.

The EMG is recorded under various conditions: a) at rest; b) the arm is flexed at the elbow; c) the arm is extended; d) the biceps are at tension produced by increasing the load.

In the last case the examined person is standing with his hands down free. Then the examined person flexes his elbow so that the forearm is in a horizontal position. Put weighs on the palm of the examined person increasing their weight, e. g. 0,5, 1 and 2 kg and asking the examined to keep the forearm horizontally.

Directions for recording the Protocol:

1. The result of the experiment: compare the character of EMG under various conditions (amplitude and frequency of impulses) visually. Draw an EMG recorded during the experiment.

2. Make a conclusion about the state of the motor center activity that innervates the shoulder biceps under the experiment.

PROTOCOL			
1. EMG drawing of the biceps under various conditions			
Rest	**Arm flexion**	**Arm extension**	**Under tension (holding the load)**
2. Conclusion: electric activity of the shoulder biceps and that of nerve centers innervating it, under experiment (while bending the arm at the elbow and particularly in additional tension of the muscle for holding the weighs) versus the state of rest is considerably _____ (increased or reduced), it being testified by _____ increase or decrease of amplitude and frequency of EMG waves).			

Work 9.4. THE STUDY OF RECIPROCAL INHIBITION OF MOTOR REACTIONS BY ELECTROMYOGRAPHY

Materials and equipment. Superficial (cutaneous) electrodes, an electromyograph.

Accomplishment. Electrodes (bipolar) are applied to the skin of the arm of the examined person in the regions of biceps and triceps, they being attached to the electromyograph.

EMG is recorded under various conditions: a) at rest; b) the arm is flexed at the elbow; c) the arm is extended; d) at synergic tension of the arm biceps and triceps.

Directions for recording the Protocol:

1. Draw EMG recorded under various conditions.
2. Make a conclusion about the state of the motor centers innervating the biceps and triceps of the shoulder under the experiment.

PROTOCOL				
EMG recording from the muscle	Rest	Flexion of the a	Extension of the	Synergic tensi
biceps				
triceps				
CONCLUSION. Activity of motor centers innervating biceps and triceps muscles at rest _____; in flexion and extension of the arm at the elbow _____; under synergic tension of the shoulder muscles _____.				

Lesson 10. THE ROLE AND FUNCTIONS OF THE SPINAL CORD, MEDULLA, MIDDLE BRAIN, CEREBELLUM, AND RETICULAR FORMATION

Basic questions:

1. Multifunctional organization of the spinal cord. Functions of the spinal cord.
2. Muscular tone. Spinal mechanisms of muscular tone regulation.
3. Basic spinal reflexes important in clinical practice. Consequences of the injuries of the spinal cord and its anterior or posterior roots.
4. The medulla. Regulation centers of the organism basic functions. Integration of autonomic and somatic functions.
5. The middle brain and pons. The most important centers. Pupillary and other reflexes. Participation in eye movement.
6. Nerve centers of the brain stem, their role in regulation mechanisms of muscular tone, pose and movements. Consequences of the brain stem injury.
7. Cerebellum, its morpho-functional organization and functions. Participation of the cerebellum in regulation mechanisms of muscular tone, pose and movements. Basic symptoms of the disorder of cerebellum functions.
8. Reticular formation of the brain stem, its functions. Ascending and descending effects on CNS functions. Participation of the reticular formation in regulation of motor and other functions of the organism.

Self check:

1. In what parts of the spinal cord are the reflex centers located: of the knee, ankle, flexion reflex of the upper extremity, extension reflex of the upper extremity? To what type of reflexes do they refer?
2. What are the consequences of a complete spinal cord rupture at the levels: a) between the cervical part and the medulla; b) between the cervical and thoracic parts; c) between the thoracic and lumber parts?
3. Why does the muscular tone decrease significantly, when posterior roots of the spinal cord are cut?
4. Explain basic causes of decerebrate rigidity.
5. What is a spinal shock? When does it occur?
6. What are basic functions of quadrigeminal bodies?
7. What symptoms occur in cerebellum disorder?

PRACTICAL WORKS

Work 10.1. STUDYING OF SOME TENDON REFLEXES (MANDIBULAR, UPPER EXTREMITY FLEXION AND EXTENSION)

Tendon reflexes are studied in the clinic to evaluate the CNS state and topical diagnosis of CNS diseases.

Materials and equipment. A percussion hammer.

Accomplishment:

a) mandibular reflex. Hit lightly at the chin with the hammer, the mouth being a bit open; observe the contraction of masticatory muscles;

b) tendon flexion reflex of the upper extremity (elbow reflex).Hold the forearm of the examined in a semi-flexed position with your left hand, supporting his elbow with the palm of your hand. Hit the biceps tendon with the hammer. Observe flexion of the arm at the elbow;

c) tendon extension reflex of the upper extremity. Stand up laterally to the examined, abduct his shoulder passively towards outside to a horizontal level supporting him with the left hand at the elbow so that the forearm be hanging at the right angle. Hit the muscular tendon near the elbow bend. Observe the extension of the forearm.

Directions for recording the protocol:

1. Evaluate the expression degree of the reflexes.
2. Make a conclusion about the state of reflex reactions and name the CNS part responsible for the reflexes described in items "b" and "c".

PROTOCOL

1. Reflexes _____ (are marked, absent, asymmetric).
2. Conclusion: the state of reflex reactions is _____ (in norm, impaired).
The _____ (CNS department) is responsible for reflexes of upper extremities muscles.

Work 10.2. PUPILLARY REFLEXES

The muscles of the iris are able to change the size of the pupil during contraction and thus regulate the light flow to the eye retina. In norm the pupil is narrowed in the light and is dilated in darkness. The examination of pupillary reaction to the light is used while diagnosing CNS diseases.

Accomplishment: direct pupillary reaction to the light

The examined should sit down with his face to the window, one eye covered with the hand. Cover the other eye of the examined with a shield and take the shield away. Observe over changing of the pupil size.

Consensual pupillary reaction to the light

Cover one eye of the examined and observe the reaction of the second eye.

Pupillary reaction on accommodation and convergence

The pupillary reaction on accommodation and convergence is characterized by narrowing of the pupils, when looking at closely located objects and their dilatation — at remote objects.

Directions for recording the Protocol:

1. Assess the expression degree of the reflexes.
2. Make a conclusion about the state of pupillary reflex reactions.

PROTOCOL

1. Pupillary reflexes_____ (expressed, impaired).
2. Conclusion: _____
_____

Work 10.3. STUDYING OF TACTILE SENSITIVITY

The examined is lying with his eyes closed. Touch the symmetric parts of the head, body and extremities of the examined with cotton wool. In norm he senses every touch and confirms his sensation with words.

Directions for recording the Protocol:

1. Describe sensations of the examined.
2. Make a conclusion about the state of tactile sensitivity in the examined.

PROTOCOL

1. The examined _____ (sensed or didn't sense) touching with cotton wool and _____ (correctly or with a mistake) localized it.
2. Condition: the state of tactile sensitivity in the examined _____.

Work 10.4. STUDYING OF MUSCLE-JOINT SENSATION (KINESTHESIA)

Accomplishment. The examined is lying with his eyes closed. Perform mild flexing and extending movements of the hand fingers of the examined, starting with end finger-cushions. In norm the examined should correctly distinguish all performed actions, giving correct answers what finger is performing a passive movement at the given moment, if flexing or extending is performed.

Directions for recording the Protocol:

1. Describe if the examined distinguishes performed actions correctly.
2. Make a conclusion about the state of the muscle-joint sensation in the examined.

PROTOCOL

1. The examined distinguishes the performed actions _____
(correctly, incorrectly)
2. Conclusion: _____
_____
_____

Work 10.5. STUDYING OF THE CEREBELLUM FUNCTIONS

Efferent signals from the cerebellum regulate neuronal activity of vestibular (Deiters') and red nuclei, the thalamus nuclei, and through them the activity of peripheral (α- and γ-motor neurons of the spinal cord and nuclei of cranial nerves) and central (cortical) motor neurons. Through these pathways efferent signals from the cerebellum regulate strength of muscle contractions ensuring the ability for prolonged tonic muscle contraction, relate the volume of a voluntary movement with the distance to the aim of this movement, and quickly change flexing to extending and vice versa. The cerebellum provides the synergy of contractions in complex movements. Cerebellum functions disorder is manifested by: decrease of muscle contraction force (**asthenia)**; loss of the ability to prolonged muscle contraction that makes standing, sitting difficult (**astasia**); involuntary change of muscular tone (**dystony**); finger trembling at rest (**tremor**); movement impairment revealed as excessive or insufficient movement (**dysmetry**); coordination impairment (**ataxy**) that is manifested in "drunk" (swaying) gait and etc.; speech motor disorders (**dysartria**); swinging rhythmic twitching of eye-balls (**nystagmus**); impairment of interchanging opposite movements (**adiadochokinesis**), etc.

Materials and equipment: a glass, a book.

Accomplishment. The examined performs actions and exercises indicated in Table 12.

Table 12

Investigation of the cerebellum control of skeletal muscles activity

Type of experiment	Technique
Romberg's pose (movements coordination assessment or **abasia** test)	The examined should stand with feet close and hands stretched forward, at first with open and then with closed eyes. In norm the person keeps the balance in Romberg's pose (i. e. the abasia test is negative)
Gait (assessment of movements coordination or **ataxia** test)	Examined should walk about the room forward and backward with open and closed eyes. In norm the gate of a healthy person is usual, without swaying to the sides and broad placing his feet (i. e. the ataxia test is negative)
Dysmetria test	The examined should take from the table and put back some object (a book, a glass). In norm the person puts the subject to the same place with an error ±2 cm (i. e. the dysmetry test is negative)
Speech (**dysarthria** test)	The examined should repeat some words difficult for pronunciation (*adiadochokinesis*, *atrioventricular*, *deoxyhemoglobin* etc.). Note, if there is slowed down, irregular or discontinuous speech
Finger-nose test (for **dysmetria** and **tremor**)	The examined should point with his index finger (at first of the left and then of the right hand) to the tip of his nose with open and closed eyes. In norm the person touches his nose tip with accuracy of ±1 cm without tremor of fingers (i. e. the test for dysmetria and tremor is negative). Persons having cerebellum disorder miss the nose tip and their fingers tremble while reaching the nose

Indications for recording the protocol:

1. Point out, if the examined succeeded to perform the offered tests correctly.

2. Make a conclusion about the quality of the cerebellum control of motor activity.

PROTOCOL

1. The tests for ataxia in the examined were _____ (+ or -), as in Romberg's pose he _____ (kept or didn't) balance, his gait was _____ (normal or impaired); tests for dysmetria and tremor were _____ (+ or -); dysarthria _____ (was or wasn't) revealed.

2. Conclusion. The cerebellum control of motor activity in the examined was _____ (in norm or impaired)

Lesson 11. THE ROLE AND FUNCTIONS OF THE THALAMUS, HYPOTHALAMUS, BASAL NUCLEI, LIMBIC SYSTEM AND BRAIN CORTEX. SYSTEMIC REGULATION MECHANISMS OF MUSCLE TONE AND MOVEMENTS

Basic questions:

1. Electrophysiological methods of studying CNS. EEG.
2. Thalamus. Morphofunctional organization, functions. Its role in forming pain sensations, sensor and motor functions.
3. Hypothalamus. Morphofunctional organization, functions. Integration of somatic, vegetative, endocrine functions. Hypothalamus participation in mechanisms forming higher psychic functions. Consequences of the impairment of hypothalamus structures.
4. Basal nuclei. Morphofunctional organization, functions. Participation in regulation mechanisms of the tone, posture and movements. The role of dophamine and acetylcholine mediator systems. Consequences of the impairment of basal ganglia.
5. Limbic system. Morphofunctional organization, functions. Participation in mechanisms forming motivation and emotions. Consequences of the impairment of the limbic system structure.
6. Cerebral cortex. Morphofunctional organization. Sensor and motor functions. Integration of sensor, motor and vegetative functions of the organism.
7. The cerebral cortex role in movements' organization.
8. Modern concepts of localization of functions in the cortex. Consequences of the impairment of various regions of the cerebral cortex.

Self check:

1. In what way will the animal food behavior change in the impairment of lateral or ventro-medial nuclei of the hypothalamus?
2. List the functions that the hypothalamus organizes and regulates.

3. What is the difference between afferent projections of specific and unspecific nuclei of the thalamus?

4. List basic symptoms of basal ganglia disorder.

5. The formation of what CNS mediator is impaired in parkinsonism?

6. List basic functions of the limbic system.

7. What brain departments suffer first of all under the conditions of hypoxia and hypoglycemia and why?

8. In what state of the human beta-rhythm is recorded on ECG?

9. In what state of the human alfa-rhythm is recorded on ECG? What is its frequency?

10. On what motor neurons of the spinal cord do pyramidal cells of the cortex form most of synapses?

PRACTICAL WORKS

Work 11.1. ELECTROENCEPHALOGRAPHY

Electroencephalography is a method for recording the total bioelectric activity of the brain.

Accomplishment. To record an ECG the examined is seated in the armchair in a shielded, grounded chamber with light and sound isolation. In points intended for electrodes application the head skin is swabbed with mixture of alcohol and ether for removing fat. Four pairs of electrodes are attached symmetrically to the occipital, parietal, temporal and frontal regions on both sides.

During ECG recording the examined should sit quietly with maximum relaxation of muscles and eyes closed. At first a calibrating signal is recorded, and then the background electric activity of various parts of the brain cortex is registered. Then the examined is asked to open his eyes, electric activity of the brain being observed.

The examined is asked again to relax his muscles and close the eyes. Some minutes later, when a clearly marked alpha-rhythm appears on the record, sudden sound is to by made and ECG changes are being observed. Alpha-rhythm is replaced by beta-rhythm on eyes opening, on sudden action of sound and other stimuli as well as during doing mental arithmetic, thinking about answers to questions, etc.

Directions for recording the Protocol:

1. The result of the experiment: paste ECG fragments in the protocol, calculate the oscillation frequency of the potential per 1 sec and the amplitude of potentials and find the areas with domination of alpha- and beta-rhythm, mark the activation reaction.
2. Fill in the table:

PROTOCOL ECG fragment. 2. Characteristic of ECG rhythms		
Rhythm	**Frequency (Hz)**	**Amplitude (mcV)**
Alpha		
Beta		
Theta		
Delta		

Lesson 12. PHYSIOLOGY OF THE AUTONOMIC NERVOUS SYSTEM

Basic questions:

1. The autonomic nervous system. General plan of the structure, functions. Effector cells, organs and tissues.
2. The concept of higher ANS centers, their association with other part of CNS.
3. Sympathetic and parasympathetic departments of the autonomic nervous system, peculiarities of their reflex arches.
4. Ganglia of the autonomic nervous system, their localization and neurotransmitter mechanisms.
5. The effect of post-ganglia neurons of the sympathetic and parasympathetic system on effector cells, their neurotransmitters and receptor mechanisms.
6. The effect of sympathetic and parasympathetic departments of ANS on functions of organs and systems. Relative antagonism and synergism of their effect. Basic autonomic reflexes.
7. The principle concept of ANS effector cells functions correction by producing effect on the receptor mechanisms in ANS ganglia and at the level of effector cells.
8. Basic factors reflecting the functional state of various parts of ANS.

Self check:

1. What are the peculiarities of ANS innervation of the medullar substance of adrenal glands?
2. What are the peculiarities of sweat glands innervation by ANS?
3. Why can sympathetic nerves produce opposite effects on vascular tone?
4. What are the metabolic effects of the sympathetic nervous system?

5. What action do sympathetic nerves produce on: the diameter of the pupil; heart function; bronchi tone; GIT (gastrointestinal tract) sphincters tone; skin vessels; vessels of skeletal muscles; secretion of gastric juice; adipose tissue; sweat glands; CNS activity?

6. What action do parasympathetic nerves produce on: the diameter of the pupil; heart function; bronchi tone; GIT motility; GIT sphincters tone; vessels of skeletal muscles; secretion of gastric juice; bladder sphincter; sweat glands?

7. What functional changes of the organism does atropine, an antagonist of muscarinic receptors, produce?

PRACTICAL WORKS

Work 12.1. DESCRIPTION OF SPINAL REFLEXES OF THE AUTONOMIC (SYMPATHETIC) AND SOMATIC NERVOUS SYSTEM

Accomplishment. The work is performed by the student independently while preparing for the lesson and is checked during the lesson.

Directions for recording the Protocol:

1. Draw a picture of a spinal cord section in the center, to the left of it — a diagram of a reflex arch of a somatic reflex and to the right — that of a sympathetic reflex; indicate links of the reflector arches with digits.

2. Fill in the table.

PROTOCOL	
Somatic reflex diagram	**Autonomic (sympathetic) reflex diagram**
Reflex arch links of a somatic reflex:	**Reflex arch links of a autonomic (sympathetic) reflex:**
1. Receptor part is presented by the following receptors of skeletal muscles: **1.1. _____;** **1.2 _____.**	**1. Receptor part is presented mainly by _____ receptors.**
2. Afferent part is presented by _____,	**2. Afferent part is presented by _____,**

which are located in _____.	**which are located in_____.**
3. Intercalating part.	**3. Intercalating part.**
4. Efferent part is presented by _____ or _____ motor neurons, which are located in _____.	**4. Efferent part is presented by 2 neurons, which are located in _____ and in _____ respectively.**
5. Working organs. They are _____ and _____ muscle fibers of skeletal muscles.	**5. Working organs. They are _____ muscle cells; cardiomyocytes; endocrine cells, etc.**
6. Signal (action potential) transmission rate is from _____ m/sec to _____ m/sec in efferent fibers, as they have _____ sheath and are referred to the type _____.	**6. Signal (AP) transmission rate is from _____ m/sec to _____ v/sec in efferent postganglionic fibers, as they DO NOT have _____ sheath and are referred to the type _____.**
7. Neurotransmitter of the neuromuscular junction is _____, which binds to the _____ type of _____ receptors.	**7. Main neurotransmitter in neuroeffector formation is _____, which binds to _____ and _____ types of _____ receptors.**

Work 12.2. CLINOSTATIC REFLEX

Reflex study allows determining the functional state of parasympathetic and sympathetic centers regulating the heart function. When a man passes from standing to lying position, the heart rate decreases normally 4–6 beats/min. Pulse decrease by over 6 beats/min evidences the increased tone of the parasympathetic part of ANS that regulates the heart functioning. The absence of reaction or its paradox character — pulse acceleration — evidences the increased tone of the sympathetic part of ANS regulating heart functioning.

Materials and equipment: a couch, a stop-watch.

Accomplishment. At first the pulse of the examined is counted, when he is standing. Then, in 10–25 seconds after the examined lay down, the pulse is counted again.

Directions for recording the Protocol:

1. Put down the pulse rate in standing position and then in lying position, count the pulse difference.

2. Make a conclusion of the tone of the sympathetic and parasympathetic departments of ANS regulating the heart functioning of the examined.

PROTOCOL

Pulse rate in standing is _____beats/min.

Pulse rate in lying_____ beats/min.

Pulse difference [PR lying–PR standing] _____beats/min.

Conclusion: _____

_____

Work 12.3. ORTHOSTATIC REFLEX

Reflex study allows determining the functional state of sympathetic and parasympathetic centers regulating the heart functioning. When a man passes from lying to standing position, the heart rate increases normally by 6–24 beats/min. Pulse increase by over 24 beats/min evidences the tone dominance of the sympathetic part of ANS, under 6 beats/min — that of the parasympathetic part of ANS.

Materials and equipment: a coach, a stop-watch.

Accomplishment. The pulse of the examined is counted when he is lying (the man is lying quietly for 4–6 min before the count starts). Then he is asked to stand up and his pulse is counted in 15–25 sec again.

Directions for recording the Protocol:

1. Put down the pulse rate in lying and standing position, calculate the pulse difference.
2. Make a conclusion of the tone of the sympathetic and parasympathetic departments of ANS regulating the heart functioning in the examined.

PROTOCOL

Pulse rate lying _____ beats/min.

Pulse rate standing_____ beats/min.

PR difference [PR standing – PR lying] _____ beats/min.

Conclusion: _____

Work 12.4. HERING'S RESPIRATORY-CARDIAC REFLEX

Reflex study allows determining the functional state (tone) of the parasympathetic center regulating the heart functioning. When respiration is held on after a deep inhalation, the tone of nuclei *n. vagi* and heart beat rate decreases normally by 4–6 beats/min. Pulse decrease by 8–10 beats/min and over evidences the parasympathetic ANS part tone increase, under 4 beats/min — tone decrease.

Materials and equipment: a stop-watch.

Accomplishment. The pulse is counted when the examined is sitting, then he is asked to make a deep inhalation and hold on the breath and the pulse is counted again.

Directions for recording the Protocol:

1. Put down the pulse rate (PR) before the breath is held on and when breath is held on during inhalation. Calculate the pulse difference.
2. Make a conclusion about the tone of the ANS parasympathetic part regulating the heart function in the examined.

PROTOCOL

Pulse rate before breath holding (BH) _____ beats/min.

Pulse rate (PR) during BH on inhalation _____ beats/min.

Pulse difference (PR on inhalation – PR before BH) _____ beats/min.

Вывод: _____

_____

Work 12.5. ASSESSMENT OF NEURO-MEDIATOR MECHANISMS OF THE EFFECT OF SYMPATHETIC AND PARASYMPATHETIC DEPARTMENTS OF ANS ON THE HEART FUNCTIONING (demonstrative computer work)

Accomplishment. The program "**Physiol** 2" is used which permits to perform virtual experiments on rats.

Directions for recording the Protocol:

1. Fill in the table. Abbreviations: **HR** — Heart Rate, **BPsyst** — Systolic Blood Pressure, **BPdiast** — Diastolic Blood Pressure, **Directions** — Mean Hemodynamic Blood Pressure.
2. Make a conclusion about the character of the effect of the ANS sympathetic and parasympathetic departments on the force and heart beat rate as well as about neuro-mediator mechanisms realizing these effects.

PROTOCOL

Effects of the heart	BPsys	BPmean	BPdiast	HR
Initial values				
Stimulation Symp. Nerves to heart T1				
Injection of noradrenaline, 5μg/kg				
Phentolamine(α-adrenoblocker),100 mg/kg + Stimulation Symp. Nerves to heart T1				
Propranolol (β-adrenoblocker), 100 mg/kg + Stimulation Symp. Nerves to heart T1				
Stimulation Vagus Nerve to heart				
Injection of acetylcholine, 5μg/kg				
Atropine (M-cholineblocker), 10.0 mg/kg + StimulationVagus Nerve to heart				

Conclusion:

_____

_____

_____

Lesson 13. PHYSIOLOGY OF THE ENDOCRINE SYSTEM 1

Basic questions:

1. The endocrine system significance for the organism. The structures of the endocrine system (glands of internal secretion, diffuse elements) and its functions. Participation of the endocrine system in regulation of homeostasis, growth and development, reproduction, utilization of energy.
2. General characteristic and mechanisms of hormone action. The concept of cellular receptors for hormones, first and second messengers of signal transmission to the cell.
3. Basic ways of signal transmission to the cells for various groups of hormones. Physiologic effects of hormone-receptor interaction at a cellular level.
4. The structure and functions of the hypophysis. Associations between the hypophysis and hypothalamus. Hormones of the hypophysis and hypothalamus, their role. Interaction of nervous and humoral mechanisms of functional regulation at a hypothalamic level.
5. Hormone secretion regulation of the hypophysis and hypothalamus. The most common manifestations of hypophysis and hypothalamus endocrine function disorders: diabetes insipidus, acromegaly, etc.
6. Functions and hormones of the epiphysis.
7. Endocrine function of sex glands. Mechanism of hormone action and their effects: characteristic manifestations of hormones excess and insufficiency. Peculiarities of sex glands endocrine function associated with age. The placenta endocrine function.

Self check:

1. What is the metabolic effect of hormones?
2. What is the permissive effect of hormones?
3. What are first and second messengers of hormone action?
4. What are the ways of the endocrine gland functional state evaluation?
5. What are the feedback mechanisms of hypophysis and hypothalamus secretion regulation?
6. What are the effects of adrenocorticotropic hormone (ACTH)? What inhibits its secretion?
7. What do the excess and insufficiency of ACTH result in?
8. What is the secretion of the thyroid stimulation hormone (TSH) regulated by? What is its thyroid action and in what way is the excess and insufficiency of ТТГ manifested in the organism?
9. What are the stimuli for secreting vasopressin (antidiuretic hormone)?
10. What are the common symptoms of diabetes mellitus and diabetes insipidus? What are the causes of these two different diseases?

PRACTICAL WORKS

Work 13.1. HUMAN HEIGHT EVALUATION

Human *height* is one of basic characteristics of the body. The body growth is an irregular process. Maximum growth rate is noted in newborns and infants and then it considerably decreases. Some increase of growth rate is noted in girls from 9 to 14 years and in boys from 11 to 16 years, then it decreases again. By 16 years in girls and by 18 years in boys the body growth is practically completed and in norm it does not exceed 1 cm/year. Complete ossification occurs by 20–23 years in a female organism and by 21–25 years in a male organism. The height of an adult of 130–200 cm in males and 120–190 cm in females is considered normal. Men less than 130 cm in height and women less than 120 cm in height are dwarfs. People-giants are women higher than 190 cm and men higher than 200 cm.

Height is an integral factor of the effect of genetic, hormonal, tissue and external factors on the bony and other tissues of the organism. The height genetic program is realized through the endocrine system including all known hormones (thyroid, insulin, calcium-regulating, adrenal, sex), but the most important is hypothalamic-pituitary regulation of growth, the central link of which is somatotropin. **Sopmatotropin** (somatotropic hormone or growth hormone) is a basic hormone stimulating linear growth. Somatotropine stimulates growth of bones in length, growth and differentiation of internal organs, development of muscle tissue. A basic effect of somatotropin at a bony tissue level is its stimulation of cartilage growth, protein synthesis and cell mitosis induction. Somatotropin effects are mediated by insulin-like growth factors (IGF-I, IGF-II) or comatomedins that are synthesized under the action of this hormone mainly in the liver and kidneys. The linear human growth is completed, when growth zones have become closed under the effect of sex hormones.

The most simple and accessible method of studying the somatotropin function is antropometric, i. e. the human height is evaluated versus its predicted height calculated on the basis of an average height of his parents. To determine the final height range the following formula is used:

Predicted final height of a male = (father's height + mother's height + 13 cm) : 2
Predicted final height of a female= (father's height + mother's height – 13 cm) : 2

The measured height of an adult must coincide with a predicted height or deviate from a calculated value no more than 2 standard deviations (CO), i.e. ±10 cm from a calculated height value. Deviations of the measured height exceeding 2 CO from a calculated height value evidence a pathologically low or high human height. In this case it is necessary to perform detailed studies of the hypophysis somatotropic function to clear up the cause of growth impairment, as well as to study the state of other glands (first of all sex and thyroid glands).

Materials and equipment: a height meter.

To perform the work one should know the ***heights of the parents***.

Accomplishment. Height measurement is performed in standing position with the height meter. The examined should stand without shoes (in thin socks) in the right position: arms down; heels together; heels, buttocks and scapulae are pressed to the board of the height meter. The head is in position of "Frankfurt's plane", i. e. the lower edge of the eye and the external auditory canal should lie on one horizontal line. Measurements are performed on exhalation. The plank of the height meter is lowered to the level of the head of the examined. Measurements are performed with precision of 0.5 cm.

Directions for recording the Protocol:

1. Measure the height of the examined with the height meter.
2. Calculate a predicted height of the examined.
3. Evaluate the received measurement result versus the predicted height of the person.
4. Answer the question: in what way will the excess or insufficiency of the growth or sex hormones in childhood or adolescence affect the final height of the person?

PROTOCOL

1. Height of the examined is _____ cm. Sex of the examined _____.
2. Parents' height of the examined: mother's _____ cm; father's _____ cm.
Calculation of Predicted Height of the examined (PH)
PH = (father's height + mother's height ± 13 cm) : 2 = _____ cm.
3. Conclusion. Height of the examined is _____
(in norm, pathologically high, pathologically low)
4. Excess of growth hormone in childhood or adolescence or insufficiency of sex hormones may result in pathologically _____ height. Insufficiency of growth hormone in childhood and adolescence or excess of sex hormones may result in pathologically _____height.

Lesson 14. PHYSIOLOGY OF ENDOCRINE SYSTEM 2

Basic questions:

1. Thyroid gland: types of endocrine cells and their hormones. Thyroid hormones, mechanisms of their action and induced effects. Regulation of hormone secretion. Characteristic manifestations of excessive and insufficient secretion of hormones.
2. Adrenal glands. Hormones of the adrenal cortex. Effects and mechanisms of hormone action. Regulation of hormone secretion. Manifestations of insufficient and excessive secretion of hormones. The role of glucocorticoids in stress.
3. Hormones of the adrenal medulla. Effects and mechanisms of hormone action. Regulation of hormone secretion.

4. The role of calcitonin, parathyroid hormone and vitamin D_3 in regulation of homeostasis of calcium and phosphorus in the organism. Human needs in calcium, factors affecting it.

5. Pancreatic hormones and their role in regulation of carbohydrate, fat and protein metabolism. Regulation of hormone secretion. Mechanisms of hormone action. The concept of hyper- and hypoglycemia.

6. The concept of hypothalamic-pituitary-adrenal and sympathoadrenal systems.

7. Participation of endocrine glands in adaptive activity of the organism. General adaptation syndrome and stress: nervous and hormonal mechanisms of their development.

8. The thymus gland and its hormones. The concept of APUD system of the intestines. The endocrine function of the heart, liver and kidneys.

9. General concept of hormones application for functional correction of the organism.

Self check:

1. What evidences the excess and insufficiency of thyroid hormones?
2. What hormones of the adrenal cortex are vitally important?
3. In what way do glucocorticoids increase the level of blood glucose?
4. What action does insulin produce on: the level of blood glucose, glucose utilization by tissues, glycogenolysis, gluconeogenesis, glycogen synthesis, exchange of proteins and fats, level of K^+ ions in the blood?
5. What processes does the blood calcium concentration depend on?
6. What hormones are most important for stress development?

PRACTICAL WORKS

Work 14.1. ANALYSIS OF THE EFFECT OF CATECHOLAMINES AS HORMONES (OF ADRENAL MEDULLA) AND AS NEUROTRANSMITTERS (OF THE SYMPATHETIC PART OF ANS) ON CARDIOVASCULAR SYSTEM (demonstrative computer work)

Accomplishment. The work is performed as virtual experiment on rats in the program "**Physiol** 2".

Directions for recording the Protocol:

1. Fill in the table. Abbreviations: HR — Heart Rate, BP_{syst} — Systolic Blood Pressure, BP_{diast} — Diastolic Blood Pressure, BP_{mean} — Mean Hemodynamic Blood Pressure.

2. Make a conclusion, what is the difference between the two types of catecholamine effects. Indicate, by what types of adrenoreceptors the effect of noradrenalin and adrenalin on the cardiovascular system is predominantly realized.

PROTOCOL				
Effect on the heart	**BP_{sys}**	**BP_{mean}**	**BP_{diast}**	**HR**
Initial values				
Stimulation Symp. Nerves to heart T_1				
Stimulation Symp. Nerves to adrenals $T_{6–8}$				
Phentolamine$^{(\alpha\text{-adrenoblocker})}$, 100 mg/kg + **stimulation** Symp. Nerves to heart T_1				
Propranolol$^{(\beta\text{-adrenoblocker})}$, 100 mg/kg + **stimulation** Symp. Nerves to heart T_1				
Propranolol$^{(\beta\text{-adrenoblocker})}$, 100 mg/kg + **stimulation** Symp. Nerves to adrenals $T_{6–8}$				
Injection noradrenaline, 5 μg/kg				
Injection adrenaline, 5 μg/kg				
Conclusion: _____ _____ _____				

TOPICS OF THE SECTION LESSONS ARE PASSED _____
Teacher's signature

PHYSIOLOGY OF CARDIOVASCULAR SYSTEM

Lesson 15. HEMODYNAMICS. FUNCTIONAL INDICES OF BLOOD CIRCULATION. MICROCIRCULATION.

Basic questions:

1. The role of the blood circulation system for tissue metabolism. Circles of blood circulation, their functional characteristic.
2. Morphological and functional classification of vessels.
3. Main factors affecting blood flow in vessels.
4. The basic law of hemodynamics — correlation between blood pressure, volume velocity of blood flow and peripheral resistance. Main factors determining vascular resistance to the blood flow.
5. Blood pressure, its types. Blood pressure in various parts of the vascular system. Main factors which determine arterial blood pressure (BP) level. The concept of normal values of BP, age-elated BP changes.
6. Techniques of blood pressure measuring.
7. Volume and linear blood flow velocities in various parts of the vascular system. Basic blood flow indices (blood pressure, blood flow velocity, vascular resistance) in arterial, microcirculatory and venous parts of the vascular system.

8. Arterial pulse, its origin and clinical-physiological characteristics. Sphygmography, sphygmogram analysis. The velocity of pulse wave propagation.

9. The structural-functional characteristic of the main components of microcirculatory system. Mechanisms of transcapillary exchange of fluids and various substances between blood and tissues.

10. Starling's equation. Fluid filtration and reabsorption in capillaries. Main factors affecting transcapillary fluid exchange.

11. Functions of the lymphatic system. Mechanisms of lymph formation and outflow.

12. Blood flow in veins, venous return. Venous blood pressure. Central venous pressure.

Self check:

1. In what organs and tissues is the organ blood flow at rest proportional to their metabolic needs and where is it higher? Why?
2. How much will the kidney blood flow change if the diameter of the renal artery diminishes 2-fold?
3. What is the basic reason of age-related systolic blood pressure increase?
4. In what way deep inspiration and expiration do affect the venous return to the heart?
5. In what way will venous return change after veins' constriction or dilation? In what way will it affect SV (stoke volume)?
6. What factors do the pulse volume (filling) and its tension depend on?
7. What is the difference between the concepts of "pulse rate", "pulse wave propagation velocity" and "linear blood velocity"?
8. What kind of transport through a capillary wall is characteristic of oxygen, carbon dioxide, water, lipo- and hydrophilic low-molecular substances; for high-molecular compounds?
9. Hydrostatic blood pressure in a capillary is 30 mm Hg, hydrostatic pressure of interstitial fluid is 2 mm Hg, colloid osmotic blood pressure is 25 mm Hg, colloid osmotic pressure of interstitial fluid is 2 mm Hg. Calculate the resulting pressure difference ensuring filtration (or reabsorption).
10. List main factors that may result in interstitial edema.

PRACTICAL WORKS

Work 15.1. STUDYING THE ARTERIAL PULSE PROPERTIES BY PULPATION

Arterial pulse is a rhythmic artery wall oscillation due to the ejection of the systolic volume of blood from the heart into the arteries and changes of pressure there during the systole and diastole.

Accomplishment. Grasp the hand of the examined in the area of his wrist

with your right hand so that your thumb is located on the back of the arm, and the rest of them — on its frontal lateral surface. Having felt the radial artery, press it with your three fingers to the underlying bone until you feel the pulse under your fingers. Assess the pulse by the following factors:

1. **Pulse rhythm**. It is determined by the duration of intervals between pulse waves. In a healthy person pulse waves follow one after the other at about regular intervals.

In norm there may occur **respiratory arrhythmia** when pulse increases on inspiration and decreases on expiration. Respiratory arrhythmia occurs more often in young people and persons with instable autonomic nervous system.

2. Pulse rate. **Pulse beats are counted during 20–30 seconds and then calculated for 60 sec (1 min). The pulse rate at rest may vary in the range 60–90 beats/min. The increase of pulse rate over 90 beats/min is called tachycardia; its decrease under 60 beats/min is bradycardia.**

3. **Pulse filling** (amplitude) is a subjective factor evaluated by the height of arterial wall elevation during palpation of pulse wave passing.

Pulse filling depends on the **systolic blood volume, elasticity of arterial walls and circulating blood volume.**

4. Pulse tension **is a subjectively estimated factor assessed by the force of pressing sufficient for ceasing of pulsation distally from the site of pressure. Pulse tension depends on the** systolic arterial pressure level**. In normal BP pulse tension is assessed as moderate. The higher is the pressure the more difficult is to cease pulsation by pressing the artery, and in high BP the pulse becomes tense or hard. In low BP the artery is pressed easily, and the pulse is assessed as soft.**

5. **Pulse wave velocity** is a subjective factor assessed by palpating the velocity of reaching the maximum oscillation amplitude by the arterial wall. The pulse velocity depends on the velocity of pressure increase in the arterial system during the systole that in turn depends on **the pulse pressure, stroke volume and artery resistance.** If during the systole a large volume of blood is ejected into the aorta and the pressure there increases rapidly, the maximum amplitude of artery extension is reached sooner. Such pulse is called rapid and occurs in insufficiency of aortal valves. When the pressure increases slowly, slow pulse is determined during the systole in the arterial system, and it is observed in stenosis of the artery.

Filling and pulse velocity may be determined objectively by recording a sphygmogram.

Fill in the table with your pulse description as well as maximum and mean values of pulse rate in the students of your group.

Table 13

Pulse property	Norm	Deviation variants	Examination data
Rhythm	Rhythmic	Arrhythmic	

Rate	60–80	infrequent (bradycardia), frequent (tachycardia)	
Filling	Good	weak, thready pulse	
Tension	Moderate	soft pulse, hard pulse	
Velocity	Normal	abrupt pulse, slow pulse	
Pulse rate in the students of the group: minimum ___, maximum ___, moderate___ .			

Conclusion: (Compare the results with the norm) _____
_____.

Work 15.2. PULSE ASSESSMENT BY SPHYGMOGRAM ANALYSIS

The computer program "Heart Sounds" is used for the work. Open the section "General Tutorials" → "Hemodynamics" → "Normal Left Heart Pressures and the Carotid Pulse". Pay attention to the time relationships of the first and the second heart sounds and the basic elements of sphygmogram: anacrotic, catacrotic waves, incisura and dicrotic wave. Note the way the sphygmogram changes in insufficiency of aortal valves and regurgitation of blood, as well as in aortic stenosis. Compare the duration of the systolic ejection period and pulse velocity in aortic insufficiency and in aortic stenosis.

On the basis of observations fill in the following points:

1. The beginning of blood pressure increase in the aorta and carotid artery coincides with the appearance of _____ heart sound. This blood pressure increase is seen on _____ (sphygmogram element).

1. The appearance of a dicrotic wave on the sphygmogram coincides with the appearance of _____ heart sound. Dicrotic wave is caused by _____.

2. The slope of the anacrotic wave in aortic stenosis _____ due to _____; the slope of the anacrotic wave in aortic insufficiency _____ due to _____.

Work 15.3. ARTERIAL BLOOD PRESSURE MEASUREMENT BY KOROTKOFF'S AUSTULTATIVE METHOD

The examined should be seated, his arm relaxed, the forearm lie on the table with his palm upwards. The cuff to the shoulder of the examined should be applied tightly, but it shouldn't squeeze the tissue. The lower edge of the cuff should be 2-3 cm higher of the ulnar pit. The pulsing brachial artery is palpated in the ulnar pit, the tonometer being applied to the site of its projection. In the cuff the pressure is created by ~30 mm Hg higher than the expected pressure in the artery, the pulse on the radial artery should disappear. On gradual lowering of the cuff pressure vascular tones in the shoulder artery are being listened to. The tones start appearing by the time, when the cuff pressure has

become equal to the systolic pressure in the brachial artery. On further lowering the pressure in the cuff, vascular tones are increasing, then become weaker and disappear. The tone disappearance corresponds to the moment, when the cuff pressure has become approximately equal to the diastolic blood pressure in the brachial artery. Without taking off the cuff, 2–3 minutes later, repeat the measurement of arterial blood pressure. The time, during which the arterial pressure is taken, should not exceed 1 minute, otherwise the signs of blood circulation impairments are observed in the extremity's distal part.

Results:

Systolic (maximal) pressure — _____

(norm — 100–140 mm Hg).

Diastolic (minimal) pressure — _____

(norm — 60–90 mm Hg).

Conclusion: (compare the results with the norm) _____

Work 15.4. ANALYSIS OF ARTERIAL BLOOD PRESSURE CHANGES UNDER THE ACTION OF ADRENALIN AND NORADRENALIN

To perform the work the computer program "**Prat**" is used. The scheme of the experiment on the rat appears after clicking the lines: Help → Preparation. Blood pressure (BP) and heart rate (HR) are registered on the monitor. The experiment uses the injection of 20 μg/kg of adrenalin. Fill in the table:

Factor	Initial value	Adrenalin 20 μg/kg	Noradrenalin 20 μg/kg
HR			
BP_{syst}, mm Hg			
BP_{diast}, mm Hg			
BP_{mean}, mm Hg			
Pulse pressure, mm Hg			

Draw BP changes under the action of adrenalin and noradrenalin:

Noradrenalin	Adrenalin

Make a conclusion about the difference between the effect of adrenalin and noradrenalin on the basic hemodynamics factors:

_____
_____

Work 15.5. VIDEO "MICROCIRCULATION"

Fill in the gaps:

1. The blood in arteries flows _____, than in venules.
2. Insert mean values of: mean linear blood velocity in capillaries _____; blood pressure in an arterial end of capillary is _____; in a venous end of capillary — _____.
3. List the mechanisms of transcapillary exchange of substances in microcirculatory blood vessels: 1) _____; 2) _____; 3) _____; 4) _____.
4. Pressures contributing to filtration (fluid outflow) from a capillary: _____; pressures contributing to reabsorption (fluid return) into a capillary: _____.

i. .

5. What is the main type of transport through the capillary wall characteristic of oxygen _____; carbon dioxide _____; water _____; glucose _____; lipophilic substances _____; high-molecular compounds _____.
6. In what way does BP increase affect the velocity of transcapillary exchange?
7. Basic factors that can result in the development of interstitial edema are:

_____
_____
_____.

Lesson 16. PHYSIOLOGICAL PROPERTIES AND PECULIARITIES OF THE HEART MUSCLE

Basic questions:

1. Functions of atria, ventricles and heart valves. The direction of blood flows in the heart. Connection of systemic and pulmonary circulations.
2. Peculiarities of metabolism and blood supply of the myocardium at a relative rest and at exercise. The coronary blood flow in the myocardium of the right and left ventricles during the systole and diastole.
3. The structure and functions of the heart conducting system. Propagation course of excitation through the heart conducting system. Automaticity mecha-

nisms. Action potential of the conducting system cells, its phases and ion mechanisms. Automaticity gradient.

4. Physiologic properties of a contractile myocardium. Action potential of contractile myocardium cells, its phases and ion mechanisms. Excitation-contraction coupling, the role of Ca^+ ions. Transmission of excitation through a contractile myocardium.

5. Time relationships of excitation, excitability and contraction of the heart muscle. Response of the heart muscle to the additional stimulation. The concept of an extrasystole.

6. Laws of the heart muscle contraction. The concept of pre- and afterload.

Self check:

1. What substances are used by the heart muscle as substrates for oxidation at rest and at exercise?

2. Why does the heart muscle response to the stimulation in "all or nothing" fashion? What is functional syncytium?

3. Why is the excitation from atria conducted to ventricles only through the atrioventricular node?

4. What phase of action potential of the conducting system cells underlies heart automaticity?

5. In what way does the ability of the heart conducting system cells to automatic excitation change while moving off the sinoatrial node?

6. What is the main law of the heart?

7. What is preload and afterload and what effect does an increase of pre- and afterload produce on the heart contraction?

PRACTICAL WORKS

Work 16.1. HEART AUTOMATICITY AND VARIOUS FACTORS AFFECTING IT

Automaticity of the heart is the ability of the heart to generate electric impulses causing its contraction. It is atypical cardiomyocytes forming the heart conducting system that have the ability of automaticity. The ability of automaticity is decreasing while moving along the conducting system from the sinoatrial node that is a pacemaker of the heart; and in norm it determines the rate of heart contractions.

Accomplishment. Video "Automation of the heart".

1. Observe the contraction of an isolated frog's heart.

2. Observe Stannius's experiment (applying a ligature between the venous sinus and right atrium).

Results: after applying a ligature of Stannius _____
_____
_____.

Conclusion (localization of the pacemaker) _____

_____.

In what way will the heart functioning change (heart rate, the sequence of atrial and ventricular contractions) in the impairment of connection between the sinoatrial and atrioventricular node? _____

_____

_____.

In what way will the heart work change, if bundle of His becomes a pacemaker? _____ Purkinje's fibers?

_____.

3. Temperature effect on automaticity of the heart.

Action potential of pacemaker heart cells of the frog is recorded *in situ* at room temperature, and then some drops of cold Ringer's solution are applied to the pacemaker's region; after restoration of heart work some drops of warm Ringer's solution are applied to the pacemaker's region.

Results: in what way will the AP rate of pacemaker's cells change in cooling: _____ and in warming of the heart's pacemaker _____.

Hence, in human hypothermia one can expect _____ of HR, and in hyperthermia — _____ of HR.

Work 16.2. MECHANISMS OF GENERATION OF ACTION POTENTIALS (AP) OF SINOATRIAL NODE CELLS AND VENTRICULAR CONTRACTILE MYOCARDIUM CELLS

Accomplishment. The work is performed on the basis of the video "Automaticity of the Heart", as well as the computer program "12 Leads".

Make a drawing of action potential of the conducting system (pacemaker's) cells on the left, and on the right — action potential of contractile myocardium cells together with changes of cardiomyocytes excitability in the process of excitation (in parallel below); mark AP phases and excitability phases.

AP of a pacemaker's cell

AP and excitability state of a contracting cardiomyocyte

Lesson 17. CARDIAC CYCLE. METHODS OF STUDYING THE HEART FUNCTIONING

Basic questions:

1. Sequence of phases and periods of the cardiac cycle. The state of valves, change of blood pressure and blood volumes in heart chambers in various phases of the cardiac cycle. Comparative characteristics of a pumping function of the right and left ventricles.

2. Systolic (stroke) and minute (cardiac output) volumes of the blood rest and at exercise. Indices of myocardial contractility.

3. Electrocardiography. Electrocardiographic leads. Calibration. Formation of ECG components. Order of ECG analysis, basic standards, diagnostic significance of ECG.

4. Heart sounds, their origin. Auscultation and phonocardiography (PCG), their diagnostic significance.

5. Mechanical manifestations of the heart activity. Apical beat, arterial pulse. Sphygmography (SG), its diagnostic significance.

6. Policardiography. Time correlation of periods and phases of the cardiac cycle, electrical (ECG), sound (PCG) and mechanical (SG) manifestations of cardiac activity.

Self check:

1. At what pressure in the left ventricle does the ejection period of the heart begin, if BP is 115/70 mm Hg?

2. What are the values of end-diastolic, stroke and end-systolic blood volumes? Calculate the ejection fraction of the left ventricle using these norms.

3. Calculate the cardiac output value if oxygen consumption is 400 ml/min, O_2 content in arterial blood is 20 vol.% and in venous blood is 12 vol.%.

4. During heart chamber catheterization the blood pressure fluctuated from 0 to 25 mm Hg, the content of blood oxyhemoglobin was 70 %. Which heart chamber was catheterized?

5. What interval (complex) of ECG makes up the "electric systole" of ventricles and in what way does its duration depend on the heart rate?

6. How is the rhythm of heart beats assessed by ECG? Calculate the duration of RR interval in heart rate (HR) 70/min and in regular rhythm. Calculate HR, if RR = 0.8 sec.

Most important indices of the heart function (at rest)

- End-Diastolic Volume — 90–140 ml
- End-Systolic Volume — 50–60 ml
- End-diastolic pressure of the left ventricle — 4–12 mm Hg
- End-systolic pressure of the left ventricle — 90–140 mm Hg

Mean limits of BP in the atria:

- Left atrium — +4 – +12
- Right atrium — -1 – +8.
- Stroke Volume — 55–90 ml
- Ejection Fraction — 50–75 %
- End-diastolic pressure of the right ventricle — 0–8 mm Hg
- End-systolic pressure of the right ventricle — 15–30 mm Hg

PRACTICAL WORKS

Work 17.1. RECORDING AN ECG AND ITS ANALYSIS

Accomplishment. While recording an ECG the patient is lying. Electrodes are applied to the extremities in accordance with accepted color marking of wires: the right arm — red color; left arm — yellow color; left leg — green color; right leg (grounding the patient) — black color. While applying breast electrodes special rubber pears are used to fix these electrodes.

To improve the quality of ECG and decrease interference a good contact with the skin should be ensured. Thus it is necessary: 1) to remove fat from the skin with alcohol in sites of electrodes application; 2) in case of considerable hairiness of the skin to swab the sites of electrodes application with soapy solution; 3) to cover electrodes with a layer of special current-conducting paste or to put pads soaked in 5-10% solution of NaCl (or in water) under electrodes, which allows maximal decreasing the resistance between an electrode and the skin surface.

At first a calibrating signal is recorded, the amplitude of which is equal to 1 mV. Standard amplification of the signal on the record must correspond to 10 mm deviation of the line. The standard tape speed is 50 mm/sec (sometimes 25 mm/sec). The ECG is recorded in 12 standard leads.

Electrocardiogram **(II standard lead)**

ECG Analysis

ECG examination is started with the assessment of its recording:

1) Check if ECG leads are marked, pay attention to the presence of various interferences.

In case of considerable interferences it is necessary to record the ECG again.

2) Check the amplitude of a calibrating signal (1 mV = 10 mm).

If its amplitude differs more than 1 mm, the amplitude of measured segments is calculated by the formula: $X = 10\ U/K$, where X — is real segment amplitude in mm; U — measured segment amplitude in mm; K — calibrating signal amplitude in mm.

3) The speed of paper movement is taken into the account while analyzing ECG record. If ECG is recorded with the speed of 50 mm/sec, 1 mm (horizontally) corresponds to 0,02 sec on paper. If it was recorded with the speed of 25 mm/sec, 1 mm = 0,04 sec.

Task: put down characteristics of given ECG:

calibrating signal: 1 mV = _____ mm;

paper movement speed: _____ mm/sec;

1 mm = _____ sec.

Further ECG analysis is performed by the following factors:

2.1. Determination of the source of cardiac rhythm (sinus or non-sinus rhythm).

In norm the sinus rhythm is recorded which is characterized by the presence of positive P waves in the standard lead II, they have similar identical shape and precede every QRS complex. The duration of PQ (PR) interval in norm is uniform and equals to 0.12-0.20 sec.

Task: determine the presence of P waves on ECG _____, their shape _____; direction_____; location relative QRS complexes _____; PQ duration _____; duration variability _____; other peculiarities _____; **conclusion** — The source of the rhythm is: _____.

2.2. Determination of rhythm characteristics (regular, irregular).

The rhythm determination is usually done by the analysis of standard lead II. The durations of 5–6 sequentially recorded RR intervals are measured. If the duration values of these intervals are equal or differ from each other no more than ±10 % of a mean value (or 0,16 sec), the rhythm is considered regular.

There occurs respiratory arrhythmia in healthy young people, when periodic gradual shortening of RR intervals is observed on inspiration and lengthening of RR internal on expiration.

Task: determine the duration of 5 RR intervals: ____; ____; _____; _____; _____. Mean RR value _____; deviation from mean value_____ %.

Conclusion: the rhythm is _____.

2.3. Determination of heart rate (HR).

HR is determined using a mean duration of RR interval that corresponds to the duration of one cardiac cycle. To calculate HR per 1 min in regular rhythm it is necessary to divide 60 sec (1 min) by the duration of RR interval in seconds:

HR = 60 : RR (in seconds)

HR of a healthy person at rest is from 60 to 90 beats/min. An increase of HR over 90 beats/min with regular sinus rhythm is called sinus tachycardia. In healthy people it occurs on exercise or emotional stress. A decrease of HR less than 59 beats/min with regular sinus rhythm is called bradycardia. In healthy people sinus bradycardia is observed in sportsmen during sleep.

Task: calculate HR using a mean duration of RR interval and make a conclusion (normal HR, bradycardia or tachycardia).

HR =

Conclusion:

2.4. Assessment of conductivity.

To assess conductivity the duration of **P** wave is measured, it characterizes the time of excitation conduction **through atria** (in norm it is 0,08–0,1 sec), the duration of **PQ** or **PR** interval (conduction time through atria, atrioventricular junction and His' bundle, i.e. the time of excitation conduction **from atria to ventricles**) (in norm it is 0,12–0,2 sec) and the total duration of ventricular complex **QRS** (excitation conduction **through ventricles**) (in norm it is 0,06–0,1 sec). If the conduction time exceeds the upper limit of the norm, the conductivity is decreased.

The duration of waves and intervals is measured on the standard lead II.

Task: P wave duration: _____

PQ (PR) interval: _____

Duration of QRS complex: _____

Compare the values with the norm and make a conclusion about conductivity of different parts of the heart:

2.5. Assessment of ECG waves amplitudes in the standard lead II.

Table 14

ECG waves	Norm (in mm)		**Obtained in measurement**
	min.	max.	
P	0,5	2	
Q	0	3	
R	10	20	
S	0	6	
T	2	5	

2.6. Assessment of ECG waves and intervals duration in the lead II.

Table 15

Waves and intervals	**Norm (in seconds)**		Obtained in measurement
	min.	**max.**	
P	0,08	0,1	
Q	0	0,03	
R	0,03	0,09	
S	0	0,03	
T	0,05	0,25	
PQ	0,12	0,20	
QRS	0,06	0,10	
QT	0,30	0,40	
RR	0,8	1,0	

2.7. Assessment of ECG waves direction in the lead II:

waves _____ are directed upwards (positive),
waves _____ are directed downwards (negative),
waves _____ are absent.

2.8. Assessment of ECG waves shape in the lead II:

waves _____ are sharp,

waves _____ are flattened,

presence of other segment shapes _____ (2-phase and others).

2.9. Segment ST analysis:

Deviation of ST segment from an isoelectric line is one of basic signs of ischemia (insufficient blood supply) of the myocardium. In norm ST segment deviation from the isoelectric line upwards or downwards does not exceed 1 mm.

The measured deviation of ST segment from the isoelectric line is (+ or -): _____ mm. Conclusion (presence or absence of myocardium ischemia signs):

TOTAL CONCLUSION on ECG analysis _____
_____
_____
_____.

Work 17.2. BASES OF PHONOCARDIOGRAPHY

To study bases of phonocardiography the computer program "**Heart Sounds and Murmurs**" is used.

1. Open: ***Heart Sounds → General Tutorials → Introduction of Auscultation → Introduction to the Phonocardiogram***. Listen and observe the difference between sounds of low, high frequency and noise.

2. Section **Listening Areas**. Using a cursor find basic points on the chest to listen to the heart sounds:

– in the 5th intercostal space on the left, along the medium clavicle line, in the apex area (***Apex***), is the point for listening to the first and the second tones;

– in the 2nd intercostal space on the right edge of the breastbone (***Aortic Area***), the second sound is listened to (aortal component);

– in the 2nd intercostal space on the left edge of the breastbone (***Pulmonic Area***), the second sound is listened to (component *a. pulmonalis*);

– On the left edge of the breastbone, in the area of the right ventricle tricuspid valve projection (***Lower Left Sternal Border***), the sounds of closing the tricuspid valve and blood ejection to *a. pulmonalis* are listened to.

3. Open: ***Introduction of Auscultation → Normal First and Second Sounds at Apex and Base → First Sound – Mitral and Tricuspid Valve Closure***. Look at the image of cardiac systole and diastole, dynamics of mitral and tricuspid valves closing and their contribution to the formation of the first heart sound which is listened to at the Apex.

Then: ***Second Sound – Aortic and Pulmonary Valve Closure***. Look at the image of heart systole and diastole, dynamics of vascular valves closing

and their main contribution to the formation of the second sound that is listened to in the 2nd intercostal space near the breastbone (parasternally).

Task: fill in the blanks:

1. First heart sound occurs during the _____ phase and _____ period of the cardiac cycle. The basic cause of the first heart sound is _____ _____.
The first sound occurrence coincides in time with _____ on ECG and with _____ of sphygmogram.
2. Second heart sound occurs during _____ phase of the cardiac cycle and coincides with the occurrence of _____ _____ on sphygmogram. The basic cause of the second heart sound is _____ _____.
3. In what way does the volume of the ventricles and BP there change during the interval between the first and the second heart sounds _____ _____, between the second and the first heart sounds _____?

Work 17.3. Recording and analysis of phonocardiogram (recorded together with ECG)

Accomplishment. The room where the PCG is recorded should be isolated from noise. Phonocardiogram is recorded on one of electrocardiograph canals using a microphone and a phonocardiographic attachment. The microphone is fixed on the chest of a lying patient in the area of an apex beat. Electrodes are applied for recording an ECG, a calibrating signal is recorded (1 mV = 10 mm). PCG and ECG are recorded on holding on the breath and on expiration. The speed of paper movement of the cardiograph is usually 50 mm/sec.

Phonocardiogram and electrocardiogram (drawing).

PCG analysis:

1. Presence of sounds and noises —
2. First sound duration — (norm 0,07–0,13 sec).
3. Second sound duration — (norm 0,06–0,10 sec).

Conclusion (compare the obtained data with the norm):

Work 17.4. Bases of ultrasound examination of the heart (echocardiography) — demonstration

Demonstration is performed using the computer program “Heart Sounds”.

Answer the following questions:

1. During ventricular systole in what way will change:
the thickness of interventricular septum _____;

the length of papillary muscles _____;
ventricular volume during isovolumetric contraction phase _____?

2. Calculate and assess the ejection fraction (EF) using the following results of echocardiographic examination of 2 patients:

Patient 1	Patient 2
End-diastolic volume = 130 ml Stroke volume = 80 ml EF = Conclusion:	End-diastolic volume = 135 ml Stroke volume = 55 ml EF = Conclusion:

3. Ultrasound examination allows assessing:

Lesson 18. REGULATION OF THE CIRCULATION 1 (REGULATION OF THE HEART FUNCTION)

Basic questions:

1. The most important factors of the heart work (HR, SV, and contractility). Determination of cardiac output, blood pressure and organ blood flow by the heart function.
2. Classification of regulation mechanisms of the heart function. Intracardial mechanisms of regulation of the heart function.
3. Extracardial mechanisms of heart regulation. Effects of sympathetic and parasympathetic parts of the autonomic nervous system on heart function.
4. Receptor, ion and molecular mechanisms of neurotransmitter and hormonal effects on the rate and force of heart contractions.
5. Reflectory mechanisms of heart regulation. The tone of nervous centers regulating heart function.
6. Characteristics of basic reflex reactions of the heart to the stimulion of vascular and non-vascular reflex zones.
7. Humoral mechanisms of regulation: the effect of catecholamines, angiotensine II, electrolytes and metabolites on heart function.
8. Characteristics of heart functioning under physical and psychoemotional exertions (HR, SV, CO, contractility, coronary blood flow, metabolism).

Self check:

1. Give the equation showing the association of Blood Pressure, Total Peripheral Resistance, Heart Rate and Stroke Volume of the heart.
2. In what way will the following factors change: K^+ output, excitability of cardiomyocytes, HR, duration of PQ, RR intervals, end-systolic volume, heart muscle contractility, cardiac energy expenditures, cardiac output, and BP, when parasympathetic effects increase?

3. In what way and why will the listed above factors change, when the heart is affected by: antagonists of the nicotinic cholinergic receptors (e. g. d-tubocurarine myorelaxant), antagonists of muscarinic cholinergic receptors (e. g. atropine)?

4. In what way will the following factors change: cardiomyocytes adenylate cyclase activity, Ca^{2+} entry to the cell, cardiomyocytes excitability, HR, duration of PQ, RR intervals, end-systolic volume, heart muscle contractility, energy expenditures and oxygen consumption by the heart, cardiac output, and BP, when sympathetic effects on the heart increase?

5. In what way and why will the listed in point 4 factors change, when the heart is affected by blockers of β-adrenoreceptors?

6. What reflectory changes of the heart function will occur in response to the fast increase of the systemic BP? Describe the reflex arch links.

7. What reflectory changes of the heart function will occur in response to the fast increase of BP in the pulmonary artery?

8. Why is reflectory suppression of the heart function possible during surgery of the abdominal cavity?

9. What changes of HR, SV, CO, BP do occur when a person quickly passes from horizontal to vertical position?

10. In what way and why will the heart function change under the influence of: significant increase of K^+ ions level; excess of Ca^+ ions; overdose of calcium canals blockers; angiotensine II?

PRACTICAL WORKS

Work 18.1. OCULOCARDIAC REFLEX (DAGNINI–ASCHNER REFLEX)

In norm, when pressure is applied to the eyeballs, the pulse rate decreases by 4-10 beats/min.

Accomplishment. Pulse rate is counted, when the patient is lying. Then during 20–30 seconds eyeballs of the patient are carefully (so as not to cause him unpleasant sensations) pressed and simultaneously pulse rate is counted. When pressing is discontinued the pulse rate is counted again during 20 seconds.

Results: Pulse rate (PR) was:

in lying position before pressing _____ beats/min;

during the pressing the eyeballs _____ beats/min;

PR difference _____ beats/min;

after pressing discontinuation_____ beats/min.

Pulse decrease more than 10 beats/min indicates an excitability increase of a parasympathetic part of the autonomic nervous system. Decrease under 4 beats/min or pulse acceleration (reversed reaction) indicates the domination of a sympathetic part of ANS.

Explain the mechanism of PR change in the examined _____
_____
_____.

Make a conclusion about the tone of sympathetic and parasympathetic parts of ANS in the examined during examination _____
_____.

What PR changes may occur on careful pressing on the projection points of the carotid sinus on the neck _____
_____?

What is the practical application of these reflexes _____
_____
_____?

Work 18.2. ORTHOSTATIC REFLEX

The work was conducted earlier at the lesson "Physiology of ANS".

When a person is passing from lying to standing position the heat rate increases in norm by 6–24 beats per minute.

Accomplishment. The pulse is counted in the examined, when he is lying in a relaxed state during 4–6 minutes. Then he must stand up quickly, and his pulse is counted again in 10–30 seconds.

Results. Pulse rate (PR) was:

in lying position _____ beat/min;

in standing position _____ beats/min;

pulse rate difference _____ beats/min.

Explain the mechanism of PR change in the examined.

Passing to standing position→ …

Make a conclusion about the tone state of sympathetic and parasympathetic parts of ANS in the examined _____
_____.

Work 18.3. EFFECT OF SOME SUBSTANCES ON THE FUNCTION OF A FROG'S ISOLATED HEART (demonstration of videos)

The preparation of an isolated frog's heart is one of classic objects of physiologic experiments used for studying humoral regulation mechanisms of heart functioning.

Task. Draw a mechanocardiogram of the frog's heart perfused with Ringer's solution that presents the effect of acetylcholine (1), adrenaline (2), excess of K^+ ions (3), calcium (4) on heart work.

Mechanocardiogram.

Answer the following questions:

1. In what way does the heart function change under the influence of: moderate increase of Ca^{2+} ions level in extracellular environment _____; considerable excess of Ca^{2+} ions _____?

2. In what way do the blockers of slow calcium channels act on the permeability of slow calcium channels of the sinus node cells _____; the automaticity of the sinus node _____; myocardial conductivity _____; duration of PQ _____ and RR intervals _____, HR _____?

3. In what way do the following factors change under the increase of the sympathetic effects on the heart: cardiomyocytes adenylate cyclase activity _____, slow calcium channels permeability _____, Ca^{2+} entry into the cell _____, excitability of cardiomyocytes _____, HR _____, duration of PQ ____, RR _____ intervals, ESV value _____, heart contractility _____, cardiac output, BP ____, myocardial energy expenditures ____, and oxygen consumption ____?

Work 18.4. Effect of parasympathetic and sympathetic parts of the autonomous nervous system on heart function

Fill in the gaps**:**

Parasympathetic heart innervation	***Sympathetic heart innervations***
1. Preganglionic neuron — localization _____ _____	1. Preganglionic neuron — localization _____ _____
2. Preganglionic fibers neurotransmitter _____	2. Preganglionic fibers neurotransmitter _____
3. Type of receptors on the membrane of postganglionic neuron _____ _____	3. Type of receptors on the membrane of postganglionic neuron _____ _____
4. Postganglionic fibers neurotransmitter _____ _____	4. Postganglionic fibers neurotransmitter _____ _____
5. Predominantly innervated myocardial structures _____ _____	5. Predominantly innervated myocardial structures _____ _____
6. Type of the myocardial receptors _____	6. Type of the myocardial receptors _____
7. Probable neurotransmitter of the signal transmission _____	7. Intracellular neurotransmitter of the signal transmission _____
8. Main changes in the cell under re-	8. Main changes in the cell under re-

ceptors stimulation _____
_____

9. Effects on the main indices of the heart function: HR _____;
Stroke Volume _____; CO _____;
excitability _____;
conductivity _____;
contractility_____.

ceptors stimulation _____
_____

9. Effects on the main indices of the heart function: HR _____;
Stroke Volume _____; CO _____;
excitability _____;
conductivity _____;
contractility_____.

Lesson 19. REGULATION OF BLOOD CIRCULATION 2 (REGULATION OF THE ARTERIAL BLOOD PRESSURE)

Basic questions:

1. Reflectory mechanisms of regulation of blood circulation. Vasomotor center, its afferent and efferent connections. Basic reflexogenic zones.
2. Short-term reflex mechanisms of BP regulation by modifying the heart function and peripheral resistance.
3. Intermediate and long-term neuro-humoral mechanisms of BP regulation. Renin-angiotensin-aldosterone system (RAAS). The role of excretory organs in long-term regulation of the circulating blood volume and blood pressure.
4. Humoral regulation of blood circulation. Receptor mechanisms of regulation of vascular smooth muscle tone by neurotransmitters, hormones and other vasoactive substances.
5. The concept of the functional system of BP regulation.
6. Local regulating mechanisms of circulation. The effect of nervous, metabolic, myogenic mechanisms and factors secreted by endothelium on the tone of smooth muscle cells of vessels walls.
7. Peculiarities of blood circulation and its regulation in coronary, cerebral, pulmonary and renal vessels.
8. Theoretic bases of methods of abnormal BP correction.

Self check:

1. Describe the sequence of arterial baroreceptor reflex in response to the fast decrease of BP.
2. In what way will the tone of pressor and depressor parts of vasomotor center change in response to the fast increase of systemic BP; decrease of pO_2, increase of pO_2, increase of pH?
3. In what way will BP, HR and vascular tone change in response to the increase of pressure in the pulmonary artery?
4. What action does noradrenalin produce on myocardial and intestinal vessels? What receptors mediate this effect?

5. What are the stimuli for renin secretion increase? Does renin produce the constriction of vessels itself? What component of RAAS causes vasoconstriction? List the main effects of RAAS activation.

6. What is the difference between basal vascular tone and resting tone?

7. In what way will the vascular tone of skeletal muscles, skin, myocardium, digestive organs change on exercise?

8. In what way will the tone of smooth muscle cells (SMC) of coronary vessels change in decrease of calcium permeability of the plasmatic membrane?

9. List the vessels constricting and dilating factors formed by the endothelium of vessels.

10. What is the myogenic autoregulation mechanism of the organ blood flow in the kidney? What is the physiologic significance of this mechanism?

11. What are the stimuli for atrial natriuretic peptide secretion, what effect does it produce on vascular tone and renal function?

PRACTICAL WORKS

Work 19.1. ORTHOSTATIC TEST

The examined is lying in a relaxed supine position in thermoneutral conditions. Take his BP 3 times during 6 minutes, count HR and take mean values of these factors. After the examined has passed to a standing position, take his BP every 2 minutes and count HR. Insert the obtained data into table 16.

Table 16

Time	**HR beats/min**	**% deviation**	**BP_{syst} mm Hg**	**% deviation**	**BP_{diast} mm Hg**	**ΔBP_{diast} mm Hg**
In supine position (mean values)						
In vertical position: 1^{st} min						
3^{rd} min						
5^{th} min						
7^{th} min						
9^{th} min						

Taking the diastolic pressure is of particular value while assessing the results of orthostatic test.

Hemodynamic reactions are considered normal, when during 10 minutes after passing into vertical position the diastolic pressure decreases no more than

5 mm Hg, systolic — changes in the range ±5 %, HR increases at an average by 20 %.

Conclusion: (Compare the obtained results with the norm) _____ _____.

Work 19.2. ANALYSIS OF RECEPTOR AND ION MECHANISMS OF REGULATION OF BLOOD PRESSURE AND HEART WORK (is performed by the students independently under supervision of the teacher)

The work is performed using the computer program "**Prat**" modeling a virtual experiment on rats.

Fill in the protocol with obtained data (Table 17)

Table 17

Effect of some vasoactive substances on BP and heart function

Effect on the heart	HR	BP_{syst}	BP_{diast}	BP_{mean}
Initial values				
Nifedipine$^{(Ca\ 2+\ channels\ blocker)}$ 2 mg/kg				
Nifedipine$^{(Ca\ 2+\ channels\ blocker)}$ 10 mg/kg				
Nifedipine$^{(Ca\ 2+\ channels\ blocker)}$ 20 mg/kg				
Isosorbide dinitrate$^{(source\ of\ NO\ formation)}$ 100 mg/kg				

Fill in the gaps in answers to questions on peculiarities of innervations and effect of parasympathetic and sympathetic parts of the autonomic nervous system on vascular tone:

Parasympathetic innervation

1. Preganglionic fibers neurotransmitter _____
2. Type of receptors on the membrane of postganglionic neuron _____ _____
3. Postganglionic fibers neurotransmitter _____
4. Innervated vessels _____ _____
5. Type of the receptors of the vessels' smooth muscle cells _____
6. Intracellular second messenger _____
7. Changes in the smooth muscle cell

Sympathetic innervations

1. Preganglionic fibers neurotransmitter _____
2. Type of receptors on the membrane of postganglionic neuron _____ _____
3. Postganglionic fibers neurotransmitter _____
4. Innervated vessels _____ _____
5. Type of the receptors of the vessels' smooth muscle cells _____
6. Intracellular second messenger _____
7. Changes in the smooth muscle cell

state under stimulation of muscarinic cholinergic receptors _____ _____.

state under stimulation of α-adrenoreceptors _____ β-adrenoreceptors _____.

Fill in the missing parts in the text:

Increase of smooth muscle cells plasma membrane permeability for calcium ions results in _____ of the vessels tone, decrease — in _____. Increase of smooth muscle cells endoplasmatic reticulum membrane permeability for calcium ions results in _____ of the tone of vessels.

Sources of calcium ions for smooth muscle cell contraction are:

Basic receptors and intracellular messengers participating in regulation of the intracellular calcium level are:

Put down a sequence of intracellular signal transmission in activation of alpha- and beta-adrenoreceptors of smooth muscular cells of vessels:

Noradrenaline+α-adrenoreceptor → …

Adrenaline+β-adrenoreceptor → …

List vasodilating and vasoconstricting factors, **formed by the endothelium** of vessels:

Vasoconstricting:

Vasodilatating:

Fill in the table (including all hormones, mediators etc.):

Vasoconstricting substances	Vasodilatating substances

Fill in the table:

Effect of adrenaline (epinephrine) and noradrenaline (noepinephrine) on vessels at moderate exercise or moderate emotional stress

Organs	Vascular response	Types of adrenoreceptors in vessels
Myocardium		
Skeletal muscles		
Intestine		
Skin		

TOPICS OF THE SECTION ARE PASSED _____

Teacher's signature

PHYSIOLOGY OF RESPIRATION

Lesson 20. LUNG VENTILATION AND BASIC TYPES OF ITS DISORDER

Basic questions:

1. The importance of respiration for the organism. Basic respiration stages.
2. Physiologic role of respiratory ways and lungs.
3. Neural control of respiratory muscles. Biomechanics of an inspiration and expiration.
4. Compliance of the lungs and chest wall. Elastic recoil of the lungs. Surfactant functions.
5. Intrapleural pressure, its changes during respiration.
6. Lung volumes and capacities. Spirometry, spirography.
7. Peak expiratory flow and other flow factors of pulmonary ventilation. Test (index) of Tiffno. The curve "flow-volume".
8. Obstructive and restrictive lung disorders, their causes and indices.
9. Blood flow in the lungs. Effect of gravity on pulmonary blood flow and ventilation. Ventilation/perfusion ratio in different regions of the lungs.

Self check:

1. What is the difference between anatomical and physiological dead space? What is the cause of alveolar dead space existence?
2. Calculate alveolar ventilation if tidal volume (TV) = 450 ml and respiration rate (R) = 10/min.
3. In what way does the respiration rate influence alveolar ventilation?
4. Calculate pulmonary residual volume and functional residual capacity (FRC), if the total lung capacity is 7l, inspiratory reserve volume (IRV) = 3,5 l, tidal volume (TV) = 0,5 l, expiratory reserve volume (ERV) = 1,5 l.
5. In what way will the surface tension of alveoli, elastic recoil of the lungs and pleural pressure change in the lack of surfactant?
6. What will be the pressure in the pleural cavity in open pneumothorax?
7. The forced expiratory volume for the 1st second (FEV_1) is 1,9 l, forced vital capacity (FVC) — 2,1 l. Calculate Tiffno's index and make a conclusion.
8. Make a conclusion on the following respiration factors:

Vital Capacity (VC) = 92 %, Peak Expiratory Flow (PEF) = 84 % of the norm; MEF_{25} = 93 %, MEF_{50} = 81 %, MEF_{75} = 62 % of the norm; Tiffno's test = 63 %.

Standards

VC (vital capacity)	men — 4–7 l; women — 3–5 l
TV (tidal volume) at rest	300–800 мл
RR (respiration rate) at rest	9–20 /min
PEF (peak expiratory flow) Due value of PEF = 1,25 × VC	men — 5–10 l/s; women — 4–8 l/s
Tiffno's test (*Tiffeneau*)	70–85 %

PRACTICAL WORKS

Work 20.1. SPIROMETRY

Materials and equipment. A water spirometer, disposable or repeatedly sterilized mouth-pieces, masks, connection hoses. Before taking respiratory volumes it better to use a special nose clamp for complete blocking of expiration through the nose.

1. Determination of vital capacity.

After a maximal inspiration a slow maximal deep expiration is made into the spirometer tube, the mouth-piece is clamped by the mouth.

One of the ways of calculating DVC (due vital capacity) is its determination using tables of Harris-Benedict. The value of due basic exchange is taken from the tables on the basis of height, body mass and age; then it is multiplied by index 2,6 for men or 2,2 for women. The difference between the measured VC and due VC should not exceed 20 %.

Results: VC = _____, DVC = _____ ml.

DVC–VC= _____, that is _____ % of VC.

2. Effect of the body posture on VC value.

Determine VC value in standing, sitting and lying position.

Obtained data:

VC in standing _____, sitting _____, lying position _____.

Conclusion (effect of the body posture on VC value):

3. Effect of expiration rate on VC value (Votchal's test).

Determine VC in the examined, then FVC (forced VC). To determine FVC a *fast* maximally deep expiration is made after a maximal inspiration. In norm the difference between VC and FVC does not exceed 300 ml. The increase of this difference evidences the constriction (obstruction) of bronchi.

Results: VC = _____, FVC = _____, VC – FVC = _____.

Conclusion:

4. Determination of the lung volumes.

The examined must make 5 quiet expirations into the spirometer. To determine a mean tidal volume (TV) the obtained total air volume is divided by 5.

To determine an expiratory reserve volume (ERV) the examined, having made a quiet expiration, expires the residue of the air into the spirometer.

Direct determination of an inspiratory reserve volume (IRV) is impossible with the spirometer, as the device is intended only for expiration into a measuring cavity. To find IRV it is necessary to extract the value of TV and ERV from VC.

Results:
TV = _____ (the norm is 300–800 ml; 15–20 % of VC).
ERV = _____ (the norm is 20–33 % of VC).
IRV = VC – ERV = _____ (the norm is 55–66 % of VC).
Conclusion (compare the obtained data with the norm):

Work 20.2. SPIROGRAPHY (teaching video)

Spirography is a method of graphic registration of inspired and expired air volumes.

To determine the most important respiratory volumes and capacities by spirography, first of all, quiet breathing of the examined is recorded, then the examined must make a maximally deep inspiration and immediately a maximal expiration — to determine VC. Then quiet breathing is recorded again. At the end of examination the examined must make a maximum hyperventilation during 12–15 sec. It allows determination of maximum ventilation of the lungs (MV) per 1 min.

Spirogram (drawing). Indicate TV, IRV, ERV, VC, FRC.

Table 18

Spirogram analysis

Factor	Measurement result	Norm
1. Respiration rate	12 /min	9–20 / min
2. Rhythmicity of respiration	rhythmic	rhythmic
3. Tidal volume	500 ml	300–800 ml
4. Inspiratory reserve volume	1500 ml	55–66 % of VC
5. Expiratory reserve volume	1200 ml	20–33 % of VC
6. Vital capacity	……	3–7 liters
8. Functional residual capacity	……	33–46 % of VC
9. Minute ventilation	…….	4–9 l/min
10. Alveolar ventilation	…….	AV = 80–65 % of VC

Conclusion (compare the obtained data with the norm):

Work 20.3. PNEUMOTACHOMETRY (PEAKFLOWMETRY)

Pneumotachometry or flowmetry is a technique for the flow velocity measurement on inspiration and expiration. The most common are peakflowmeters taking the maximal (peak) flow velocity of an expiration (Peak Expiratory Flow).

Accomplishment. The device switch should be in position "expiration". The examined, clasping tightly the peakflowmeter tube with his mouth, makes a maximal forced expiration through the mouth. The result is determined by a maximum deviation of the manometer meter.

To determine the flow velocity of an inspiration the device switch is set to position "inspiration", then a maximum forced inspiration is made through the tube.

The peak (maximum) expiratory flow in adults is 4–10 l/sec. To find the due volume flow of expiration (DPEF) the following formula is used:

$$DPEF = 1{,}25 \times VC$$

The acceptable deviation of DPVV must not exceed ±20 %.

Peak inspiratory flow is usually a bit less than PEF, but it shouldn't be less than 3 l/sec.

Peakflowmetry has a great significance in diagnosing obstructive disorders of the lungs. In marked bronchi obstruction PEF is significantly reduced.

Obtained results:

Peak expiratory flow =

Due peak expiratory flow =

Peak inspiratory flow =

Conclusion (if any signs of obstructive impairments revealed):

Work 20.4. STUDYING OF VENTILATION INDICES USING COMPUTER SYSTEM CARDIOVIT CS-100

Table 19

Basic ventilation indices and their abbreviations used in studies of external respiration

Symbols	Measurement u	Full name
VC	l	Vital capacity
FVC	l	Forced vital capacity
TV	l	Tidal volume
FEV_1	l	Forced expiratory volume for the 1st sec

Ending of the table 19

Symbols	Measurement u	Full name
FEV_1/FVC	%	Tiffno's test = Tiffno's index
PEF	l/sec	Peak expiration flow
MEF_{25}	l/sec	Maximum (instant) expiration flow at the moment of 25 % FVC
MEF_{50}	l/sec	-------- ------- at the moment of 50 % FVC
MEF_{75}	l/sec	-------- ------- at the moment of 75 % FVC
$MEF_{25–75}$	l/sec	Mean expiration flow from 25 % to 75 % FVC
$MEF_{75–85}$	l/sec	-------- -------- -------- from 75 % to 85 % FVC
MV	l/min	Minute volume
MVV	l/min	Maximum ventilation

Accomplishment of the test: When the signal "Ready" appears on the monitor, the examined makes a maximally deep inspiration and then he makes a forced maximally deep expiration into the tube or mask connected to the device, then immediately — a forced maximally deep inspiration. The device traces the value of air volume flow at every moment of the respiratory cycle and gives out graphs of expiration and inspiration flows, a number of calculated factors and a conclusion of the state of external respiration of the examined.

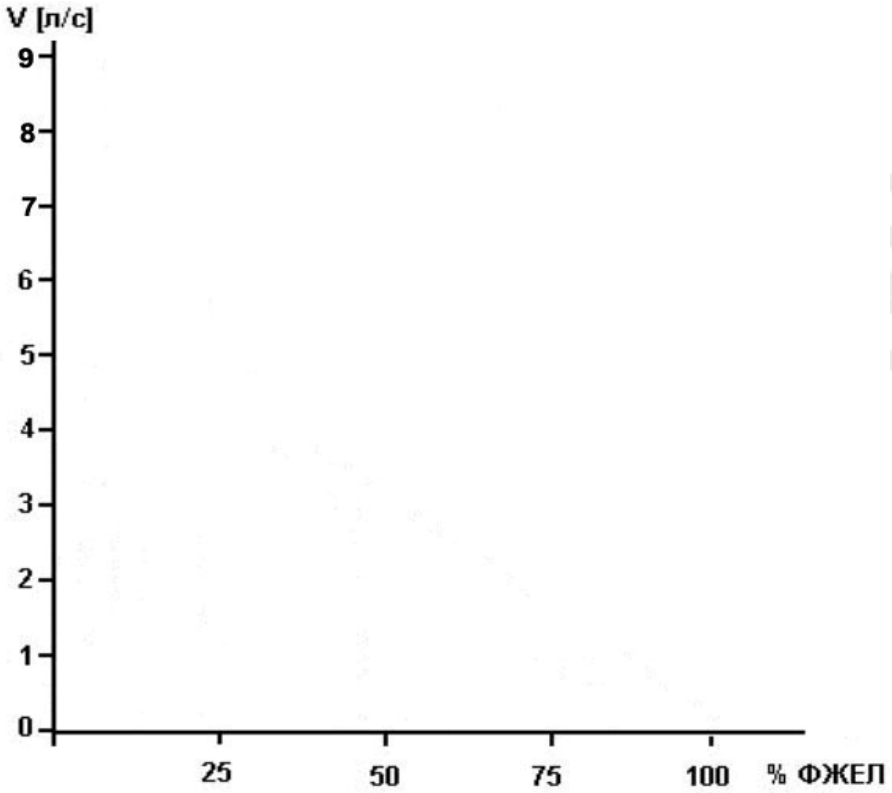
Test results of one of the examined are given for analysis

Table 20

Factors	Measured values	Due values	% of the norm
Forced vital capacity (FVC)	**4,63 l**	5,25 l	**88**
Forced expiratory volume for the 1st sec (FEV_1)	**3,94 l**	4,16 l	**71**
Index Tiffno (FEV_1/FVC)	**63,5%**	81,4%	**78**
Peak expiration flow (PEF)	**7,21 l/sec**	9,47 l/sec	**76**
Maximum expiration flow at 25 % FVC (**MEF_{25}**)	**4,74 l/sec**	8,21 l/sec	**58**
Maximum expiration flow at 50 % FVC (**MEF_{50}**)	**1,96 l/sec**	5,27 l/sec	**37**
Maximum expiration flow at 75 % FVC (**MEF_{75}**)	**0,53 l/sec**	2,03 l/sec	**26**
Mean expiration flow 25 % to 75 % FVC (MEF_{25-75})	1,52 l/sec	4,26 l/sec	36
Mean expiration flow 75 % to 85 % FVC (MEF_{75-85})	0,36 l/sec	1,00 l/sec	36

On the basis of obtained results (**MEF_{25}, MEF_{50}, и MEF_{75}**) draw the curves "flow-volume" — one curve for measured values and the other — for the due values of flow expiration velocity. Take into consideration that at the start and by the end of expiration the flow velocity is 0.

Curve «flow-volume»



On the basis of all obtained data make a conclusion of the presence or absence of any signs of the obstructive or restrictive lungs disorders in the examined.

Conclusion:

Lesson 21. GAS EXCHANGE IN THE LUNGS AND TISSUES. TRANSPORT OF GASES BY THE BLOOD

Basic questions:

1. The composition of atmospheric, expired and alveolar air.
2. Partial pressures of oxygen and carbon dioxide in alveolar air and their tension in blood.
3. Factors affecting O_2 and CO_2 diffusion between alveolar air and blood.
4. Oxygen transport in blood. States of hemoglobin bound with gases. Oxygen capacity of the blood.
5. Oxyhemoglobin dissociation curve. Factors affecting the affinity of hemoglobin to oxygen.
6. Carbon dioxide transport in blood. The role of carbonic anhydrase.
7. Gas exchange between the blood and tissues.
8. The oxygen utilization coefficient for the tissues at rest and at exercise.

Self check:

1. Why does the exhaled air contain more oxygen than the alveolar air?
2. What is the value of oxygen partial pressure (pO_2) in alveolar air in mountain climber during ascent to the mountain, where P_{atm} = 547 mm Hg, if the oxygen content in alveolar air is 15 %?
3. Determine the oxygen blood capacity, if the blood Hb content is 120 g/l.
4. In what way will the affinity of hemoglobin to O_2 and dissociation of oxyhemoglobin change: in acidosis, in increase of pCO_2; in temperature decrease?
5. What is the mean value of pCO_2 of venous blood? What is the percentage content of oxyhemoglobin in venous blood at this pO_2 level?
6. If at pO_2 = 60 mm Hg the blood contains 95 % of oxyhemoglobin, does it correspond to the norm or is it a sign of the shift of the oxyhemoglobin dissociation curve to the right or to the left?
7. Oxygen consumption in the examined is 250 ml/min, blood volume is 5 l, Hb content is 150 g/l. Calculate the amount of O_2 that is contained in the blood of this person. For how long will this oxygen amount be enough in the given level of its consumption?
8. Calculate the cardiac output (minute blood volume) if the O_2 consumption by a man is 750 ml/min, Hb content in the blood is 90 g/l, oxygen content in venous blood is 5 vol.%.

Standards

Diffusion capacity of the lungs for oxygen (at rest)	15–30 ml/min/mm Hg
Oxygen tension in arterial blood, pO_2	85–100 mm Hg
CO_2 tension in arterial blood, pCO_2	35–45 mm Hg
Oxygenation of hemoglobin in arterial blood, % of HbO_2	95–98 %
Oxygen utilization coefficient: at rest at exercise	30–40 % 50–60 %
Oxygen volume, bound by 1 g of hemoglobin	1,34 ml

PRACTICAL WORKS

Work 21.1. EVALUATION OF ALVEOLAR AND EXPIRED AIR CONTENT. CALCULATION OF FUNCTIONAL DEAD SPACE VOLUME (demonstration of a teaching video)

To perform the work a precision analyzer of CO_2 is necessary, a spirometer, a spirograph, and a chamber for collecting alveolar air.

The method for calculation of the **physiological dead space** (PDS) volume is based on determination of the CO_2 content difference in expired and alveolar air. As this difference is due to the presence of dead space, its value must be proportional to

the difference of CO_2 contents. In assuming that CO_2 content of atmospheric air is equal to 0, the Bohr's formula for calculating dead space looks as follows:

$$PDS = \frac{TV \cdot (\%\ CO_{2\ alv} - \%CO_2}{\%\ CO_{2\ alv}},$$

where TV — tidal volume, % CO_{2alv} and % CO_{2ex} — percentage content of carbon dioxide in alveolar and expired air respectively.

Accomplishment. To get expired air the examined must make 5 quiet expirations into the spirometer. To calculate the respiration rate the time spent on these 5 respiratory cycles is determined by the stop-watch. The mean value of respiratory tidal volume (TV) is calculated by dividing the obtained volume by 5. Then CO_2 content (%CO_{2ex}) is determined in the collected expired air.

To determine the content of carbon dioxide in alveolar air (%CO_{2alv}) the examined must expire only the last portion (300–400 ml) of the expiratory reserve volume into a special chamber. Then the obtained alveolar air is passed through the gas analyzer and CO_2 content is determined.

In norm the value of PDS is 20–35 % of the tidal volume (TV), and alveolar ventilation is 65–80 % of minute volume (MV). Increase of PDS evidences the decrease of external respiration efficiency and impairment of normal ventilation/perfusion ratio.

Obtained results: (tidal volume, respiration rate, minute ventilation**)**

TV = _____ ml, RR = _____, MV= _____ ml.

% $CO_{2\ ex}$ = _____, % $CO_{2\ alv}$ = _____,

PDS = TV × = $\frac{(\%\ CO_{2\ alv} - \%CO_2}{\%\ CO_{2\ alv}}$ = _____

PDS/TV ratio = % (in norm — 20–35 % of TV).

PDS factor is used for calculation of *effective* alveolar ventilation (AV_{ef}) of the examined: $AV_{ef} = MV - (RR \times PDS)$.

Conclusion: (assess PDS value and put down the definition of physiological dead space).

Work 21.2. OXYHEMOMETRY, OXYHEMOGRAPHY, PULSE OXYMETRY (demonstration of a teaching video)

The listed methods are based on measurement of light absorption (or reflection) of waves of a certain wavelength by blood hemoglobin in tissues transillumination (of the ear, fingers, etc.). These methods allow continuous observation of blood oxygen saturation changes.

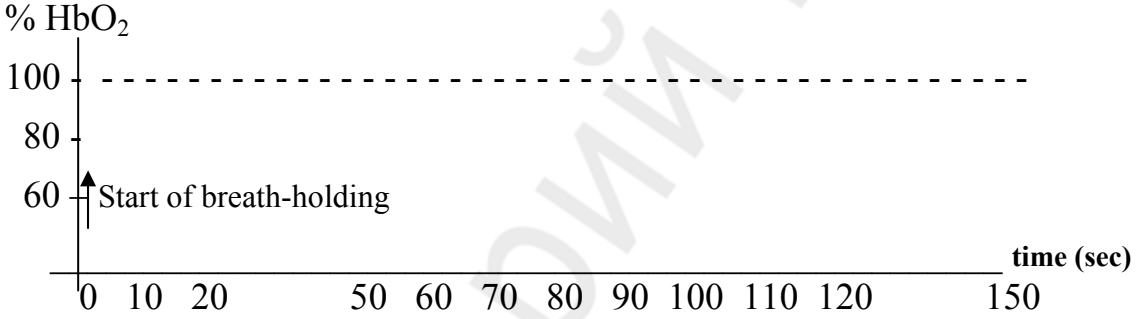
Effect of breath-holding on blood oxygen saturation

The examination is performed on healthy people. During the test the state of the examined must be carefully monitored. In abrupt acceleration or weakness of pulse, arrhythmia appearance, occurrence of paleness or change of the skin and lips color, the test should be discontinued. Breath-holding lasts 90 sec (1,5 min). Blood oxygenation is registered during the test and for 1 minute after the holding of breath has been discontinued.

Results (obtained in a video):

	Breath-holding								**Restart of respiration**			
Time in sec	0	10	20	50	60	70	80	90	100	110	120	150
% HbO_2	96	96	95	92	88	75	70	60	85	90	92	94

Present the obtained results as a graph:



Conclusion: (In what way does % HbO_2 change during the breath-holding? How fast does the oxygen blood saturation restore on restart of respiration?)

Work 21.3. MODELING A MISMATCH OF VENTILATION AND BLOOD FLOW IN THE LUNGS, ITS EFFECT ON GAS EXCHANGE AND EXTERNAL RESPIRATION

The work is performed using the program **PhysioLogy** that allows modeling the effect of various factors on functions of the hemocardiorespiratory system and determination of respiration, blood flow, gas transport and gas exchange changes in the organism depending on the conditions of external and internal environment.

The monitor shows a diagram of ventilation and blood flow in the lungs, as well as a number of factors characterizing respiration, gas exchange and blood flow.

Factors used in work 21.3:

PAO_2 — pO_2 of alveolar air, 105–110 mm Hg.

PaO_2 — pO_2 of arterial blood, 90–100 mm Hg.

SaO_2 — hemoglobin saturation with oxygen, 95–99 %.
$PACO_2$ — pCO_2 of alveolar air, 36–40 mm Hg.
$PaCO_2$ — pCO_2 of arterial blood, 35–45 mm Hg.
$PaCO_2$–$PACO_2$ — difference of arterial and alveolar pCO_2, up to 4 mm Hg.
Vd/VT — PDS/TV ratio, up to 35 %.
RR — respiration rate = 9–20 /min, TV — tidal volume, 0,3–0,9 l.
MV — (in this program) — alveolar ventilation.
V:Q — ventilation/blood flow ratio.

The increase of VENTILATION/PERFUSION ratio (↑V/Q) in the lungs may occur both due to **ventilation increase (↑V)** and to the **blood flow decrease (↓Q).**

Modeling pulmonary hyperventilation (↑V). In rubric **Respiratory** replace **Variable** for **Fixed** with a click. Then click a left key of the mouse and change the normal value of alveolar ventilation (MV) equal to 5–5,0 L/min for a bigger one — 12 L/min. Discontinue hyperventilation in 30 sec (**File**, **Pause**). Fill in the table with factors of gas composition of alveolar air and blood that have changed during hyperventilation.

Modeling decrease of pulmonary blood flow (↓Q) in upper lobes of the lungs. Open the program **PhysioLogy** again. Using the mouse gradually decrease the blood flow in the upper lobe of the lungs from 25 to 0 that corresponds to a stop of blood flow in the upper lobe. Such situation may occur in marked hypovolemia, in blood loss, pulmonary artery embolism, etc. Stop the process in 2 minutes (**File**, **Pause**). (The necessary factors are already filled in the table).

Table 21

Factor	In norm	In hyperventilation for 30 sec	After stop of the pulmonary artery blood flow for 2 min
PAO_2	107,9 mmHg		123,6 mmHg
PaO_2	100,7 mmHg		106,1 mmHg
SaO_2	96,3 %		96,7 %
$PACO_2$	36,5 mmHg		22,8 mmHg
$PaCO_2$	37,0 mmHg		37,6 mmHg
$PaCO_2 – PACO_2$	0,5 mmHg		14,6 mmHg
Vd/VT	25,2 %		50,8 %
pH	7,4		7,37
RR = Resp. rate	10 /min		12 /min
TV	0,62		0,80 L
MV (AV)	4,7 L/min		7,66 L/min

Answer the questions:

1. What is the effect of hyperventilation on the composition of alveolar air and gases content in the blood?

2. What unfavorable changes may occur in the organism as a result of excess ventilation in the lungs?

3. Which of the above factors carry most information for revealing a mismatch of ventilation and pulmonary blood flow?

4. What factors may help determine that decrease of alveolar pCO_2 is caused by hyperventilation and not by decrease of pulmonary blood flow?

Lesson 22. REGULATION OF RESPIRATION

Basic questions:

1. Respiratory center, its parts. Mechanisms ensuring respiratory periodicity.
2. Central and peripheral receptors of pH, CO_2 and O_2 in the organism, their role. Factors stimulating the respiratory center of the brainstem.
3. Receptors of respiratory ways, lungs and respiratory muscles. Reflex reactions to their stimulation. Herring-Breyer's reflexes.
4. Relationship between gas exchange and acid-base balance.
5. Nervous and humoral mechanisms of regulation of the respiratory ways.
6. Respiration at exercise, at increased and decreased atmospheric pressure.
7. Mechanisms of the first inspiration of a newborn.
8. Hypoxia and its signs. Theoretic bases of artificial respiration.

Self check:

1. What consequences for respiration and other functions will the spinal cord rupture at level C_1–C_2 and C_8–Th_1 produce?
2. Why not pure oxygen is used in reanimation, but carbogen — a mixture of 93–95 % O_2 and 5–7 % CO_2?
3. Calculate the blood volume flowing through pulmonary circulation if oxygen content in arterial blood is 20 vol.%, in mixed venous blood — 15 vol.%, and O_2 consumption = 300 ml/min.

4. In what way will respiration change in the following factors of arterial blood: pO_2 82 mm Hg, pCO_2 51 mm Hg, pH 7,30?

5. In what way will pH of the blood change in hyperventilation? In what way will respiration change in alkalosis?

6. In what way will respiration change in stimulating j-receptors (juxta-capillary)? What stimulates these receptors?

7. What effect do acetylcholine, histamine and adrenaline produce on respiratory ways?

8. What factors cause pulmonary ventilation increase at exercise?

PRACTICAL WORKS

Work 22.1. TESTING THE STRENGTH OF RESPIRATORY MUSCLES (demonstration of a teaching video)

Evaluation of respiratory muscles strength is important for differential diagnosis of external respiration disorders caused by respiratory system pathology or associated with weakness of respiratory muscles.

Weakness of respiratory muscles may occur in damage of the respiratory center, in impairments of excitation conduction in descending nerves and neuromuscular junctions, as well as in diseases of muscles themselves.

Weaknesses of respiratory muscles may be due to hereditary or acquired diseases of the nervous system, poisonings of the respiratory center with narcotics and toxins, epileptic states, electrolyte level dysbalance, particularly of potassium, calcium, magnesium; impairments of neuromuscular transmission in botulism, poisoning with organophosphorous compounds, overdose of myorelaxants; muscular lesions in collagenoses, myopathias of various nature, etc.

The strength of respiratory muscles is judged by maximum inspiration pressure (MIP) and maximum expiration pressure (MEP). The initial position of the thoracic cavity for evaluating muscular strength of an inspiration is a maximum expiration, for evaluating muscular strength on expiration — a maximum inspiration.

Normal MEP for men is 120–230 cm of water column (12–23 kPa, 85–170 mm Hg), for women — 80–150 cm of water column (8–15 kPa, 55–110 mm Hg). Normal value of MIP for men is 40–130 cm of water column (4–13 kPa, 30–95 mm Hg), for women — 30–90 cm of water column (3–9 kPa, 20–65 mm Hg).

Measurement results:

MIP = _____, MEP = _____.

Conclusion:

Answer the question: The patient has VC = 70 % of the norm, MIP = 20 cm of water column; MEP = 40 cm of water column, Tiffno's index = 70 %. Is it possible to make a conclusion about the presence of restrictive disorder in the patient on the bases of these factors? Why?

Work 22.2. Effect of CO_2 tension increase in alveolar air on external respiration

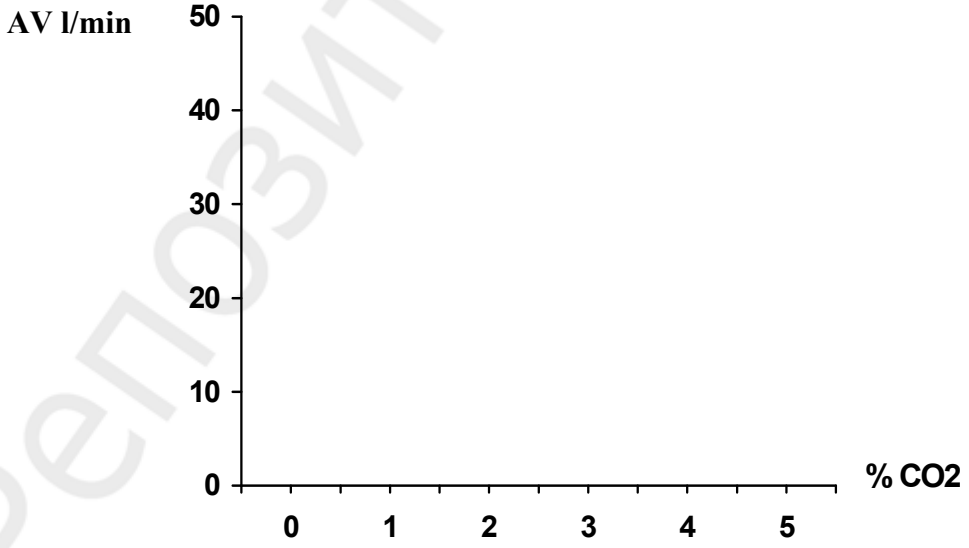
The computer program **PhysioLogy** is used for this work. Full names of the factors were presented in work 21.3.

Modeling pCO_2 increase in the alveolar air: set factor $FiCO_2$% in section **Inspired gas** for 30–40 sec to 3 %, then to 4 % and 5 %. (Initial values of factors and their changes after pCO_2 increase are already recorded in the table.)

Table 22

Factor	CO_2 content in inspired air			
	0 %	**3 %**	**4 %**	**5 %**
$PACO_2$	36,5 mm Hg	37,2	38,8	39,4
$PaCO_2$	37 mm Hg	37,8	39,3	39,7
MV	**4,71 l/min**	**13,1**	**18,5**	**51,1**
RR	10 /min	15	18	29
TV	0,62 l	1,02	1,20	1,93
pH	7,41	7,40	7,39	7,38

Draw a dependence graph of alveolar ventilation (the line is in bold type) versus CO_2 content in inspired air.



Conclusion: (in what way does CO_2 content of the alveolar air affect pulmonary ventilation (by the graph) and pH (by the table data))

Lesson 23. TESTING RESERVES OF THE CARDIO-RESPIRATORY SYSTEM

Basic questions:

1. Calculation of functional reserves of external respiration for oxygen supply to the lungs in a healthy person.
2. Calculation of oxygen diffusion value in the lungs at rest and on maximal strenuous exercise.
3. Calculation of reserves of oxygen blood transport in a healthy person.
4. Indices of the heart functional reserves. Coronary blood supply as a limiting factor of cardio-respiratory system reserves in a healthy person. Factors evidencing the sufficiency of coronary blood supply.
5. Maximal oxygen consumption. Calculation, methods of evaluation, clinical-physiological assessment.
6. Threshold of anaerobic exchange. Evaluation and assessment.
7. Oxygen debt. Its fractions, evaluation and assessment.
8. Oxygen utilization coefficient of the organism as a whole and of various organs, at rest and at exercise.

Self check:

1. What amount of oxygen is delivered to alveolar space under maximal lung ventilation = 83 l/min and respiration rate 20/min?
2. In what physiological state is a person (rest, mild, moderate, heavy exercise), if his or her cardiac output is 26 l/min?
3. What is the oxygen blood capacity if Hb content is 100 g/l? 140 g/l?
4. How much oxygen is transported by arterial blood per 1 min if Hb content is 150 g/l and cardiac output (CO) is 5 l/min?
5. Hb content is 150 g/l, CO = 25 l/min, O_2 utilization coefficient = 60 %. Calculate the maximal oxygen consumption (MOC).
6. Calculate oxygen consumption by heart muscle, if coronary blood flow is 500 ml/min, O_2 utilization coefficient of the myocardium is 75 %.

Standards

Specific value of MOC (maximum oxygen consumption) in ml/min/kg and its assessment (for untrained people):

MOC value:	Men (under 25 years)	Women (under 25 years)
High	49–54	38–44
Moderate	39–48	31–37
Low	33–38	24–30

PRACTICAL WORKS

Work 23.1. TEST OF A 6-MINUTE WALK

The test is based on measurement of maximum distance that the examined can cover for 6 minutes of intensive walk. The functional blood circulation class (FC) is assessed approximately by table 23.

Table 23

Distance (in meters), covered for 6 min	Functional class of blood circulation
426–550	FC 1
300–425	FC 2
150–300	FC 3
Less than 150	FC 4

Work 23.2. TEST PWC_{170}

Test PWC_{170} (**P**hysical **W**orking **C**apacity) is intended for the evaluation of physical working capacity of sportsmen. Physical working capacity of the tested is expressed by the power of physical load producing HR increase up to 170 beats/min. The choice of this pulse rate is due to the following:

1. Optimal functioning of the cardio-respiratory system in sportsmen is reached in HR range from 170 to 200 beats/min. Thus, the test allows evaluating the intensity of exercise that brings the cardio-vascular system to the limit of its optimal functioning.

2. There is a linear dependence between exercise power and HR till HR = 170 beats/min is reached; in higher HR this dependence is lost. The stronger is the exercise power, when HR reaches 170 beats/min, the greater are reserves of the cardio-vascular system. However due to this linear dependence between the exercise power and HR the tested doesn't need to endure the load resulting in pulse increase exactly to this value. It is sufficient to determine HR in two increasing loads; value of the load producing HR 170 beats/min is calculated by the formula.

The test is performed on bicycle ergometer.

HR of the tested is determined when he is at rest and in sitting position. For 5 minutes he performs the 1st load (N1), the amount of which depends on his body mass (see table 24). The rate of treadling the pedals is constant and equals to 60 turns/min. HR is calculated during the last 30 sec of the load (F1). Then after 3-minute rest the examined performs the 2nd load (N2), the power of which depends on F1 (see table 25). The second load, as a rule, is twice as big as the first one. F2, heart rate after the second load, is determined during the last 30 sec of the test. Normally during performing of the 1st and 2nd loads the pulse of the examined does not reach 170 beats/min.

The power of load, at which HR reaches 170 beats/min (PWC_{170}) is calculated by the formula:

$$PWC_{170} = N_1 + (N_2 - N_1) \cdot (170 - F_1)/(F_2 - F_1),$$

where PWC_{170} is the power of physical load in bicycle ergometer, in kgm/min; N_1 и N_2 — powers of the 1st and 2nd load (in kgm/min); F_1 и F_2 — HR at the end of the 1st and 2nd load perfoming (in beats/min).

In healthy untrained men the value of PWC_{170} is 700–110 kgm/min, in women — 450–750 kgm/min. The relative value of PWC_{170} per 1 kg of body mass in untrained people is on the average: 15.5 kgm/min — in men and 10,5 kgm/min — in women. In sportsmen the value of PWC_{170} may reach 1500–1700 kgm/min.

Table 24

Power of the 1st load (N1) for evaluating PWC_{170} depending on body mass of the examined

Body mass (kg)	Power(kgm/min)*
59 and less	300
60–64	400
65–69	500
70–74	600
75–79	700
80 and over	800

Table 25

Power of the 2nd load (N2) for evaluating PWC_{170} depending on HR during the 1st load power

Power of the first load	Power for the 2nd load, kgm/min				
	HR after the 1st load, beats/min				
	80–89	90–99	100–109	110–119	120–129
400	1100	1000	900	800	700
500	1200	1100	1000	900	800
600	1300	1200	1100	1000	900
700	1400	1300	1200	1100	1000
800	1500	1400	1300	1200	1100

*To evaluate kgm/min in W the value in kgm/min is divided by 6.

Results:

N_1 — kgm/min, N_2 — kgm/min,

F_1 — beats/min, F_2 — beats/min,

$PWC_{170} = N_1 + (N_2 - N_1) \cdot (170 - F_1)/(F_2 - F_1) =$

Body mass of the examined:

Relative value of PWC_{170} per 1 kg of body mass =

Conclusion: (compare the results with the norm; make a conclusion about physical working capacity of the examined).

Work 23.3. REVEALING THE HIERARCHY OF HOMEOSTATIC FACTORS OF RESPIRATION AND BLOOD CIRCULATION (video)

A complex of devices allowing to give graduated physical exercise and follow the parameters of blood circulation and respiration (bicycle ergometer, Cardiovit CS-100, "Spirolit", pulse oxymeter, oxyhematograph, pneumotachograph, tonometer, phonendoscope, analyzer of electrocardiograms, etc.) was used to carry out this work.

The examined is admitted for tests with maximal physical exercise if contraindications are absent. The pulse of the examined must be rhythmic, HR 60–80 beats/min, systolic arterial pressure must not exceed 130, diastolic — 90 mm Hg, oxygenation of arterial blood should be in the range 95–98 %, there must be no signs of myocardial ischemia on ECG, respiration rate no more than 20/min, TV≤ 900 ml, well being of the examined must be good. Only having received these data the examined may start performing the graduated physical exercise.

The exercise consists of 3 stages, each lasts 4 minutes. The power of the 1st stage load is 50 W, the 2nd — 100 W and the 3rd — 150 W. The study is continued for 3 minutes after the exercise has been completed.

Table 26 gives data obtained during bicycle ergometer testing.

Table 26

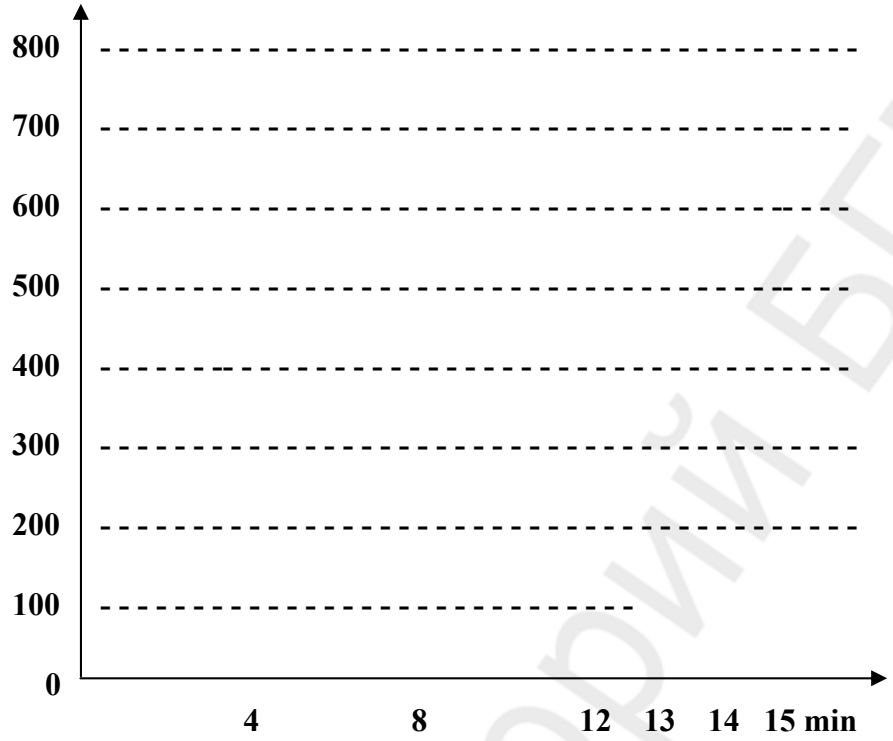
Factors of respiration and blood circulation of the examined at physical exercise (age — 19 years, body mass — 60 kg)

Registered factor	Value of registered factor						
	initial	Load (Wt)			Time after the load (min)		
		50	100	150	1	2	3
RR	**11** 100%	**17** 155%	**19** 173%	**25** 227%	**22** 200%	**20** 182%	**10** 91%
TV	**0,6** 100%	**0,7** 117%	**1,1** 183%	**1,2** 200%	**0,9** 150%	**0,8** 133%	**0,7** 117%
HR (beats/min)	**82** 100%	**118** 144%	**148** 180%	**176** 215%	**168** 205%	**124** 151%	**95** 116%
BP syst/diast (mm Hg)	**130/80** 100%	**140/80** 108%	**150/80** 115%	**170/80** 131%	**165/80** 127%	**150/80** 115%	**135/80** 104%
VO_2 (l/min)	**0,3** 100%	**1,1** 367%	**2,0** 667%	**2,5** 833%	**0,9** 300%	**0,6** 200%	**0,3** 100%
HbO_2 (%)	**96** 100%	**94** 98%	**95** 99%	**95** 99%	**96** 100%	**96** 100%	**96** 100%
pO_2 (mm Hg)	**95** 100%	**90** 95%	**93** 98%	**93** 98%	**95** 100%	**95** 100%	**95** 100%

Abbreviations: RR — respiration rate, TV — tidal volume, VO_2 — oxygen consumption; HbO_2% — content of oxyhemoglobin in the blood; pO_2 — oxygen tension of the arterial blood (is evaluated by HbO_2% and oxyhemoglobin disso-

ciation curve); HR — heart rate, BP **syst/diast** — systolic and diastolic blood pressure.

Using the data from the table draw graphs reflecting the dynamics of studied factors (in % relative to initial values) under the effect of loading. Initial values of all factors are assumed 100 %.



On the basis of obtained data answer the questions:

1. Which of the studied factors changes most of all on physical exercise?

2. Which of the studied factors changes least of all on physical exercise?

3. Due to the shifts of what factors is the constancy of this factor value maintained?

4. Which of the studied factors is the most important for the organism during intensive exercise?

Work 23.4. CALCULATION OF SOME INDICES OF CARDIO-RESPIRATORY SYSTEM RESERVES

There are 2 ways of studying reserves of the cardio-respiratory system. The first is conducting tests requiring maximum physical exercise and the determination of maximal oxygen consumption, cardiac output, etc. Such method gives authentic data about the reserves of studied systems. However, even for healthy people such loads are not safe, and for sick people they are unacceptable. That is why clinical practice uses predominantly tests based on calculations, which allows evaluating reserves of respiration and blood circulation with sufficient precision and minimal physical loads.

Bicycle ergometer testing, performed in the previous work, use moderate, sparing physical loads. Using data obtained in that work we'll calculate a number of factors characterizing functional reserves of cardio-respiratory system of the examined.

Evaluation of maximum oxygen pulse

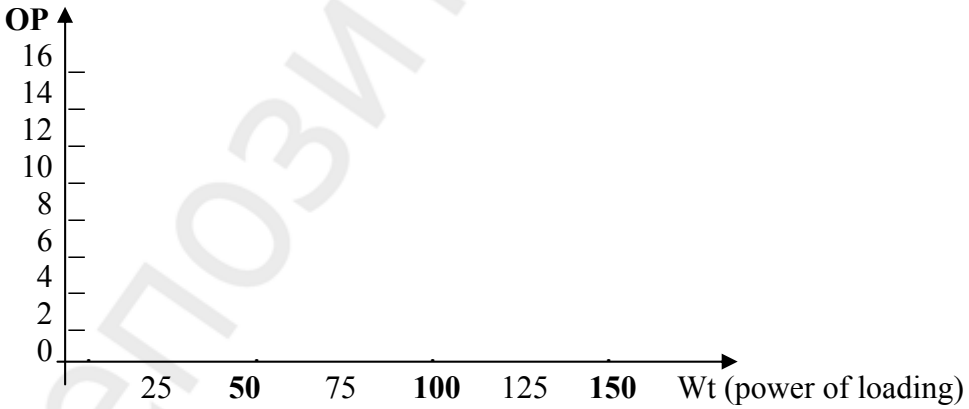
Oxygen pulse (OP) characterizes the oxygen volume consumed from the systolic (stroke) blood volume. It is calculated be the formula:

$$\mathbf{OP}\ (\text{ml/beat}) = \mathbf{V_{O2} / HR},$$

where V_{O2} — oxygen consumption in ml/min; HR — heart rate, beats/min.

Calculate oxygen pulse on loading and make a graph:

	Before loading	**1-st stage**	**2-nd stage**	**3-rd stage**
VO_2, l/min	**0,3** (300 ml/min)	**1,1** (1100 ml/min)	**2,0** (2000 ml/min)	**2,5** (2500 ml/min)
HR, beats/min	**82**	**118**	**148**	**176**
OP, ml/beat				



Approximating the curve of oxygen pulse (to the point of becoming horizontal), determine the value of ***maximal*** oxygen pulse.

OP^{max} = (ml/beat).

Table 27

Normal values of maximal oxygen pulse

Age (years)	**OP^{max} (ml/beat)**

18–19	17,1
20–40	16,8
41–50	15,6
51–60	13
Over 60	11
In sportsmen	To 26
In patients with ischemic disease	Less than10

Conclusion about maximum OP of the examined:

Calculation of maximal oxygen consumption (MOC)

To calculate MOC the formula is used:

$$MOC(ml) = OP^{max} \times HR^{max},$$

где OP^{max} — maximal oxygen pulse (determined above); HR^{max} — heart rate, when the limit of the pumping capacity of the heart is reached. For men at the age of 20–-29 years it is 195 beats/min, for women — 198 beats/min. Thus,

MOC of the examined = OPmax × 195 =

Evaluate the specific MOC per 1 kg of body mass of the examined:

MOC ml/kg/min = MOC : 60 kg =

MOC is evaluated using tables developed for sportsmen, healthy untrained and sick people.

Table 28

MOC and its assessment in UNTRAINED HEALTHY PEOPLE (according to V. L. Karpman et al., 1988)

MOC assessment	MOC value (ml/kg/min)	
	men under 25 years	women 20–29 years
Very high	55	44
High	49–54	38–44
Moderate	**39–48**	**31–37**
Low	33–38	24–30
Very low	33	24

To assess the degree of decreasing the reserves of cardio-vascular system in clinic the concept of functional classes 1–4 is introduced.

Table 29

Functional class of cardio-vascular system by MOC test

Functional cl	Consumption of	Consumption of	Working capacity

	ml/kg/min	(met)	
1	Over 21	7–16	Practically without limits
2	Over 14–21	5–7	Moderate limits
3	Over 7–15	2–5	Considerably limited
4	Less 7	1–2	Complete disability

Using MOC value it is possible to calculate acceptable levels of load intensity (work, training, etc.). It is considered that energy expenditures for physical activity during working day must not exceed 25–35 % of maximum aerobic power level, i. e. MOC.

Conclusion (give the assessment of MOC of the examined):

THE TOPIC IS PASSED_____

Teacher's signature

PHYSIOLOGY OF DIGESTION

Lesson 24. FUNCTIONAL SYSTEM OF NUTRITION. DIGESTION IN THE ORAL CAVITY AND IN THE STOMACH

Basic questions:

1. General characteristic of functional system of nutrition, the role and place of digestion processes in it.
2. Nutritional motivations. Physiological mechanisms of hunger and satiety. Appetite.
3. Types of digestion depending on peculiarities of hydrolysis and its localization.
4. Experimental and most important clinical methods of studying functions of gastro-intestinal tract.
5. Digestive and non-digestive functions of the digestive system.
6. Peculiarities of functional regulation of the digestive system.
7. Digestion in the oral cavity. Salivation (composition and properties of saliva), mastication and swallowing. Mechanisms of their regulation.
8. Digestion in the stomach. The composition and properties of gastric juice. The role of hydrochloric acid of gastric juice. Physiologic protection mechanisms of the stomach mucosa from injuring factors.
9. Regulation mechanisms of gastric juice secretion. The role of gastrointestinal peptides.
10. Motor and evacuator gastric function during fasting and after meals.

Self check:

1. What is bulimia and anorexia?
2. What consequences may result from the destruction of the hunger center in hypothalamus?
3. Which gastrointestinal peptides are hormones?
4. What consequences may result from prolonged insufficiency of salivation?
5. In what way will HCl secretion change under the action of antagonists of histamine H_2-receptors?
6. Why is the secretion of gastric juice significantly reduced after the pyloric part of the stomach has been removed?
7. Which factors stimulate gastrin secretion in the stomach?
8. Why may non-steroid anti-inflammatory drugs cause lesions of gastric mucosa?

Standards

Saliva:

- *Daily secretion — 500–2000 ml.*
- *Specific gravity — 1,002–1,020.*
- *pH = 5,6–7,6.*

Gastric juice:

- *Gastric juice on an empty stomach no more than 50 ml.*
- *On an empty stomach: total acidity — ðo 40 mmol/l, free HCl — up to 20 mmol/l.*
- *Basal gastric secretion: total acidity — 40–60 mmol/l, free HCl — 20–40 mmol/l.*
- *Amount of gastric juice produced during 24 hours, — 2–3 l.*
- *Specific gravity of gastric juice— 1,004–1010.*
- *pH of pure gastric juice — 1,49–1,8.*
- *pH of gastric content — 6,0 and more.*

PRACTICAL WORKS

Work 24.1. DIGESTION OF STARCH BY HUMAN SALIVA ENZYMES

The saliva contains amylolytic enzymes — amylase and maltase. Their optimal action is in the limits of medium neutral reaction at normal body temperature (37 ºC).

Materials and equipment: a thermostat or water bath with temperature 37–38 ºC, a spirit-lamp, a stand-holder with test-tubes, pipettes, a small funnel, human saliva, 1 % solution of boiled starch, 3 % iodine or compound iodine solutions, 0,5 % HCl solution, litmus paper, a pencil for glass, ice or a fridge, distilled water.

Accomplishment. Saliva (about 5 ml) is collected into a test-tube with a funnel. After the test-tubes are numbered and put into a stand-holder, per 1 ml of saliva is added to each of them. Then 3 ml of boiled starch is added into the 1st test-tube; the 2nd test-tube is warmed over the spirit-lamp till boiling, cooled and 3 ml of 1 % boiled starch is added into it; 0,5 % of HCl solution is being added to the 3rd test-tube till persistent staining of the litmus-paper is reached, then 1 % solution of boiled starch is added; 3 ml of 1 % solution of fresh starch is added into the 4th test-tube; and 3 ml of 1 % solution of boiled starch is added into the 5th test-tube.

The first 4 test-tubes are placed into the thermostat or water bath at 37-38 ºC; the 5th test-tube is put into the fridge or a glass with ice. In 30 minutes the test-tubes content is examined for the presence of starch. The content of test-tubes, where starch is present, acquires a blue color, when 1–2 drops of compound iodine solution is added.

Results and recording:

1. Fill in table 30 according to the results of the experiment.
2. On the basis of test-tubes color on addition of the compound iodine solution make a conclusion, if starch digestion has taken place in the test-tubes.

Table 30

Test-tubes №	Content of test-tubes	Color of test-tubes content after addition Lugol's iodine solution	Results of experiments
1	**1ml of saliva +** **3 ml of boiled starch** (thermostat)	_____	_____
2	1 ml of boiled saliva + 3 ml of boiled starch (thermostat)	_____	_____
3	1 ml of saliva + 0,5 %-solution of HCl + 3 ml of boiled starch (thermostat)	_____	_____
4	1 ml of saliva + 3 ml of raw starch (thermostat)	_____	_____
5	1 ml of saliva + 3 ml of boiled starch } To cold		

3. Answer the question: in what way did the following actions influence the fermentative properties of saliva:

- warming of saliva: _____
- pH shift of saliva to acidic side: _____
- cooling of saliva: _____

Work 24.2. STUDYING FERMENTATIVE PROPERTIES OF GASTRIC JUICE

Materials and equipment: water bath or a thermostat, a spirit-lamp, a stand-hold with test-tubes, pincers, natural gastric juice, fibrin, 0,5 % solution of HCl, 0,5 % solution of $NaHCO_3$, a glass pen, litmus paper.

Accomplishment. Four test-tubes are numbered and: into the 1st test-tube 2 ml of gastric juice are added; into the 2nd — 2 ml of gastric juice and it is boiled over the spirit-lamp; into the 3rd — 2 ml of gastric juice and the solution of soda till weak alkaline reaction takes place (red litmus-paper becomes bluish); into the 4th — 2 ml of 0,5 % solution of HCl. An equal amount of fibrin (0,1–0,3 g) is added to all test-tubes, and they are placed on water bath for 30–40 minutes or into the thermostat with temperature 38 ºC.

Results and their recording. In 30–40 minutes take the test-tubes from the thermostat and assess changing of fibrinogen in all test-tubes. Fill in table 31 with the results.

Table 31

Test-tubes №	Test-tube content	State of fibrin pieces	Causes of fibrin changes in test-tubes
1	2 ml of gastric juice + fibrin		
2	2 ml of boiled gastric juice + fibrin		
3	2 ml of gastric juice + Solution of $NaHCO_3$ + fibrin		
4			

	2 ml of 0,5 % – solution of HCl + fibrin		

Work 24.3. STUDYING MOTOR FUNCTION OF HUMAN STOMACH BY ELECTROGASTROGRAPHY (demonstrative work)

Electrogastrography allows recording electric activity of stomach muscles by superficial electrodes and assessing the state of motor and evacuator functions of the stomach in gastro-intestinal tract diseases.

Three kinds of motions occur in the stomach filled with food: peristaltic waves, fast monophase contractions of the antral zone with high amplitude and tonic contractions with high amplitude and duration from 1 to 5 minutes. The character of motility is due to a type of food, degree of preliminary processing, thoroughness of mastication, time after taking food, rate of intestine emptying from the chime, reflectory and humoral effects on gastric pacemaker. The majority of healthy people have a normokinetic type of peristaltic gastric waves (frequency of biopotentials (n) = 3 pulses/min, average amplitude (A_{av}) = 0,2–0,4 mV). In some diseases, when increasing of smooth muscles tone and HCl secretion are observed, a hyperkinetic type of EFF is noted ($n \geq 4$ pulses/min, $A_{av} > 0,4$ mV), and in decreasing of muscular tone and HCl secretion — a hypokinetic type ($n < 2$ pulses/min, $A_{av} < 0,2$ mV).

Directions for recording the protocol:

1. Draw an electrogastrogram or paste its part in.

2. Analyze the EGG. Calibration: 1 division on the diagram along the vertical line (4 mm) = 0,1 mV, along the horizontal line (10 mm) = 1 min.

Frequency of peristaltic waves = ___ impulse/min, and the mean amplitude $A_{mean} = (A_1 + A_2 + \ldots + A_n) / n =$ ___ mcV.

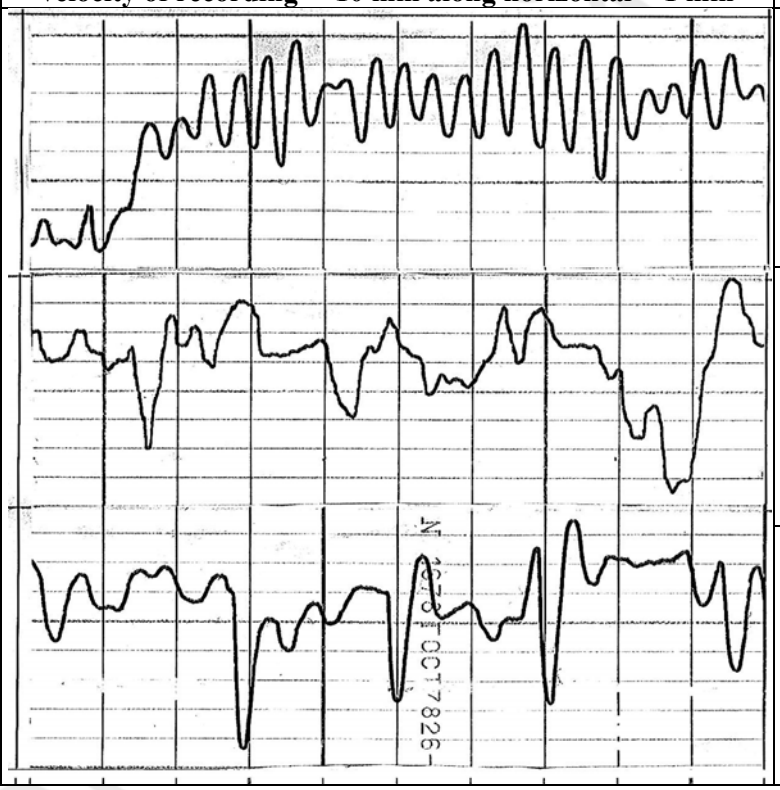
3. Compare the obtained EGG with EGG patterns recorded in various periods after taking food (table 32).

Results. At rest in impulse frequency _____ per minute the mean amplitude of muscular potentials (peristaltic waves) of the stomach is _____.

Conclusion. Stomach motility type is: normo-, hyper- or hypokinetic (underline the chosen variant).

Table 32

Examples of electrogastrograms in healthy people at the age of 20 years at various periods of time after meal

Time of EGG recording after taking food	Electrogastrograms. Calibration: amplitude — 10 mm along vertical = 250 mcV, velocity of recording— 10 mm along horizontal = 1 min	Note
5 min		Peristaltic waves
1 h		Peristaltic waves on the background of tonic contraction
2 h		Propulsive contractions

8 h		«Hungry» motility

Lesson 25. DIGESTION IN SMALL AND LARGE INTESTINE. THE ROLE OF THE PANCREAS AND LIVER FOR DIGESTION

Basic questions:

1. Digestion in duodenum. The role of the pancreas for digestion. Composition and properties of pancreatic juice.
2. Regulation mechanisms of pancreatic juice.
3. Composition and properties of bile, its participation in digestion processes.
4. Regulation mechanisms of bile formation and bile excretion.
5. Digestion in the jejunum and ileum. Composition and properties of intestinal juice.
6. Regulation mechanisms of intestinal secretion.
7. Cavitary and parietal hydrolysis of nutrients.
8. Absorption of products of fats, proteins and carbohydrates hydrolysis in various parts of gastrointestinal tract, its mechanisms. Hydrolysis and absorption coupling.
9. Motor function of small intestine and its regulation.
10. Digestion in large intestine. The significance of large intestine microflora for the organism.
11. Motor function of large intestine. Defecation.

Self check:

1. In what way does neutralization of acid chyme, coming from the stomach, occur?
2. What enzymes of pancreatic juice are excreted in an inactive form?
3. What is the factor activating trypsinogen? Proelastase?
4. In what way does the pancreatic juice secretion change in diet rich in: 1) proteins, 2) fats, 3) carbohydrates?
5. What factors (humoral, nutritious, etc.) stimulate formation and secretion of bile?
6. What consequences may occur, when bile stops to enter the intestines?
7. Why is evacuation of chyme from the stomach delayed, when fatty food comes from the stomach into duodenum?
8. In what part of the intestines does the absorption of vitamin B_{12} occur?
9. What common transport mechanism is used for absorption of amino acids, glucose, galactose, bile acids in small intestine?

Standards

Cystic bile (B bile):

- *Daily amount — 500–1200 ml.*

Hepatic bile (C bile):

- *Specific density — 1,008–1,015.*

- *Specific density — 1,011–1,032.*
- *pH = 5,6–8,0.*

Small intestine juice:

- *Daily amount — about 1000 ml.*
- *pH = 5,05–7,07.*

Pancreatic juice:

- *Daily amount — 1500–2500 ml.*
- *pH = 7,5–8,8.*
- *pH = 6,2–8,5.*

Large intestine juice:

- *Daily amount — 270–1550 ml.*
- *pH = 6,1–7,31.*

PRACTICAL WORKS

Work 25.1. BILE EFFECT ON FATS

Materials and equipment: cover glasses, a magnifying glass, glass sticks, bile, oil, distilled water.

Accomplishment. Apply a drop of water and a drop of bile on the cover glass. Add 2–3 drops of oil to every drop, stir and examine the content of both drops under the magnifying glass.

Results and their recording. Draw the distribution of fat in a drop of water and a drop of bile.

Conclusions: (mechanism of bile effect on the state of fat).

Work 25.2. PARIETAL DIGESTION

Materials and equipment: a strip of rat's jejunum, test-tubes, a stand-holder, glass sticks, threads, water bath, Ringer's solution, compound iodine solution.

Accomplishment. Apply per 1 drop of Ringer's solution and starch solution into two test-tubes. Dip into one of the test-tubes a part of the rat's jejunum turned inside out, it being tied to a stick glass with a ligature. Put both test-tubes on water bath for 20 minutes at 38 ºC, on completion of incubation take the gut out of the test-tube and add per one drop of compound iodine solution into both test-tubes.

Results. Mark, in what test-tube the digestion of starch took place.

Conclusion: (explain the mechanism of starch digestion in the given experiment).

Work 25.3. AMYLASE ACTIVITY OF BLOOD PLASMA

Evaluation of amylase activity in blood plasma has an important diagnostic significance and is used in clinics to assess the function of pancreas.

Materials and equipment: test-tubes, a stand-holder, glass sticks, water bath, rat's blood plasma, starch solution, compound iodine solution.

Accomplishment. To 1–2 ml of blood plasma add 1 ml of starch solution and incubate in water bath for 20 minutes at 38°C. On completion of incubation add 1 drop of compound iodine solution.

Results. Mark, what happened with starch in blood plasma:

Conclusion:

THE SECTION TOPICS ARE PASSED _____

(Teacher's signature)

Lesson 26. ENERGETICS AND METABOLISM

Basic questions:

1. The concept of metabolism in the organism. Characteristic of anabolic and katabolic processes and their correlation.
2. Plastic and energetic role of proteins, fats and carbohydrates. Indispensable for the organism substances.
3. Basal metabolism, its amounts, master factors. Diagnostic significance of basal metabolism determination.
4. Total metabolism, its components. Working metabolism. Energy consumption in various kinds of working activity.
5. Evaluation methods of energy income and expenditure (direct and indirect calorimetry, calculation by tables and formulas).
6. Body mass as an objective factor of income and expenditure balance of energy. Indices for body mass estimation.
7. The concept of human daily needs in nutrients, vitamins, mineral ions and water. Physiological standards of nutrition depending on age, sex, type of working activity and state of the organism.
8. Basic principles of healthy nutrition as a component of healthy life. Principles of compiling diets.

Self checks:

1. Why can the amount of energy expenditures be assessed using data of O_2 volumes consumed by the organism?
2. List the standard conditions for basal metabolism evaluation.
3. What is the caloric equivalent of oxygen? What substances have the highest caloric equivalent of oxygen?
4. What is the respiratory coefficient determined for?
5. Calculate the calorific value of the product containing 3 g of protein, 3 g of fat and 6 g of carbohydrates per 100 g of mass.
6. What is the protein minimum? What optimal amount of protein must a human organism receive daily?
7. Assess the body mass of a man, if his body mass index is 29.
8. Lung ventilation of a person at rest is 5 l/min. The content of O_2 in expired air is 16 %. Calculate daily energy expenditures in mixed diet (caloric O_2 equivalent = 4.86 kcal/l O_2).

PRACTICAL WORKS

Work 26.1. CALCULATION OF DUE VALUES OF BASAL METABOLISM BY TABLES AND FORMULAS

Basal metabolism means minimum energy expenses necessary for sustaining vital processes of the organism in standard conditions. **Standard conditions** allowing to exclude additional energy expenditures include: 1) the state of **being awake** (during sleep energy expenditures are reduced by 8–10 % as compared to quiet being awake); 2) the state of physical and mental **rest in lying position**; 3) state of **fasting**, **in 12–16 h after meal** (to exclude its specific dynamic action); 4) external "**temperature of comfort**" (18–20 ºC for a person lightly dressed), that doesn't cause a perception of cold or heat. Basal metabolism energy is spent for renewal of cellular structures, sustaining constant body temperature, functioning of internal organs, tone of skeletal muscles and contraction of respiratory muscles, etc.

The value of basal metabolism (BM) is easy to calculate by formulas and tables developed by the results of a great number of studies of daily energy expenditures by healthy people of different sex, age, body mass and height. There are many evaluation methods of due basic metabolism (due BM). One of them is calculation by formulas given in table 33.

Table 33

Calculation formulas for human DBM depending on age, sex and body mass (BM)

Age, years	Due BM (kcal/24 h)	
	Men	Women
0–3	60,9 · BM – 54	61,0 · BM – 51
3–10	22,7 · BM + 495	22,5 · BM + 499
10–18	17,5 · BM + 651	12,2 · BM + 746
18–40	**1,0 ·BM · 24** **15,5 · BM + 679**	**0,9 · BM · 24** **14,7 · BM+ 496**
40–60	11,6 · BM + 879	8,7 · BM + 829
Over 60	13,5 · BM + 487	10,5 · BM + 596

One of the most widely used methods of evaluating basal metabolism is the method for evaluating basal metabolism by tables of **Harris–Benedict**. There are two types of tables — for men and for women. Each of them contains 2 tables, A and B. From the first table number A is found, it depends on body mass; and from the second — number B depending on height and age. The sum of these numbers (A+B) gives the value of due BM.

One more widely used method of evaluating due BM is **Dubois's method**. It is based on the law of body surface according to which energy expenses of a warm-blooded organism are proportional to the area of body surface. It is established that heat production per 1 m^2 of the human body surface depends on

age and sex. To calculate due BM, the value of heat production in kcal/m^2 found in table 34 should be multiplied by the area of body surface (in m^2) and by 24 hours. The body surface area is found by the nomogram depending on body mass and height.

Table 34

Expenditures for basal metabolism of healthy people depending on age and sex

Age, years	Men , ккcal/m^2· hour	Women, kcal/m^2·hour
14–16	46,0	43,0
16–18	43,0	40,0
18–20	41,0	38,0
20–30	39,5	37,0
30–40	39,5	36,5
40–50	38,5	36,0

The difference between factors of proper basal metabolism calculated by different methods does not usually exceed 10 %.

Directions for recording the protocol:

1. Calculate your own due BM by several methods — by formulas, by tables of Harris-Benedict and by body surface area.

2. Compare the obtained results. The most precise method is the method using tables of Harris-Benedict and method of Dubois. The results obtained by these two methods usually differ insignificantly (as a rule no more than 50–150 kcal).

PROTOCOL

1. **Sex_____ (m/f); height _____ cm; BM= _____ kg; age _____ years.**
2. **Due BM= _____ · BM · 24 = _____ kcal/24 hrs;**
   (by formula from table 33)

   Due BM = _____ · BM + _____ = _____ kcal/24 hrs;
   (by formula from table 33)

   Due BM=A+B= _____ kcal/24 hrs.
   (by tables of Harris-Benedict)

   Body surface area (S) by nomogram = _____ m^2,
   Heat production (E) on m^2 per hour (from table 34) = _____ kcal/m^2·hour

   Due BM= $E_{kcal/m^2 \cdot hour} \cdot S_{м2} \cdot 24_{hour}$ =_____ kcal/24 hrs
   (by Dubois)

Work 26.2. EVALUATION OF BODY MASS (BM)

BM is an important factor of human physical development during all age periods. To sustain stable BM in a healthy adult the energy income to the organism must be equal to its expenditures. BM increase is one of basic risk factors of health impairment and development of cardiovascular, endocrine and oncological diseases. Its decrease is also a risk factor of health impairment, and sometimes is a symptom of the disease already present.

It is recommended to periodically control BM. In case of its increase or decrease in a healthy person one should introduce an appropriate correction to the amount of calories brought to the organism with food and modify physical activity. Inconsiderable fluctuations of body mass reflect basically changes of water balance.

Materials and equipment: scales, a height meter.

Accomplishment. Evaluate body mass.

Compare the values of found BM and calculated due BM (DBM). DBM depends on the height, sex, age, type of constitution and some other factors. There are many methods to determine DBM: formulas, nomograms, tables, etc. The simplest method of evaluating DBM is associated with its calculation by the formula of Bock-Brugsh (1):

DBM = height (cm) – 100 (in height ≤ 165 cm);

DBM = height (cm) – 105 (in height 166 – 175 cm);

DBM = height (cm) – 110 (in height > 175 cm).

Formulas for calculating DBM depending on height and sex of a person (2):

DBM (for men) = 48 + (height (cm) – 152) · 1.1 kg/cm;

DBM (for women) = 48 + (height (cm) – 152) · 0.9 kg/cm.

In *asthenic* type of constitution DBM may be decreased by 10 %, in *hypersthenic* constitution — it may be increased by 10 %. After 30 and 50 years DBM may be increased by 3–13 % versus DBM at 20 years.

Both increased and decreased DBM is a risk factor for health.

Increase of BM of a person versus DBM:

– by 15–29 % — evidences obesity of the I degree;
– by 30–49 % — evidences obesity of the II degree;
– by 50–100 % — evidences obesity of the III degree;
– over 100 % — evidences obesity of the IV degree.

Decrease of BM of a person versus DBM:

– by 10–20 % — may present a light degree,
– by 21–30 % — a moderate degree, and
– by 31–40 % — a severe degree of protein-energetic insufficiency of the diet;
– over 40 % — shows the presence of cachexia (exhaustion).

Body mass index (BMI) is calculated by the formula:

$$BMI = BM_{kg}/(height_m)^2.$$

On the basis of body mass index the risk degree of developing some diseases can be evaluated.

Table 35

Body mass, BODY MASS INDEX and risk of health impairment

	Hypotrophy(decreased BM)	**Normal BM**	**Obesity (increased BM)**
BMI	<18,5	18,5–25,0	>25,0
Risk of the disease	Anemias; deterioration of immunity and increased incidence of infectious diseases of the lungs, urinary tract, etc; osteoporosis, cachexia	Minimum	Obesity, diabetes mellitus, atherosclerosis, arterial hypertension and etc.
General recommendations	To modify dietary regimen and physical activity in such a way that energy income with food exceeded its expenditure	To keep to the present dietary regimen and physical activity	To modify dietary regimen and physical activity so that energy income with food was less than its expenditure

Directions for recording the protocol:

1. Indicate your measured body mass (BM) …….. kg.
2. Calculate and assess your DBM, BM and BMI.

DBM_1 =
(by formula 1)

DBM_2 =
(by formula 2)

BMI =

SECTION TOPICS ARE PASSED_____
(teacher's signature)

PHYSIOLOGY OF THERMOREGULATION

Lesson 27. THERMOREGULATION

Basic questions:

1. Temperature of the human body and its daily fluctuations. The core temperature of the body and the skin ("the cover") temperature. The significance of constancy of the organism internal environment temperature for normal course of vital processes.
2. Sources of heat production in the organism. Regulation of heat production.
3. Heat loss of the organism. Physical and physiologic mechanisms of heat loss. Regulation of heat loss.
4. Thermoreceptors. Thermoregulation center. The concept of "set point" for temperature control.
5. The functional system for the maintenance of temperature constancy of the internal environment of the organism. Peculiarities of the thermoregulation system.
6. The concept of hypo- and hyperthermia. Fever and its difference from hyperthermia.

Self check:

1. Will the body temperature of a person change in case of increase of his heat production?
2. Due to what mechanisms does a man maintain a constant body temperature, when heat loss associated with external cooling increases?
3. In what way will heat production of the organism change in activation of posterior nuclei of hypothalamus?
4. What type of heat loss does not require the presence of temperature difference between the human skin surface and the environment?
5. Why is high temperature of the environment (30^oC) in high humidity tolerated worse than in low humidity?
6. What is the main way of regulating heat loss from the skin surface?
7. What is the difference between the mechanisms of body temperature increase in physical hyperthermia and in fever?

PRACTICAL WORKS

Work 27.1. MEASUREMENT OF THE AXILLARY TEMPERATURE

Body temperature is an important index of the state of human health.
The normal body temperature for adults in the state of being awake and physiologic rest (while taking it in the armpit) is temperature from 36 ºC to 36,9 ºC.
But it should be taken into consideration that during sleep from 3 till 5 o'clock in the

morning body temperature may reach its minimum values — 35,1–36,0 ºC. Thus, the norm of body temperature measured in the armpit comprises 36 ± 0,9 ºC (**35,1–36,9 ºC**). Temperature 37 ºC and over is considered elevated (***hyperthermia***) and 35 °C and lower — decreased (***hypothermia***). When the temperature is taken in deep areas of the body (rectum, esophagus), its normal values are 0,5 °C higher than in the armpit.

The purpose of the work is to determine minimal time necessary for precise taking axillary temperature with mercury or electronic medical thermometers.

Materials and equipment: a maximum mercury thermometer, a stopwatch, 70 % solution of alcohol, cotton wool.

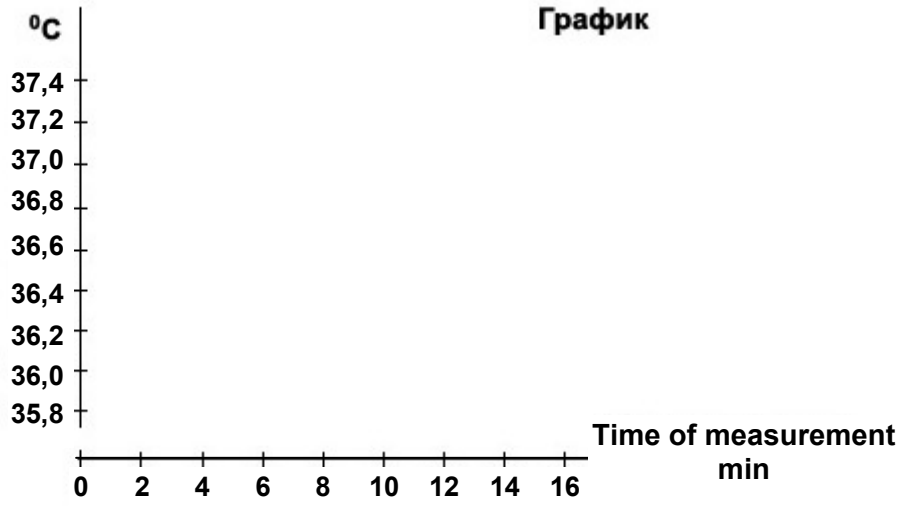
Accomplishment. The skin in the armpit must be dry, because, if the skin is wet, the thermometer will show low values of temperature due to evaporation of moisture from the surface of mercury reservoir. The examined must keep the thermometer during the whole period of taking temperature tightly clasping the shoulder to the chest. During taking temperature the person should be in the state of being awake and complete rest.

Examine the medical thermometer, make sure it is intact and swab it with alcohol. Shake the thermometer till 35 °C. Put the thermometer in the armpit. Take the thermometer readings in 3, 5, 8, 10, 15 minutes. Then perform thermometry with an electron thermometer recording the scale readings of the device in 30 sec, 1, 2, 3, 5, 8, 10, 15 minutes. While performing the work be sure that the head of the mercury thermometer and the tip of the sensor of electronic thermometer were kept on median-axillary line.

According to experimental results draw reading graphs of the mercury and electron thermometer versus the time of taking temperature.

Results:

Readings of the thermometers:	**30 sec**	**1 min**	**2 min**	**3 min**	**5 min**	**8 min**	**10 min**	**15 min**
Mercury	–	–	–					
Electron								



Conclusion: axillary body temperature of the examined is _____, duration of its taking with the mercury thermometer must be no less than _____ min.

Work 27.3. FUNCTIONAL MOBILITY OF SWEAT GLANDS AND ITS SIGNIFICANCE FOR REGULATION OF HEAT LOSS IN HUMAN

The purpose of the work is to reveal the alteration of perspiration intensity at exercise. Minor's colorimetric method is used to indicate sweat drops; it is based on chemical interaction of iodine with starch resulting in the formation of reaction products of dark-blue color.

Accomplishment. The study is performed at room temperature (18–20 ºC). The examined must wash his hands and dry them. The skin on the back of his hand in the region of II–III metacarpal bones is painted with Minor's solution (5 % solution of iodine and castor oil in proportion 9:1). When the skin is completely dry, powder it a little bit with starch. Sweat drops form dark points or spots on a regular white background that are seen with naked eye. To calculate the spots draw a circle 5 mm in diameter on the skin. Using a magnifier calculate the number of sweat drops inside the circle at rest and after exercise (running on the spot for 1 min).

Results:

The number of sweat drops at relative rest —

The number of sweat drops after exercise —

Conclusion: (indicate, in what way and why perspiration changes on exercise).

Work 27.4. STUDYING THE ROLE OF BLOOD CIRCULATION IN THE PROCESS OF HEAT TRANSFER IN SUPERFICIAL TISSUES BY THE METHOD OF COLOR THERMOGRAPHY (demonstration of computer slides)

To demonstrate heat distribution in superficial tissues the wrist of the human hand was painted with special thermographic compound changing its color on heating. A miniature heat source (39 ºC) was placed on the back of the hand in the projection zone of a superficial vein. On a series of slides one can observe the spread of heat to adjoining the heater tissues as the hand tissues are being warmed up, it is seen as staining of the thermographic compound is changing (from black to red, then to blue-green color). Changing of compound staining followed the way of superficial veins that evidences the role of the blood flow in heat transfer in the organism. The absence of changes in staining on the areas of the skin between veins, even near the heat source, evidences low heat conductivity of tissues of the organism and their inconsiderable participation in heat transfer inside the organism.

Lesson 28. PHYSIOLOGY OF EXCRETION

Basic questions:

1. The essence of excretion processes. Organs and excretion systems of the organism. The characteristic of excretion processes in the skin, respiratory system, gastrointestinal tract.
2. The structure of a kidney. Nephron as a morpho-functional unit of the kidney, types of nephrons, their structure and functions. Peculiarities of blood circulation in the kidney.
3. Basic processes of urine formation.
4. The mechanism of glomerular filtration. The composition of primary urine.
5. Reabsorption in nephron tubules and collecting ducts.
6. Countercurrent system and its mechanisms.
7. Processes of the excretory secretion in tubules.
8. Methods of renal function studying. Evaluation of filtration, secretion, reabsorption. Clearance.
9. Regulation of urine formation.
10. Non-excretory functions of the kidney: the role of kidneys in regulation of the systemic arterial blood pressure; regulation of blood volume; maintaining of the blood osmotic pressure, acid-base balance and ion blood composition; participation in the blood formation and in metabolic processes.

Self check:

1. What is the effective filtration pressure, if glomerular capillary pressure is 45 mm Hg, Bowman's space hydrostatic pressure is 10 mm Hg, and oncotic blood pressure is 27 mm Hg?
2. What is the renal excretion threshold and what substances are referred to as threshold ones?
3. In what cases may glucose be found in the final urine of a healthy person and why?
4. In what way does diuresis change on inhibition of Na^+, K^+ and Cl^- ions reabsorption in the thick ascending limb of the loop of Henle?
5. What changes in the organism does hypo- and hypersecretion of aldosterone result in?
6. What is the mechanism of water reabsorption in the distal tubules and collecting ducts?
7. What factors increase release of renin by the cells of juxtaglomerular apparatus of the kidney?

Factors of urine analysis in norm

Physical properties:

Color — straw-yellow;
Transparency — transparent;
Density — 1,008–1,025;
Daily volume — 0,8–1,5 l/day.

Chemical composition:

Reaction — pH 5,0–8,0;
Protein — 10–100 mg/day;
Glucose — 0,72 mmol/day;
Ketone bodies— 20–50 mg/day;
Urobilin — no more than 6 mg/day;
Bile pigments — are absent;
Chlorides — 141–310 mmol/24 hrs.

Microscopy of the sediment:

Erythrocytes — do not occur, or are single in the preparation;
Leukocytes — do not occur, or are single in the preparation;
Epithelial cells — pavement and transitional epithelium cells — from single in the preparation to single in the field of vision;
Cylinders (protein moulds of tubules) — single (1–2 in the preparation) hyalinous

PRACTICAL WORKS

Work 28.1. PERFORMING COMMON URINE ANALYSIS

Urine analysis has a great practical significance as obtained results allow assessing the renal function and some aspects of metabolism in the organism.

Common urine analysis allows to assess its physical (color, transparency, smell, amount, specific density, urine reaction), physicochemical properties (revealing inorganic substances, urobilinogen, bilirubin), the presence of pathological urine components (protein, glucose, acetone bodies, blood cells), as well as to reveal the content of accidental elements in the urine (nitrates, mercury, bismuth, arsenic, bromide and bromide compounds, etc.)

Evaluation of 10 factors of the final urine in this study is performed by the method of colorimetry: a test-strip has 10 various indicator cushions changing color (or color intensity) after contacting biological fluid.

Accomplishment:

1. Collect urine in a glass (9–10 ml) and pour it with a funnel into a test-tube (the column height is 9–10 cm).
2. Dip a test-strip into the tested urine, moistening all 10 indicator cushions. Take the test-strip and take away the excess of fluid with a napkin. For this purpose put the test-strip on the napkin with the side without cushions.
3. Bring the test-strip on the napkin carefully to a control scale located on the package and determine the results of 10 factors of the tested urine comparing the color of every indicator cushion to standard samples located on the package.

Directions for recording the protocol:

1. Insert obtained factors of tested urine into table 36.
2. Assess the obtained result with the norm.

Table 36

Test		Measurement units	Result
1. Leukocytes	***WBC***		
2. Nitrates	NIT		
3. Urobilinogen	URO	E.U./dL	
4. Protein	PRO	mg/dL	
5. pH	PH		
6. Occult blood	OB		
7. Specific density	SD		
8. Ketone bodies	KET		
9. Bilirubin	BIL		
10. Glucose	GLU	g/dL	

Conclusion **(compare the results with the norm):** _____
_____

Work 28.2. STUDYING SOME RENAL FUNCTIONS ON A MODEL

The work is performed using computer program "Kidney", section "Loop of Henle", mechanisms of concentrating the urine (countercurrent system).

Answer the following questions:

1. **What processes occur in the descending limb of the loop of Henle?**

2. What processes occur in the ascending limb of the loop of Henle?

3. In what way and how will the final urine volume and osmolarity change?

a) in hyperglycemia _____
_____

b) in taking a great amount of salt _____
_____

c) in water deprivation _____
_____

d) in excessive water loading _____
_____

e) in taking furosemide (lasix), inhibitor of Na^+, K^+ and Cl^- reabsorption in the ascending limb of the loop of Henle _____
_____

f) in hypersecretion of antidiuretic hormone (ADH) _____
_____

g) in hyposecretion of ADH _____
_____

SECTION TOPICS ARE PASSED_____
(Teacher's signature)

PHYSIOLOGY OF SENSORY SYSTEMS

Lesson 29. GENERAL PROPERTIES OF ANALYZERS. VISUAL SYSTEM.

Basic questions:

1. The concept of sense organs, analyzers, sensory systems. I. P. Pavlov's theory of analyzers. General principles of analyzers structure, their classification.
2. General properties and functions of analyzers. The significance of analyzers for brain development and cognitive processes.
3. Types of sensory receptors. Mechanisms of signal transformation in sensory receptors.
4. **Mechanisms of transmission and encoding information in afferent pathways. The concept of the structure and functions of specific and unspecific ways of information transmission.**
5. Processes of higher cortical analysis of afferent signals. Sensory fields and nuclei, associative fields. Interaction of analyzers.
6. Adaptation of analyzers, its peripheral and central mechanisms.
7. Visual system. Structure and functions. Peculiarities of the structure and properties of the eye. Refraction and accommodation.
8. The structure and functions of the eye retina. Photochemical processes in receptors of the retina under the action of light. Functions of pigment, horizontal, bipolar and ganglionic cells of the retina. Adaptation mechanisms of vision.
9. Eye movements and their role for vision.
10. Conducting and cortical parts of a visual analyzer. Formation of visual images.
11. Theories of color perception. Basic forms of color perception disorders.

Self check:

1. What is the difference between the primary-sensitive analyzers and secondary-sensitive analyzers?
2. What are the manifests of receptor adaptation? Which receptors are fast-adapting and which ones are slow-adapting receptors?
3. What mechanisms ensure sharp vision of objects placed at various distances?
4. What is the acuity of vision? What formula is used for evaluation of visual acuity?
5. What are the causes of nearsightedness (myopia)? What lenses are needed for its correction?
6. What photoreceptors possess a greater light sensitivity?

7. What phenomena are registered on the photoreceptor's membrane under action of light? What ion mechanisms are they due to?

8. In studying visual fields of the patient bilateral loss of the left halves of visual fields is revealed. What part of visual pathways is damaged?

PRACTICAL WORKS

Work 29.1. EVALUATION OF VISUAL ACUITY

Visual acuity is the ability to see clearly surrounding objects placed at various distances. Vision acuity is evaluated by a minimum vision angle, under which the eye is capable to discern two points as separate. A normal eye is capable to discern 2 points under the angle of vision 1' (1 angle second). It is associated with the fact, that for separate vision of two points it is necessary to have minimum one unexcited cone of retina between two excited cones. As the diameter of cone is 3 μm, the distance between images of these points on the retina must be no less than 4 μm. Such image value occurs under visual angle 1'. That is why when looking at two neighboring points under visual angle less than 1' they fuse into one point.

Materials and equipment: special tables (*Golovin's* or *Sivtsev's*) for evaluating visual acuity, a pointer, a 5-meter tape-measure.

Accomplishment. The study is performed using tables with letters of decreasing sizes. Next to each letter a distance is indicated, from which a normal eye must see letters of the given line under angle 1'. The table is hung on a well lighted wall. The examined must be at the distance of 5 m from the table. The study is performed for every eye separately. The examined covers one eye with a special shield. The examiner points to letters on the table with the pointer, and the examined must name them. Evaluation is started from the upper line and, descending, comes to the lower line, all the letters of which are clearly seen and correctly named by the examined. Then the visual acuity is calculated by the formula:

$$V = d/D,$$

where V — visual acuity (*visus*); d — distance to the table (i. e. the distance, from which the examined sees the line); D — distance, from which a normal eye must clearly see letters of the given line.

Evaluate visual acuity of both eyes and compare it with the norm.

Visual acuity of the left eye: _____

of the right eye: _____

Conclusion:

Work 29.2. EVALUATION OF VISUAL FIELD LIMITS (PERIMETRY)

Visual field is the space seen by a human eye, when the sight is fixed at one point. The value of visual field is not identical in different people and depends on the functional state of the retina, depth of the eye-ball, sizes and forms of superciliary arches and the nose. There are color (chromatic) and colorless (achromatic) visual fields. Achromatic visual field is larger than the chromatic one; it is due to the presence of rods located predominantly on periphery of the retina. For various colors visual field is not identical either: it is the greatest for yellow color and the narrowest for green color. Approximate limits of the achromatic visual field towards outside is 100º, towards inside and upwards — 60º and downwards — 65ºº.

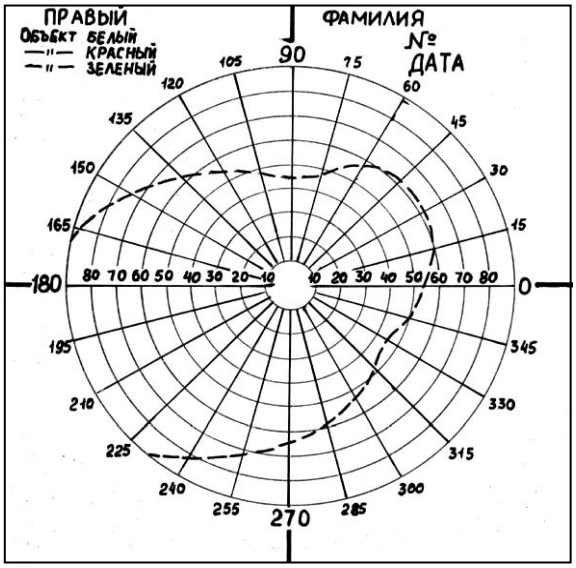
Materials and equipment: forster's perimeter, objects of various colors, a ruler, colored pencils.

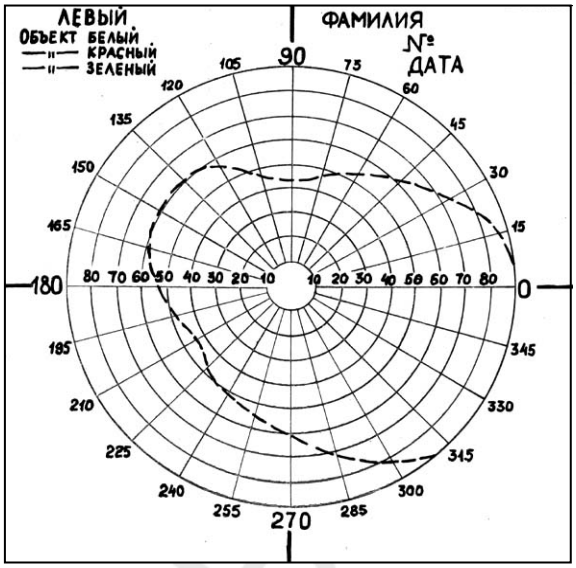
Accomplishment. The study is performed using Forster's perimeter that is a stand-holder with a movable calibrated (in degrees) metal arch with divisions on a lateral side. The examined must be seated with his back to light and put his chin on a rest of the stand-holder at the right (while examining the left eye) or at the left (while examining the right eye). Regulate the height of the rest so that the lower edge of the eye cavity was at the sight-plate level. During the whole experiment the sight of the examined stays fixed on a white point of the perimeter, the other eye is covered with a shield. Start the examination with a horizontal position of the perimeter. Slowly move the object (a white square or a circle 5–10 mm in diameter) along the internal arch surface from 90º to 0º; the examined should point out the moment of appearing the object in the visual field and name its color. Repeat the study in a vertical and two oblique positions of the perimeter for objects of white, green or blue color. Insert the results (in degrees) into the table.

Using the obtained results draw a diagram of visual fields for white and other colors.

Table 37

Direction of axes	Limit of visual field of the eye in degrees	
	for white color	**for green or blue color**
90° (upwards) 270° (downwards) 0° (outwards) 180° (inwards) 45° (outwards above) 45° (outwards down) 45° (inwards above) 45° (inwards down)		





Conclusion: (compare the size of the visual field for white color with the norm marked on the diagram and visual fields of other colors; explain the reason of difference between them).

Work 29.3. SENSITIVITY EVALUATION OF THE RETINA CENTRAL REGIONS

Sensitivity evaluation of central parts of the retina has an important significance as it determines visual acuity in many aspects. Sensitivity depends not only on neurons' functional state in this part of the retina but on the blood flow in its vessels, the state of the optic nerve, visual pathways, visual cortex and other factors.

Accomplishment. The work is performed using program "**Field sensitivity test**". On entering the program a coordinate net appears on the screen that corresponds to angular dimensions of the retina's central region. 68 points are marked on the net; they will appear one by one on the screen at random.

The work is performed after darkness vision adaptation in a semi-darkened room. Your eyes should be at the distance of 30 cm from the screen at the level of its medium part. Try to keep the head motionless.

The study is performed for each eye separately. One eye should be closed. During the whole study the sight should be fixed at a cross in the center of the screen. Some time later a fluorescent point appears in the vision field. The point intensity increases gradually, and at some moment it becomes sufficient to be discerned on a dark screen. As soon as the point becomes discernable, press "Enter" immediately. As sooner you note the fluorescent point, the smaller is the brightness necessary for perception of a stimulus with the given part of the retina, i. e. the greater is its sensitivity.

To start testing press "Enter" again, the coordinate net will disappear and a cross will appear in the center for sight fixation. There will be a back count of points starting with 68 in the upper left corner. Don't forget that the sight is constantly fixed at the center of the screen all the time.

After the last point has appeared, the testing results will be presented as a colored distribution of points of the coordinate net in accordance with the color scale. Depending on the time needed for finding the points, the sensitivity of every part of the studied region of the retina is evaluated. Points of blue color correspond to the area of maximum light sensitivity, points of light blue, green, yellow, red and pink color — to the areas with less and less sensitivity in the central part of the retina. Predomination of blue and light-blue color evidences high sensitivity of the retina, of green and yellow color — normal moderate sensitivity. Points of red and pink color predominate, when sensitivity of the retina is reduced.

A considerable impact on the results of the study produces the degree of darkening and time of preliminary darkness adaptation. But while performing the work in similar for the whole group conditions the results of different examined people can be compared even in short times of darkness adaptation.

To exit from the program press “Esc”.

Results: On the screen points of _____ colors predominate.

Conclusion: retina sensitivity of the examined eye is_____
(high, moderate or reduced)

Work 29.4. EVALUATION OF LIGHT SENSITIVITY USING ADAPTOMETER (demonstration)

The visual analyzer ability to react to light flow changes is a fundamental property of the visual system and is determined by absolute light sensitivity. Absolute light sensitivity is characterized by the least amount of light energy, under the exposure to which a sense of light appears. In norm the absolute threshold of light sensitivity of the human eye in complete darkness adaptation with duration of 60 minutes and more is equal to $8{,}7923 \cdot 10^{-8}$–$2{,}355 \cdot 10^{-6}$ apostilb (asb), and in 10-minute adaptation it fluctuates from $1{,}75 \cdot 10^{-4}$ to $1{,}1 \cdot 10^{-5}$ asb (at an average $4{,}2 \cdot 10^{-5}$).

Materials and equipment. An adaptometer, a table, an armchair, cotton-gauze napkins and 70 % solution of ethanol.

Accomplishment. Evaluation of light sensitivity and visual acuity is performed under the conditions of darkening, after 10–15-minute adaptation of the examined to darkness. Some figure (a square, a ring or a cross) is set in the visual field of the adaptometer. The study is started in complete darkening of the vision field with light filters. Light intensity is increased slowly by reducing the number of light filters and changing the size of the diaphragm to the moment of the examined gets a perception of light that doesn’t disappear for 10–15 sec. The obtained intensity value is the absolute threshold of light sensitivity that is expressed in asb. Then brightness of the figure is being increased till the examined has determined correctly its shape (e. g. a square). This brightness value

presents distinction threshold. The difference between values of distinction threshold and absolute light sensitivity is difference threshold of distinction.

Results: While studying the absolute threshold of light sensitivity the total density of light filters and diaphragm is _____, brightness is _____ asb.

While studying the distinction threshold the total density of light filters and diaphragm is _____, brightness is _____ asb.

Difference threshold is_____ asb.

Conclusion: (evaluate light sensitivity of the retina of the examined in 10-minute adaptation to darkness)

In what way does light sensitivity depend on the duration of adaptation?

Work 29.5. STUDYING COLOR VISION

The human eye can discern both shades of black, white, grey colors and all colors and shades of the rainbow. However, there occur various disorders of color perception in some people. Complete color blindness occurs extremely rare. People with this form of color vision disorder see only various shades of grey. Partial color blindness occurs more often.

Studying color vision has a particular significance for people, whose profession requires good orientation in all colors.

Materials and equipment: polychromatic tables of E. B. Rabkin, a shield for covering one eye, a centimeter tape.

Accomplishment. Every table should be set at the eye level of the examined at the distance of 1 m from him. The exposure duration of one and the same table is about 5 sec. Each eye is examined separately, the second eye being covered with a special shield.

Directions for recording the protocol:

1. Describe the results of studying color perception.
2. In case of a disorder revealing point out, to which type it is referred.

Conclusion: (if there are any color perception disorder in the exam**ined).**

Work 29.6. THRESHOLD EVALUATION OF VISUAL COLOR SENSITIVITY

The work is performed using the program “Color test” after darkness adaptation of vision in a semi-darkened room. On switching on the program “Color test” two illuminated squares appear on the screen.

A. Increasing gradually the intensity of the left square by pressing key “D”, find the threshold value of color intensity of the square, when the examined determines its color with confidence. Press key “Enter” and record the relative thresh-

old perception value of the given color. Ask the examined not to look at the screen and by pressing keys "S" and "W" change the color for another, diminish its intensity up to 0 by consequent pressing key "A". Then increase color intensity pressing key "D" and find threshold color intensity of the left square, when the examined determines a new color with confidence. Press key "Enter" and record a relative perception value of the given color. Repeat evaluation of perception threshold for other colors.

B. By sequential pressing key "D" set an arbitrary (medium) intensity of the left square color. The examined must adjust by pressing keys → or ← the color intensity of the right square to the identical. After completing the adjustment press key "Enter" and record digital values of difference threshold of color perception. In full coincidence of color intensity the difference threshold is 0.00; adjustment discrepancy is marked with positive and negative values of thresholds difference.

Threshold values of color perception are:

Red _____; yellow _____; green _____; blue _____.

Difference threshold value of perception of _____ color is _____.

Work 29.7. VELOCITY EVALUATION OF SIMPLE SENSOR-MOTOR REACTION

The velocity of sensorimotor reaction characterizes the time expenditures for accomplishment of such physiologic processes as perception of a visual signal by the retina, transmission of afferent nerve impulses from the retina to the primary visual cortex, signal transmission from the visual cortex to cortical motor regions of the frontal lobes and transmission of efferent signals from there by corticospinal pathways to motor neurons of the spinal cord, the axons of which innervate the muscles of the forearm and hand fingers.

Accomplishment. Choose the program "Reaction test", press *Enter*. A bright triangular object appears in the center of the screen. Each time after the object appears on the screen press key *Enter* as soon as possible. After every object appearance (except the 1st one) the screen shows a *mean* value of your sensorimotor reaction.

Recording the protocol. To estimate the received values of your reaction time compare it with mean reaction time values for the students of your group. Insert the data into the protocol.

Mean time of sensorimotor reaction (from 5-6 evaluations) is _____.

Mean value of sensorimotor reaction time in the students of the group is _____

Lesson 30. PHYSIOLOGY OF AUDITORY, VESTIBULAR, TASTE, OLFACTORY AND TACTILE ANALYZERS

Basic questions:

1. The auditory system. Peculiarities of the structure and properties of sound-perceiving and sound-conducting apparatuses. Mechanisms of sound perception and analysis. Transmission and processing of information in conducting pathways and central parts of the auditory system.

2. The vestibular system. Peculiarities of the structure and properties of the receptor part ensuring perception and assessment of the body position in statics and dynamics. Transmission and processing of information in conducting pathways and central parts of the vestibular system. Organism reaction to stimulation of the vestibular apparatus.

3. The taste system. Taste reception. Conducting pathways and central parts of the taste system. Taste perception. Classification of tastes. The organism reaction to taste stimulation.

4. The olfactory system. Reception of smells. Conducting pathways and central parts of the olfactory system. Perception and classification of smells. The organism reaction to stimulation of the olfactory system. Protective reflexes.

5. The somatovisceral sensory system. Skin sensitivity. Mechanoreceptors. Types of receptors. Transmission and processing of information in conducting pathways and central parts.

6. Proprioceptive sensitivity. Receptor mechanisms. Peculiarities of the structure of conducting pathways and central parts. The role in perception and assessment of body position in space, in forming muscle tone and movements.

7. Interoceptive sensitivity. Receptor mechanisms. Types of interoceptive sensitivity. Organism reactions to stimulation of interorerceptors. The role of interoreception in maintaining homeostasis.

8. Nociception. Reception of pain stimuli. Peculiarities of the structure and properties of conducting pathways and central parts. Central mechanisms of pain. Antinociceptive systems. Neurochemical mechanisms of antinociception. The concept of anesthesia. Projection and reflected pains.

Self-check:

1. In what way will the amplitude, strength and frequency of sound oscillations change in their transmission through the middle ear structures?

2. In what part of the cochlea the width of the basal membrane is the greatest? What frequencies are perceived by hairy cells located in this part of the basal membrane?

3. In what way can the impairment of the sound-perceiving apparatus of the human internal ear be revealed with the camertone?

4. Due to what do otolithic apparatus receptors react to linear accelerations and acceleration of gravity while the receptors of semi-circular canals don't?

5. Afferent fibers of what analyzer don't switch in the thalamus and don't come to the opposite side of the brain?

6. To what taste substances is the human sensitivity maximal?

7. What regions of the skin possess the highest ability to spatial discrimination?

8. Which antinociceptive systems do you know?

PRACTICAL WORKS

Work 30.1. EVALUATION OF SOUND SOURCE DIRECTION

The man and animals possess spatial hearing that allows placing a sound source, the degree of its remoteness and direction of its movement as well as increases the clearness of perception. Time characteristics of spatial hearing are based on joining data received from both ears (binaural hearing). Determination of the direction to the source of the sound is based on the two factors. For *low frequencies* the basic factor is the time difference, and for *high frequencies* — the intensity difference of a sound wave reaching the left and the right ear.

Materials and equipment: a camertone, a phonendoscope with tubes of different lengths.

Accomplishment. The examined with closed eyes must determine the direction of a sound source created by tapping (e.g. with a pencil over pencil) on the right, on the left, in front of, behind the back of the examined. Then insert into the ears of the examined olives of the phonendoscope, one of the tubes of which is considerably longer than the other. The phonendoscope must be behind the examined. Repeat the experiment for determination of the sound source direction.

Results:

Conclusion: (explain, why the sound seems to be shifted to a shorter way of sound conduction).

Work 30.2. STUDYING BONE CONDUCTION

Weber's test

There is bone conduction and air conduction. Air sound conduction is ensured by transmission of a sound wave by usual way through a sound-conducting apparatus. Bone conduction is the transmission of sound waves directly through cranial bones.

Materials and equipment: a camertone, a stop-watch, cotton pads.

Accomplishment. Apply the handle of the vibrating camertone to the top of the head in its middle line. Ask the examined if he hears by both ears the sound of the same intensity or it is heard better with one ear. In the damage of the sound-perceiving apparatus lateralization of the sound is noted to the side

of a healthy ear, in the damage of the sound-conducting apparatus the sound is lateralized to the side of an damaged (that poorly hears) ear. Repeat the experiment covering the one auditory canal with cotton.

Results:

Sound intensity on the left and on the right in the initial state: _____

After closing the auditory canal — _____

Conclusion:

The cause of sound lateralization on closing one auditory canal:

Rinne's test (comparison of air and bone sound conduction).

Accomplishment. Apply the hand of the camertone to a mastoid bone at one side and take the time till sound perception disappears (the time of bone conduction). Then bring the same still vibrating camertone to an external auditory canal. In norm the examined must hear sound of the camertone that is still oscillating. Take the total time, during which the sound is heard (the time of air conduction). In norm the time of air conduction is greater than that of bone conduction (a positive Rinne's test). When the sound-conducting apparatus is impaired, the time of air conduction does not exceed the time of bone conduction (a negative Rinne's test).

Air conduction time: on the left — , on the right — .

Bone conduction time: on the left — , on the right — .

Conclusion: **Rinne's test _____.**

Work 30.3. STUDYING THE DEPENDENCE OF AUDITORY SENSITIVITY ON SOUND FREQUENCY

The human ear perceives sound oscillations in the range of 16–20 000 Hz. The greatest sensitivity to sound oscillations is in the range 1–3 kHz that coincides with the frequencies range of the human speech.

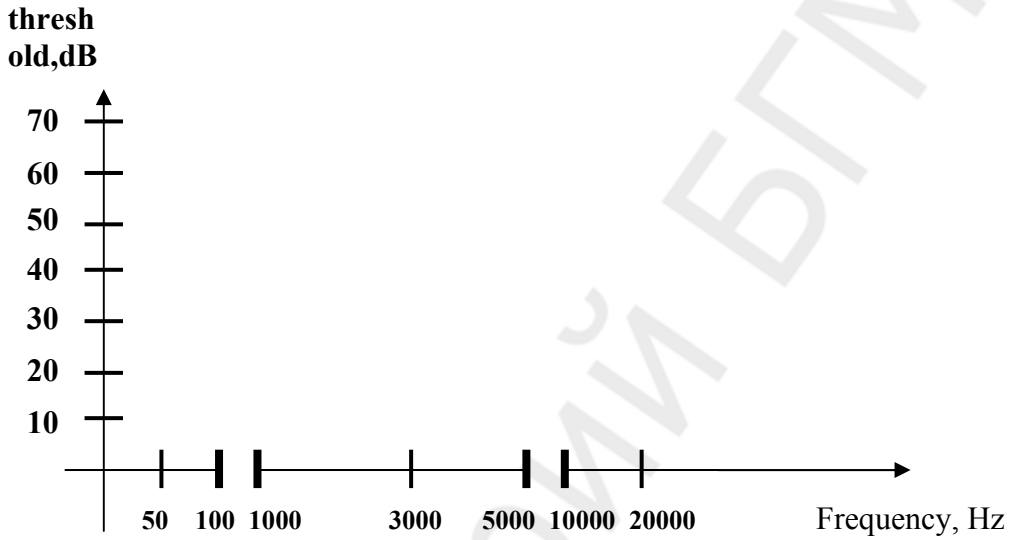
Sensitivity of the auditory analyzer is evaluated by a minimum value of sound pressure sufficient for a sense perception to appear; i. e. by hearing threshold. To determine this minimum sound pressure audiometers are used. They permit precisely dosing sound oscillations frequency in the range from 100 to 10 000 Hz and sound intensity in the range from 0 to 100 dB. To characterize the state of the auditory analyzer in the examined one should find hearing thresholds for every fixed frequency of sound oscillations and draw a graphic relationship of the hearing thresholds and sound frequency — an *audiogram*.

Materials and equipment: an audiometer, ear-phones.

Accomplishment. Using the sound generator 3G-10, determine thresholds of absolute auditory sensitivity (in decibels) for the left and right ear for the following frequencies:

Results:

50 Hz —	100 Hz —	1000 Hz —
5000 HZ —	10000 Hz —	15000 Hz —



Audiogram of the examined

Conclusion: **(point out the frequency range of the highest auditory sensitivity)**

Work 30.4. Studying tactile sensitivity. Esthesiometry (measurement of spatial thresholds)

Tactile sensitivity is measured by esthesiometry. There is a *spacial sensitivity* that is characterized by a spatial threshold, and sensitivity that is determined by a power threshold. Spatial threshold of tactile sensitivity is characterized by that *least distance* between two points of the skin, in simultaneous touching to which *a sense of two touches* occurs. It characterizes the spatial discriminative ability of the skin.

Materials and equipment: an esthesiometer (Weber's compass).

Accomplishment. The examined must be seated with closed eyes. The esthesiometer with branches brought together maximally close is brought in touch with some regions of the skin. It is necessary to observe that both needles of the esthesiometer touched simultaneously and with identical pressure. Touching is repeated with gradual increasing the distance between the esthesiometer branches (every time by 1 mm), and a minimum distance is found, when a sensation of two separate touching appears. This distance is a spatial threshold

for the given region of the skin. Evaluate the spatial threshold of skin surface on the regions indicated in the table.

Fill in the table:

Table 38

Skin surface	Spatial threshold (in mm)
Internal side of the forearm	
External side of the forearm	
Tip of index finger	
Cheek	
Forehead	
Lip	

Compare spatial thresholds of tactile sensitivity of the examined skin regions. Explain the reasons of their difference.

Work 30.5. STUDYING THE FUNCTIONAL STATE OF THE VESTIBULAR ANALYZER AND ITS EFFECT ON SOMATIC AND AUTONOMIC FUNCTIONS OF THE ORGANISM

In adequate stimulation of the vestibular apparatus due to multiple associations of its central parts with other parts of CNS various reflex reactions occur: tone reflexes of skeletal muscles of the neck, trunk, extremities, ocular muscles and autonomic reflexes of internal organs — the heart, gastrointestinal tract, vessels, etc.

During rotary movement the nystagmus of the head is noted, it is characteristic that at first the head slowly turns to the side opposite the rotation direction and then quickly returns to the initial state. During rotation a rhythmic ocular nystagmus is also noted. It includes two components: a slow one that is manifestation of a statokinetic reflex to angular acceleration, and a faster one that follows it and is characterized by the movement of the eye-ball (jump) in the opposite direction. The slow nystagmus component occurs at the beginning of the movement, when endolymph moves towards ampoule more slowly under the action of acceleration, and is always directed towards the side opposite to rotation. There is no nystagmus during rotation itself, because endolymph moves with the same velocity as the semicircular canals. At the stop or slowing the movement, i.e. in the presence of negative acceleration, endolymph moves by inertia, but in the opposite direction and a post-rotary nystagmus occurs. The ocular nystagmus occurring on turns of the head or on rotations is important for adaptation as it ensures preservation of normal visual orientation and allows fixing the image of objects on the retina during changing the pose and position of the head.

Materials and equipment: an armchair of Barany, a frequency-meter (Ч3-22), a photoplethysmograph (ФПГ-02), eye-bandage, a stop-watch.

Accomplishment.

1. Measuring the nystagmus duration. The examined is rotated in the armchair of Barany with the speed of 10 turns per 20 seconds. During rotation the eyes must be closed. After stop the examined must fix his sight at an immovable object. The character the observed eye-balls nystagmus depends on predominant stimulation of these or other semi-circular canals, which is determined by the position of the head of the examined during rotation. A horizontal nystagmus is noted in rotation with the head inclined forward by 15º, a rotary nystagmus — in the head inclination by 90º, a vertical one — in the head inclination to the left or right shoulder. The duration of the nystagmus is measured with the stop-watch (in norm from 20 to 30 sec). Insert the obtained data into the table.

Table 39

Stimulation effect of vestibular receptors with centrifugal acceleration on duration of a post-rotary nystagmus

Head position	Canals activation of the vestibular apparatus	Type of the nystag-mus	Duration of nystagmus (sec)
Inclination forward by 15º	Horizontal canals	Horizontal	
Inclination forward by 90º	Vertical canals	Rotary	
Head inclination to the shoulder	Saggital canals	Vertical	

2. Stimulation effect of the vestibular apparatus on cardiac cycle duration. The examined is seated into the armchair of Barany and his cardiac cycle is determined from 10 contractions. An instant value of heart rate is calculated by the formula: HR^{inst} = 60000 msec/mean duration of the cardiac cycle. A photoplethysmograph, the sensor of which is fixed to the first phalanx of the left index finger, is attached to the frequency meter. The left hand is preliminarily warmed in warm water for increasing the blood flow. Before rotating the examined the photosensor is disconnected from the plethysmograph, and after rotation it is quickly connected to it. Then within a minute with intervals of 5 sec the duration of the cardiac cycle is measured. To stimulate vestibular receptors rotation with angular velocity of 10 turns per 20 sec is used, the head is inclined forward by 90°. Insert the obtained data into table 40.

Table 40

Stimulation effect of the vestibular apparatus on cardiac cycle duration (CCD)

Factor	Rest			After rotation		
	horizontal	rotator	vertical	horizontal	rotator	vertical
CCD mean, msec						
HR^{inst}						

Conclusion: (explain the nystagmus mechanism and the vestibular apparatus effect on the cardiovascular system, list other stimuli causing nystagmus).

Work 30.6. STUDYING TASTE SENSITIVITY

Materials: Solutions of common salt, sugar, citric acid and quinine, each solution in 4 concentrations: 1 %, 0,1 %, 0,01 % and 0,001 %.

Accomplishment**. T**he examined is given 2–3 ml of the solution of unknown to him substance with a pipette or in a test-tube starting with a minimal concentration. Having kept the solution in the mouth for 20–30 sec (without swallowing), he must identify the taste of the solution. If the examined cannot identify the taste, he is given the solution of greater concentration of the substance — until he surely identifies the taste. The solution concentration, at which the examined correctly defined the substance taste, is threshold. The less is this concentration the higher is sensitivity to this substance.

Fill in the table:

Substance	Threshold concentration
Bitter (quinine)	
Sweet (sugar)	
Salty (common salt)	
Acid (citric acid)	

Conclusion: (compare thresholds of taste sensitivity to various substances)

SECTION TOPICS ARE PASSED_____

(Teacher's signature)

INTEGRAL BRAIN ACTIVITY

Lesson 31. INNATE AND ACQUIRED ADAPTIVE REACTIONS OF THE ORGANISM TO ENVIRONMENTAL CHANGES. MEMORY. TYPES OF HIGHER NERVOUS ACTIVITY

Basic questions:

1. Unconditioned reflexes and instincts: classification, conditions for manifestation, biological role.

2. Conditioned reflexes. Conditions, structural and functional basis and neuro-physiological mechanisms of formation and manifestation of conditioned reflexes. Temporary connection, mechanisms of its locking.

3. The adaptive role of conditioned reflexes. Inhibition of conditioned reflexes.

4. The concept of dynamic stereotype and its significance for learning and acquiring working skills.

5. Memory. Classification of memory types. Basic neurophysiological mechanisms of short-term and long-term memory.

6. The role of different parts of the brain for realization of congenital and acquired forms of behavior, for learning and memory.

7. The theory of I.P. Pavlov of the higher nervous activity and its types.

Self check:

1. What are the common features and differences between unconditioned and conditioned reflexes?

2. Which stimulus — conditioned or unconditioned — must be the first to act in formation of a classic conditioned reflex?

3. What kind of inhibition of the formed conditioned reflex is observed, when its reinforcement stops?

4. What brain structures are most important for memory processes?

5. What is the difference between the mechanisms underlying the processes of short-term and long-term memory?

6. What common features has a sanguine and a phlegmatic person? What features differentiate them from each other (by Pavlov)?

7. What common features has a sanguine and choleric person? What features differentiate them from each other (by Pavlov)?

PRACTICAL WORKS

Work 31.1. ASSESSMENT OF THE ASSOCIATIVE MEMORY VOLUME

Associative memory is based on independent active usage of abilities by a person to memorize, store and reproduce information. Associative memory allows establishing a meaningful association between a new presented event (word) and its association with other current or former events (environment, time, objects, etc.).

Materials: pens, blank sheets of paper.

Accomplishment. A number of words (word combinations) are presented to the students. They must memorize them having listened only once (in **slow** reading). To make memorizing easy one should fix associations caused by the words making notes on the paper — symbols or drawings, but **not words**. The number of word combinations — 18–20; the interval between them must be sufficient for fixing associations. Then the drawings should be taken away and left for 30–60 minutes. In the indicated period of time every student must independently use his own notes and recollect and put down all word combinations. Then correctness of reproduction is checked and the number of mistakes is counted. A mistake is any deviation from the initial word combination (replacement of the word, preposition, case, etc.). 1 score is given for every correctly reproduced word combination. Assess the result by the scale:

The assessment of associative (meaningful) memory:

20 scores — very highly developed associative memory;
16–19 scores — highly developed associative memory;
8–15 scores — moderately developed associative memory;
4–7 scores — low developed associative memory;
0–3 scores — poorly developed associative memory;

Results:

Number of mistakes —
Scores —

Conclusion:

Assessment of a dominated type of thinking

Peculiarities of a thinking type are reflected by types of drawings of the examined. All images can be classified into 5 basic types:

– *abstract* — as lines not formed into an image;
– *sign-symbolic* — as signs or symbols (geometric figures, arrows, etc.);
– *concrete* — concrete objects;
– *plot* — imaged subjects, personages are joined in some situation, plot;
– *metaphoric* — images as metaphors, fiction, etc.

Depending on most frequently used type of imaging one can make a hypothesis of peculiarities of the thinking type of the examined. If he uses predominantly abstract or sign-symbolic drawings, it evidences the predomination of the tendency to generalization and synthesis of information. Such people are characterized by a high level of development of the ***abstract-logical*** thinking. Plot and metaphoric images predominate in people with a ***creative*** type of thinking. When concrete images predominate, one can suppose a ***concrete-action*** type of thinking.

Examine the drawings made, determine their predominant type and make a conclusion of a supposed thinking type.

Conclusion:

Work 31.2. EVALUATION OF A SHORT-TERM AUDITORY MEMORY VOLUME USING LETTER AND DIGIT COMPLEXES IN THE HUMAN

Letter or digit signal complexes are used for the fast evaluation of a short-term memory volume. They are used to find the maximal number of digital and letter signs that a person can memorize (by ear or reading) and reproduce after one presentation.

Materials: tables with digital and letter complexes.

Accomplishment. The work uses two equivalent tables (41 and 42) with complexes of letters or digits. Each table contains 8 rows; the number of signs in every row increases from 3 in the first row to 10 signs in the last row. The work is accomplished in pairs. One student reads to the other lines from the first table beginning from the shortest (for example, 9, 7, 2 or А, Ы, О) with the rate of 3 signs per 2 sec. An interval of 5-7 sec must be given after every complex. The examined must immediately repeat by memory the heard row in the same sequence. If the row of digits (or letters) is reproduced without mistakes, the examined is read the next, longer line. After a mistake (missing or replacing a sign or changing the sequence of their reproduction) the examined is read a new complex with the same number of elements, now from the second table. In case of successful memorizing this complex the next complex with greater number of elements is read to. If a mistake is made again, the number of signs in the last correctly reproduced complex is the upper volume limit of short-term memory of the examined.

An adult person memorizes **7**±2 signs at an average from the first presentation. Analogous results were received in consequent presentation of geometric figures, object images or words that have no meaningful association; digits and words being memorized better than letters.

Table 41 *Table 42*

9 7 2 **1 4 5 6** **3 9 3 1 8** **4 7 6 2 8 5** **3 1 5 6 2 9 7** **3 8 3 9 1 2 7 4** **7 6 4 5 8 3 1 2 9** **2 1 6 4 3 8 9 5 7 3**	**6 4 1** **2 7 3 5** **8 5 9 4 3** **7 6 5 2 9 4** **1 5 3 8 7 9 6** **2 9 6 8 1 3 5 7** **3 4 2 8 6 5 1 2 9** **4 7 9 5 3 8 8 2 1 5**
А Ы О **Е Ю У Ы** **О У Ю Е А** **Ы О Е А Ю У** **У Е Ю А Ы О Е** **Ю А Е У О Ы А Ю** **А Ю Ы О У А Е Ы О** **Е У А Ы Е У Ю О А Ы**	**Ю А Ы** **У Е О А** **Ы О А Ю Е** О Ы У Е А Ю **Е У А Ю Ы Е О** **А Ю Ы У О А Ы У** **Ю Ы О А У Ы Ю Е А** **У Е Ю О Ы У А О Е Ы**

Volume of short-term auditory memory:
digits — _____ signs, letters — _____ signs,
Conclusion:

Lesson 32. HIGHER INTEGRATIVE BRAIN FUNCTIONS AS PHYSIOLOGICAL BASES OF HUMAN PSYCHIC FUNCTIONS

Basic questions:

1. States of sleep and being awake and their neurophysiologic mechanisms. The cycle sleep — wakefulness. Sleep phases. The state of CNS functions, somatic and autonomic functions of the organism during sleep and wakefulness.

2. Localization of functions in the cerebral cortex and other brain structures. Functional peculiarities of cerebral cortex activity: asymmetry and dominance.

3. The first and second signaling systems. Speech and its types. The role of sensory (Wernicke) and motor (Broca) centers in speech function. The concept of aphasia.

4. Attention and its neurophysiologic mechanisms. The role of attention in processes of perception, memorizing and learning.

5. Physiological needs of the organism, motivations and dominants. Kinds of motivations, the concept of their formation mechanisms and significance for vital activity.

6. Emotions, their types. The concept of neurophysiologic mechanisms of emotion formation. The role of the cerebral cortex, limbic system. The state of CNS functions, somatic, autonomic, endocrine functions of the organism in various emotions.

7. Systemic analysis of purposeful behavior from the position of functional systems theory by P.K. Anokhin. The structure of a behavioral act.

8. The concept of thinking, states of consciousness and subconsciousness. Basic medical criteria of consciousness.

Self check:

1. In what way do electroencephalographic (EEG) factors differ in the state of wakefulness and sleep in the human?
2. During what phase of sleep is a minimal skeletal muscles tone noted?
3. What EEG frequency is characteristic of fast sleep?
4. Where is the motor cortex localized?
5. Where is the auditory cortex localized?
6. What is the functional asymmetry of the brain hemispheres expressed by?
7. In what kind of aphasia is there understanding and meaning of speech impaired but the ability of fluent speech retained?
8. In what kind of aphasia is there pronunciation of words and construction of phrases impaired but understanding of speech retained?
9. What is the name for the whole complex of excitations caused after the satisfaction of a need?
10. What are the components of the afferent synthesis stage by Anokhin?
11. At what stage of a behavioral act is the acceptor of the action result formed?
12. By what features is it possible to assess the presence or absence of consciousness in the human?

PRACTICAL WORKS

Work 32.1. ASSESSMENT OF A LATENT PERIOD OF SIMPLE AND COMPLEX SENSORIMOTOR REACTION (computer program)

The work is performed in the program "**Reaction test**". A light triangle appears on a dark screen. It will disappear in 2–3 sec. When it appears again it is necessary to press *Enter* maximally quickly. The value of a latent period of your simple sensorimotor reaction in milliseconds will appear in the upper part of the screen.

Repeat the test again. Immediately, after the triangle disappears, start mental subtraction of 7 from 200 (200 – 7 = 183, 183 – 7 = 176 etc.) with maximum speed. Without discontinuation of the count and on appearing of a triangle, press *Enter* as fast as you can. Put down the obtained value of a latent period of a complex sensorimotor reaction.

On the basis of the obtained latent periods compare the speeds of a simple and complex sensorimotor reaction.

Results:

Latent period of a simple sensorimotor reaction is _____ msec.

Latent period of a complex sensorimotor reaction is _____ msec.

Conclusion:

Work 32.2. MANIFESTATION OF HEMISPHERES FUNCTIONAL ASYMMETRY

To assess functional correlation of the right and left hemisphere in the human, multiple tests of various complexities are used. The work offers one of the simplest tests.

Materials and equipment: paper, a calculator.

Accomplishment. Answer the following questions using the 11-score system. 0 scores correspond to categorical negation, to unconditional consent — 10 scores. But if the first question embarrasses you, as you don't consider yourself a gloomy person, but at the same time are not in a hurry to join the rows of happy optimists, then scores from 1 to 9 are at your disposal. Try to give yourself a fair assessment for your "mood".

1. I have predominantly a good mood.
2. I remember what I learnt some years ago.
3. Having listened to a melody, I can reproduce it correctly.
4. When I listen to a story, I imagine it in persons.
5. I consider that emotions only interfere with the conversation.
6. Mathematics is difficult for me.
7. I memorize unfamiliar faces easily.
8. Being with my friends I am the first to start a conversation.
9. If somebody's ideas are discussed, I demand arguments.
10. I have predominantly a bad mood.

Scores by points 1, 2, 5, 8, 9 (L) = _____

The value of L **characterizes the left hemisphere.**

Scores by points 3, 4, 6, 7, 10 (R) = _____

The value of R characterizes the right hemisphere.

Analysis of the results:

1. L is greater than R. If the difference exceeds 5 scores, then logic type of thinking dominates.

2. R is greater than L. It is probable that artistic type of thinking dominates.

3. R is equal to L. The most probable that logic and artistic types of thinking are combined.

Conclusion:

Work 32.3. ASSESSMENT OF ATTENTION INDICES USING A CORRECTION TEST

Attention is one of the main psychological processes, on characteristics of which depends the state of cognitive readiness for learning, successfulness of academic and professional activity.

Basic characteristics of attention:

– *stability* — the ability to keep attention on one and the same, sufficiently high level during a long period of time;

– *distribution* — the ability allowing to keep simultaneously a number of inhomogeneous events in the sphere of attention;

– *switching* — a property that is characterized by the speed of switching attention from one object to the other, the ability to distract from the first and concentrate on the second;

– *attention volume* — is the number of objects or events that can be simultaneously in the sphere of attention of a person.

The correction test suggested for the first time by B. Bourdon in 1895 allows assessing the ability of concentration and stability of attention.

The study is performed using special correction tables — forms with rows of randomized Landolts' rings, letters, digits, figures, etc. The work offers a letter variant of tables.

Materials and equipment: a stop-watch, a pencil, standard correction tables with rows of small letters placed randomly without intervals.

Accomplishment. The work is performed either individually or by the whole group of students. Standard correction tables contain 1600 signs. The time of accomplishment is 5 min.

Instruction for the examined. By a signal you should start looking through attentively every row of table 43 from the left to the right, find and cross out that letter, with which the line starts. The work is performed for a time with maximal speed and precision. Every minute on command "line" mark with a vertical line that place on the form, where the command caught you. The work stops on command "stop".

After completing correction:

1. Evaluate the number of letters looked through for every minute and for 5 minutes in total.

2. Evaluate the number of mistakes (missed or incorrectly crossed out letters) made per each minute and during 5 minutes.

3. Calculate the attention indices for every minute of work and for 5 minutes as a whole:

Attention volume is assessed by the number of looked through signs for 5 minutes (in norm 850 letters and over).

Attention concentration is assessed by the number of mistakes made for 5 minutes (in norm 5 and less).

Attention switching index is calculated by the formula:

$$C = (O_S : K_S) \times 100\ \%,$$

where O_S — the number of lines looked through with mistakes; K_S — total number of lines in the part of the table looked through.

Index of attention productivity and stability is calculated by the formula:

$$S = (0.5\ N - 2.8\ n) : t,$$

where S — index of attention productivity and stability per time unit; *N* — the number of signs looked through per time unit; *n* — the number of mistakes made per a time unit; *t* — time of work, sec.

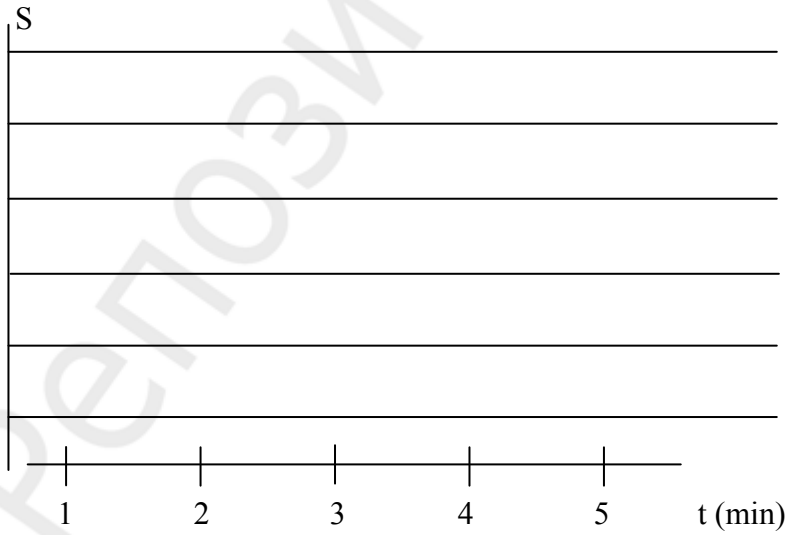
PROTOCOL

1-я min — N = _____; n= _____; S = _____;
2-я min — N = _____; n= _____; S = _____;
3-я min — N = _____; n= _____; S = _____;
4-я min — N = _____; n= _____; S = _____;
5-я min — N = _____; n= _____; S = _____;
For 5 min in total — N = _____; n= _____; S = _____;

Assessment of results:

S	Scores	Attention productivity and stability
Over 1,25	**10 scores**	**very high**
1,0–1,25	**8–9 scores**	**high**
0,5–1,0	**4–7 scores**	**medium**
0,2–0,5	**2–3 scores**	**low**
0,0–0,2	**0–1 score**	**very low**

Using all obtained indices of attention productivity and stability (S) draw a graph reflecting the dynamics of changing the attention productivity and stability during the task accomplishment.



Make a conclusion on the volume, concentration, switching, productivity and stability of attention.

Conclusion:

Table 43

Standard letter table for correction test

СХАВСХЕВИХНИСХНВХВКМНАИСЕМВХЕНАИСНПУКСОВ
ВЕНХИВСНАВВСАВСАЕКМАХВКЕОРУМЛПНАВЫВАМПРИ
НХСРОВНВОТКНЛМЧАМОЛТВНЛМИСМГУБВВНСМЛОТЛБ
ХАКИТОНВММБЛЧСХНГХАИХКМИНГСБЧХФИСБЛМОГНХ
АХВСТМОНЕУБСТГАХЫЧНАТНВЛСМНГАХВВЛГМВЕМНМ
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Кубарко Алексей Иванович
Северина Татьяна Геннадьевна

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