NORMAL PHYSIOLOGY

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МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
КАФЕДРА НОРМАЛЬНОЙ ФИЗИОЛОГИИ

НОРМАЛЬНАЯ ФИЗИОЛОГИЯ

NORMAL PHYSIOLOGY

Практикум
для иностранных студентов, обучающихся на английском языке
по специальности «Лечебное дело»

2-е издание

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А в т о р ы: А. И. Кубарко, Т. Г. Северина, В. А. Переверзев, Д. А. Александров, Н. А. Башаркевич, А. А. Семенович

Р е ц е н з е н т ы: д-р мед. наук, проф., чл.-корр. Национальной академии наук Беларуси, зав. каф. патологической физиологии Белорусского государственного медицинского университета Ф. И. Висмонт; канд. мед. наук, доцент каф. биохимии Белорусского государственного медицинского университета А. В. Колб

Нормальная физиология = Normal physiology : практикум для иностранных
Н83 студентов, обучающихся на английском языке по специальности «Лечебное дело» / А. И. Кубарко [и др.]. – 2-е изд. – Минск : БГМУ, 2021. – 171 с.

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Представлены описания лабораторных работ и протоколы их оформления, а также вопросы к практическим и итоговым занятиям по нормальной физиологии. Приведены задания для организации самостоятельной работы студентов. Первое издание вышло в 2019 году.

Предназначен для иностранных студентов 2-го курса лечебного факультета, обучающихся на английском языке.

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INTRODUCTION

The Practical book is designed to assist students in their preparation for the lessons and recording practical works in Normal Physiology. It meets the requirements of the standard program in normal physiology for higher educational establishments that is approved by the Health Ministry of the Republic of Belarus in 2014. The new edition of practical book is intended to improve the quality of medical students' theoretical and practical training.

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 book is aimed at studying the status of physiological function of a healthy human organism. The teaching and testing programs are available in the computer class of the Department. The practical book 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 evaluation by modern clinical methods of blood testing, gases analysis, electroencephalography, investigation of the cardio-respiratory system reserves, etc.

It is recommended to use the practicum while preparing for every class. It contains the main points of the themes to be considered during classes as well as self-control questions, and the students can use them while getting ready for regular and concluding classes (colloquiums) as well as during preparation for examination. Present Practical book edition contains the lists of questions for all concluding classes (colloquiums) which make the main part of the examination questions. Along with the textbooks the lectures of the Normal Physiology department and related disciplines should be used.

At the end of every Physiology section provided that the student has acquired practical skills and sufficient amount of theoretical knowledge of performed works and discussed questions, the teacher puts his signature (credit test is passed).

The accomplishment of all practical works and correct execution of works protocols with conclusions is the obligatory condition for the student's admission to the credit test and to the examination in Normal Physiology.

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

PHYSIOLOGY OF BLOOD

Lesson 1. INTRODUCTION. THE SUBJECT AND TASKS OF NORMAL PHYSIOLOGY. HOMEOSTASIS. PHYSICOCHEMICAL CONSTANTS OF BLOOD

Basic questions:

1. The subject of Normal Physiology. The significance of Normal Physiology for the system of knowledge required for higher medical education.
2. Safety provisions while performing practical works.
3. Physiological concept of internal environment of the body. Homeostasis as the constancy of internal environment and functions of the organism as well as the mechanisms regulating them.
4. Basic homeostasis constants of the blood, cardiovascular, respiratory and other systems of the organism. Relative constancy of homeostatic constants at rest and their changes at higher levels of activity of the organism.
5. The role of water for vital functions. The content and distribution of water in the organism. The main fluid compartments of the body.
6. The main strict physicochemical constants of blood. Osmotic blood pressure, its role in water distribution between extracellular and intracellular compartments. The main blood substances contributing the osmotic pressure creation.
7. Cellular dehydration and hyperhydration (cellular edema). Isotonic, hyper- and hypotonic solutions.
8. Colloid osmotic (oncotic) blood pressure, its role in water exchange between blood and interstitial fluid (tissues). The main blood proteins contributing to the oncotic blood pressure. The interstitial edema.
9. H^+ ions concentration in blood is its index (pH) as the strict homeostatic constant. Acidosis and alkalosis. Mechanisms of normal pH maintaining in the body. Buffer systems of blood, respiratory and renal compensation of acid-base balance disturbances.

***Self-check*:**

1. What body fluid is called the internal environment of the organism?
2. What is the total blood volume of an adult human?
3. What is the percentage of water in the body of an adult human?
4. What is the normal value of blood plasma osmolarity?
5. Arrange the following osmotically active substances according their contribution to the plasma osmotic pressure in descending order: proteins, glucose, sodium, potassium, chlorine, bicarbonate.
6. Is there difference of Na^+, Cl^- and K^+ concentration between blood plasma and interstitial fluid? Between interstitial and intracellular fluid?
7. Why is the 0.9 % solution of NaCl isotonic?

8. What is the concentration of isotonic glucose solution?

9. What is the value of colloid osmotic (oncotic) blood plasma pressure?

10. What protein components (globulins or albumins) and why it is this blood protein type that mainly determine the oncotic pressure level?

11. 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.

After the completion of safety rules studying it is necessary to put your signature in the "Safety Register for students" in the computer class, room 104.

PRACTICAL WORKS

Work 1.1. LEARNING METHODS OF WORKING IN THE COMPUTER ROOM

The computer room of the Department allows the visual presentation of information for learning the discipline. The use of computer programs allowing modeling organs and systems responses to various effects makes it easier to learn and understand the educational material.

The testing of students' knowledge of every theme in Physiology permits to monitor the degree of learning the educational material by the students as well as their understanding level and ability to solve the tasks which require mastering 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 perform the tests. One test is performed in order to assess the level of knowledge "survived" from the previous year of studying, including basic materials studied in Biology, Chemistry, Physics, Anatomy and Histology. The other test is performed to evaluate the degree of learning the material of the first lesson in Physiology. Every following lesson includes performing the corresponding test as well. The usual number of questions in a test is 30, but tests for some lessons may consist of up to 50 questions.

While performing any control test in the computer room it is not allowed to use mobile phones. In the computer room phones should be kept away.

Work 1.2. ACQUAINTANCE WITH BASIC INDICES OF BLOOD HOMEOSTASIS, CARDIOVASCULAR AND RESPIRATORY SYSTEMS OF THE ORGANISM

The table 1 should be filled with the necessary values of indices using materials of lectures, textbooks and the corresponding sections of this practical book.

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) in men		cells/L of blood
Red Blood Cells (Erythrocytes) in women		cells/L of blood
White Blood Cells (Leukocytes)		cells/L of blood
Platelets (Thrombocytes)		cells/L of blood
Hematocrit: in men		–
in women		–
Osmotic blood pressure		mosm/kg, mosm/L
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
Ejection fraction (EF) at rest		%
Cardiac output (CO) at rest		L/min
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

PROTOCOL

Give examples of the **strict homeostatic constants**:

1. _____
2. _____
3. _____

Give examples of the **soft** (changing within wide range of limits) homeostatic constants:

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**, **mechanical**, **thermal**, **chemical** and **biological**. Physiological hemolysis is the result of ageing and destruction of red blood cells.

Materials and equipment: 4 test-tubes; blood of a rat; 0.9 % solution of NaCl; 5 % glucose solution; ammonium chloride; alcohol; iodine; distilled water; cotton wool; masks; rubber gloves; 3 % solution of chloramine.

Accomplishment. 2 ml of 0.9 % solution of NaCl are added into one test-tube, 2 ml of 0.9 % solution of NaCl and 5 drops of ammonium chloride into the second test-tube, 2 ml of 5 % glucose solution into the third test-tube and 2 ml of distilled water into the forth 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**	**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. EVALUATION 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 extracellular fluid and the cells of the organism.

The value of **blood plasma osmotic pressure** in a healthy individual on average is **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 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. Thus, the freezing temperature of blood plasma sample is determined, and recalculated into the value of blood plasma osmotic pressure.

Fill in the normal limits of blood plasma osmotic pressure:

_____ mosmol/kg (mosmol/kg)

minimal maximal value

Lesson 2. 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. Blood. Functions of the blood. Blood volume. Composition of blood, its basic physical and chemical properties. Blood plasma proteins, their functions.
3. 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.
4. Hemoglobin, its main types. Peculiarities of the structure and properties of adult hemoglobin providing its functioning. Normal hemoglobin amount, evaluation methods.
5. Color Index and red blood cells indices (MCH, MCHC, MCV, RDW), their calculation. Its significance in diagnosing anemias.
6. Erythropoesis. The concept of a stem cell, the role of microenvironment of a stem cell. Signal molecules regulating blood formation (cytokines, hormones, neurotransmitters and etc.). Needs of the organism in essential nutrients, vitamins and trace elements for maintaining normal blood formation.
7. Erythrocyte destruction. Red blood cells destruction products, their utilization.
8. Neurohumoral mechanisms of erythropoesis regulation. Erythropoietin, its origin, role and application of in clinical practice.
9. Erythrocyte sedimentation rate (ESR), main factors affecting it, and methods of determination. Diagnostic significance of ESR.
10. Platelets, their count, structure and functions. Count methods. Thrombocytosis and thrombocytopenia. Thrombocytopoesis and its regulation.
11. 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?

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

Demonstration is shown in the computer room as teaching video.

Common clinical blood test is one of the most widespread 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 affected person <u>should</u>**:

– 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 4th 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 4th 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** _____

(**student's signature**)

Work 2.2. 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 should be diluted for easier cells counting. For Red Blood Cells counting under microscope the hypertonic **3 % solution of NaCl** is used, where Red Blood Cells shrinkage occurs what makes their color more intensive and their counting easier. For automatic counting equipment usually various versions of isotonic solution are used for blood dilution.

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. So, 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, or ml.

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 ml (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 line. Calculate the content of red blood cells in 1 liter of blood by the formula. Evaluate the received result versus the norm.

Mixer for RBC

PROTOCOL

1. RBC count in large squares is:
   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:
   $X=\frac{E\times 4000\times 200}{80}\times 10^6=E\times 10^{10}$ $X = \_\_\_\_\_ \times 10^{12}/L.$
3. **Conclusion:** _____

Work 2.3. 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.

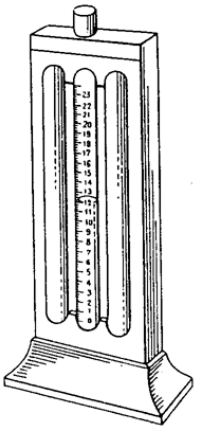
The simplest method is a colorimetric method, based on the formation of muriatic hematin (hematin chloride) — the substance giving the solution a brown color, when hemoglobin interacts with hydrochloric acid. For this purpose, Sali's hemometer is used. It consists of a stand, the back wall of which is 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. After this time ***muriatic hematin*** is formed and the solution becomes 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:

Determine 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. Normal blood Hb content is:
   in men _____ g/L
   in women _____ g/L
4. **Conclusion:** hemoglobin content in tested blood is _____ (normal, increased or decreased)
5. Decreased blood Hb content and / or decreased RBC count is referred to as _____

Work 2.4. EVALUATION OF A COLOR INDEX AND OTHER INDICES OF RED BLOOD CELLS

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 pg). Its value is obtained by division of the Hb content in 1 liter by Red Blood Cells count in 1 liter of blood.

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: $\mathrm{CI} = \dfrac{3 \times Hb(g/L)}{\text{Red Blood Cells} \times 10^{-10}}$.

For example, the blood hemoglobin content is 152 g/L, the erythrocyte count is 4.56×10^{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:

Calculate MCH and CI of the tested blood using the data of works 2.2 and 2.3.

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 _____ $\times 10^{12}$/L.

Index	Normal range
MCH = Hb:Er = : =	
CI = 3 × : =	

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

Work 2.5. 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) **local vasoconstriction** (contraction of smooth muscles of vessel wall);

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, and bleeding time evaluation*.

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 is _____ (normal, increased, reduced).
The function of _____ hemostasis is _____.

Work 2.6. APPEARANCE OF RED BLOOD CELLS AND PLATELETS UNDER THE MICROSCOPE (demonstration)

Observe on the screen in the computer room the shape, sizes, color and intercellular organelles of reticulocytes; those of RBC and platelets.

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 from _____ to _____% of the red blood count. An increase of reticulocytes in the blood reveals the _____ (increase or decrease) in erythropoesis.
The cells forming platelets are called _____.

Work 2.7. STUDYING THE NEEDS IN VITAMINS, TRACE ELEMENTS AND ESSENTIAL FOOD SUBSTANCES NECESSARY FOR NORMAL HEMOPOESIS (is done independently)

Fill in tables 2 and 3.

Table 2

Daily need in vitamins

Name	Daily norm	Function: is necessary for
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} (cyano-cobalamin)		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 (Fe)		To form hemo- and myoglobin; enzymes in an electron transport chain in mitochondria; DNA synthesis; cell division; efficiency of detoxification mechanisms involving cytochrome P450

Name	Daily norm	Purpose
Cobalt (Co)		To synthesize hemoglobin; stimulates iron utilization. To stimulate synthesis and excretion of erythropoietin in kidneys. In cobalt insufficiency anemia develops
Copper (Cu)		To absorb iron in the gastrointestinal tract, mobilization of its reserves from the liver and reticular cells
Zinc (Zn)		To provide functions of enzyme carbonic anhydrase. In zinc insufficiency leucopenia develops
Selenium (Se)		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 WHITE BLOOD CELLS. LEUKOPOESIS. NON-SPECIFIC AND SPECIFIC RESISTANCE OF THE ORGANISM. PHYSIOLOGIC ASSESSMENT OF THE COMMON BLOOD TEST

Basic questions:

1. White blood cells, their types. Leucocyte formula.
2. Granulocytes, their types. Functions and properties of neutrophils. Granulocytopoesis. Types of neutrophils depending on the degree of their maturity. Shifts of the leucocyte formula.
3. Functions and properties of basophils and eosinophils.
4. Monocytes and tissue macrophages. Monocytopoesis. Peculiarities of the structure and properties providing macrophages functioning. Mechanisms of phagocytosis. Concept of the complement system.
5. T- and B-lymphocytes, peculiarities of their maturation and functions. Lymphocytopoesis. Null and plasma cells.
6. Concept of cellular and humoral immunity; immune response. Functions of immunoglobulins.
7. Basic indices included into the common blood test. Physiological assessment of the total blood test results. Diagnostic value of the common blood test.
8. Age associated changes of common 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 common blood test characterize the respiratory function of the blood?
3. What is a leukocyte formula? Normal values of the leukocyte formula of a healthy adult person.
4. What is the leukocyte formula *shift to the left*?
5. What is the difference between physiologic and reactive (true) leukocytosis? Causes of physiologic and reactive leukocytosis.

6. Make a conclusion for the blood test of a man of 20 years: red blood cells — 5×10^{12}/L; hemoglobin — 160 g/L; Color Index, MCH — *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, MCH — *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, MCH — *calculate*; white blood cells — 5×10^{9}/L; platelets — 80×10^{9}/L; ESR — 12 mm/h.

PRACTICAL WORKS

Work 3.1. WHITE BLOOD CELLS COUNT IN THE COUNTING CHAMBER UNDER THE MICROSCOPE (demonstration)

Teaching video “Evaluation of RBC and WBC count” is shown in the computer room.

The white blood cells content in the blood in norm is $(4–9) \times 10^{9}$/L.

Materials and equipment: rat’s blood; 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 taken into the mixer to the mark 0.5 and then **5 % solution of acetic acid** stained with methylene blue to the mark 11 (**20**-fold dilution of the blood) is added. The acetic acid destroys membranes of all blood cells (chemical hemolysis), so all blood cells become destroyed, including White Blood Cells. However, each WBC leaves its nucleus, in contrast to the other blood cells. Methylene blue that is added to the acetic acid stains nuclei of White Blood Cells thus making their counting easier. The mixer is shaken for 1–2 min. The chamber is filled in from the mixer ampoule. White Blood Cells (White Blood Cells nuclei) are counted at small magnification in 25 large squares.

Directions for recording the Protocol:

1. Calculate the total count of leukocytes in 25 large squares.
2. Calculate the leukocyte count per in 1 liter by the formula.
3. 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:

$$X = \frac{L \times 4000 \times 20}{400} \times 10^6 = 2L \times 10^8 /L$$

$$X = \_\_\_\_\_ \times 10^9 /L$$

4. Normal count of WBC: _____

5. **Conclusion:** _____

Work 3.2. 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. Assess the obtained result versus the norm.

PROTOCOL

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

Factor	Total WBC	Basophils	Eosinophils	Neutrophils			Monocytes	Lymphocytes
				young	band	segmentonuclear		
% in a blood smear	100	0–1	1–5	0–1	1–5	46–68	2–9	18–40
	100							

Conclusion on the leukocyte formula: _____ _____ (in norm; baso-, eosino-, neutrophilia (or -penia); monocytosis, lymphocytosis (or -penia)).

Work 3.3. 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).

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 3.4. PHYSIOLOGICAL ASSESSMENT OF THE COMMON 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 common blood test indices the doctor may assess the **respiratory** function of the blood (by the ***hemoglobin*** content, ***RBC*** count); **erythropoesis** intensity (by the ***reticulocyte*** count); suggest the presence of infectious, inflammatory and autoimmune processes in the organism (by the WBC count, shift of the leukocyte formula to the left and ESR changes) etc.

Directions for recording the Protocol:

Consider and estimate blood analysis results given in the table. Calculate necessary indices (color index, shift index). Indicate each deviation from norm, when it is found, by arrow directed up or down.

Make a conclusion on the given analysis results.

PROTOCOL

Index	Norm	Analysis for evaluation (man)
1. Red Blood Cells (RBC)	(**3.9–5.1**) × 10^{12}/L, men (**3.7–4.9**) × 10^{12}/L, women	**3.4** × 10^{12}/L
2. Hemoglobin (Hb)	**130–170** g/L, men **120–150** g/L, women	**110** g/L
3.Color Index	**0.8–1.05**	Calculate
4. ESR	men **1–10** mm/h women **2–15** mm/h	**10** mm/h
5. White Blood Cells (WBC)	(**4–9**) × 10^{9}/L	**5.6** × 10^{9}/L
6.**Leukocyte formula**	Per 100 cells (100 %)	
6.1. Basophils	**0–1 %**	**1%**
6.2. Eosinophils	**1–5 %**	**3%**
6.3. Neutrophils: myelocytes young neutrophils band neutrophils segmentonuclear	 **0 %** **0–1 %** **1–5 %** **46–68 %**	 **0%** **1%** **4%** **56%**
6.4. Monocytes	**2–9 %**	**7%**
6.5. Lymphocytes	**18–40 %**	**28%**
Additional indices:		
Shift index*	**0.05–0.1**	Calculate
Reticulocytes	**0.5–1.2 %**	**0.9 %**
Platelets	(**150–450**) × 10^{9}/L	**320** × 10^{9}/L

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

Conclusion:

Lesson 4. BLOOD TYPES. ABO SYSTEM. RHESUS (Rh) SYSTEM. PHYSIOLOGICAL BASES OF BLOOD MATCHING FOR THE TRANSFUSION. BLOOD SUSBSTITUTING SOLUTIONS

Basic questions:

1. Antigens of blood cells. Basic systems of red blood cells antigens: ABO and Rh system.

2. Blood types in the ABO system. Antigens (agglutinogens) and antibodies (agglutinins) of blood types.

3. Incompatibility reactions of blood types in improper transfusion. Consequences of mismatched blood transfusion in ABO system.

4. Blood typing in the ABO system. Standard sera. Monoclonal sera.

5. The Rh system of antigens (Rh). Consequences of mismatched blood transfusion in the Rhesus system.

6. Other systems of blood cells antigens. The system of HLA leukocyte antigens, its significance.

7. Basic principles of blood matching. Tests performed before blood preparations transfusion.

8. Risk factors for the recipient. Prevention of infecting the recipient during transfusion of donor blood or blood preparations.

9. Donor blood preparations. Blood substituting solutions, their functions. Basic requirements to blood substituting solutions.

***Self-check*:**

1. What are the main differences between the ABO and Rh system?
2. Which antibody (agglutinins) are present in blood type I(O)?
3. What kind of substances are the ABO system antigens A and B? Where are they located? What kind of substances are α and β antibodies?
4. Determine the blood type by the results of blood typing:

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

5. Determine the blood type by the results of blood typing:

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

6. What are the reasons of Rhesus incompatibility of the blood?
7. What consequences may result from mismatched blood transfusion in ABO system?
8. What are the consequences of the first and the second (any subsequent) mismatched blood transfusion of Rh-positive blood to Rh-negative recipient?
9. What is the difference between the methods of blood typing in ABO system using standard sera and monoclonal sera?

PRACTICAL WORKS

Work 4.1. BLOOD TYPING IN THE ABO SYSTEM USING STANDARD SERA (demonstration)

The ABO system blood type is determined by the presence of agglutinogens in red blood cells which is revealed by the hemagglutination reaction using standard sera. 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 sera are known, red blood cells antigens of the tested blood and consequently the blood type in the ABO system are determined by the presence or absence of agglutination.

Materials and equipment: standard sera of 0αβ(I), Aβ(II), Bα(III) and AB0(IV) types 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. One large drop (about 0.1 ml) 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) type. As agglutination occurs, but not earlier than in 3 minutes, one drop of NaCl isotonic solution is 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 sera of all 3 types did not cause agglutination, and all drops stayed regularly stained in red. In this case the blood belongs to type 0αβ (I) (**type O**).

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

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

4) Agglutinins of standard sera of all three types caused a positive reaction of agglutination. The tested blood belongs to AB0(IV) type (**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) type 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) type. The presence of agglutination with the serum of AB0(IV) type 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 sera 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.

Note. In case of a doubtful or unclear result during the first determination of blood type a repeated test of the blood type of the same blood with standard sera of other series should be done. If the results remain still unclear, the blood type should be determined by a cross-method using standard sera 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.

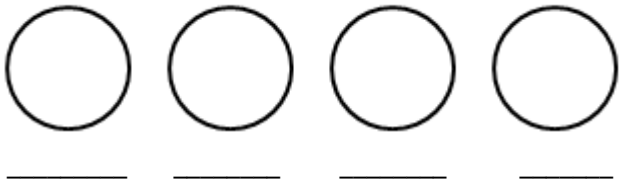
PROTOCOL

Table 4

Blood types	**Red blood cells agglutinogens (antigens)**	**Serum agglutinins (antibodies)**
0αβ (I)		
Aβ (II)		
Bα (III)		
AB_0 (IV)		

Table 5

Blood types	**Standard sera**			
	0αβ (I)	Aβ (II)	Bα (III)	ABO (IV)
0αβ (I)				
Aβ (II)				
Bα (III)				
AB_0 (IV)				

Sign antibodies below serum drops  _____ _____ _____ _____ 2. Fig. ABO system blood typing (indicate agglutination)	3. **Conclusion:** the tested blood is type _____ of ABO system, as its Red Blood Cells _____ (contain/do not contain) antigen(s) _____ (A, B).

Work 4.2. 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 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 type or type I(0) in ABO system and standard rhesus-negative red blood cells of the same blood type in ABO system as the tested blood, is done.

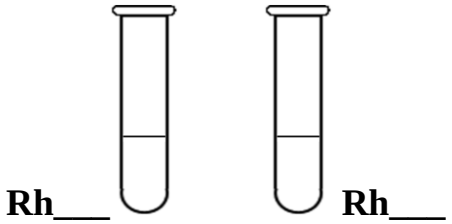
Agglutination presence manifested by flakes of red blood cells on the background of the cleared up fluid indicates that the tested blood is rhesus-positive (Rh^+). Agglutination absence indicates that the tested blood is rhesus-negative (Rh^-).

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 type in ABO system as the tested blood.

Directions for recording the Protocol:

1. Add the view of the results of blood typing in Rhesus system to the picture of test tubes (for both cases, Rh^+ and Rh^-).

2. Make a conclusion about Rhesus system blood type of the tested blood.

 Rhesus system blood typing	When blood is mixed with the universal anti-Rhesus reagent in the test-tube, and: • agglutination **is** observed, then the tested blood is _____ (Rh^+ or Rh^-), • agglutination **is not** observed, then the tested blood is _____ (Rh^+ or Rh^-).

MONOCLONAL SERA:
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 sera 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 sera have low activity and one has to use sera 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 wash-out of tissue culture 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 and Rh system using monoclonal sera

Per one large drop of anti-A, anti-B and anti-D reagents is applied on a special plate or a porcelain dish under corresponding signs "anti-A", "anti-B" and "anti-D". 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. The assessment of agglutination results is presented in tables 6 and 7.

Table 6

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

Table 7

Blood type	Reaction of tested red blood cells with monoclonal reagents anti-D
Rh +	+
Rh –	–

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 indices

1. WBC (white blood cells) — total leukocyte number.
2. RBC (red blood cells) — erythrocyte number.
3. HGB (hemoglobin) — hemoglobin content.
4. HCT (hematocrit) — hematocrit.

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. MPV (mean platelet volume) — mean thrombocyte volume.

15. PDW (platelet distribution width) — distribution width of platelets by the volume.

Basic physiological indices of blood

Table 8

	Index	Value
1	**Blood volume (%** of the body mass**)**	**6–8 %**
2	**Hematocrit** (blood cells share in the total blood volume):	**40–49 %** in men **36–42 %** in women
3	Plasma volume (of the total blood volume)	51–64 %
4	Blood plasma **osmotic pressure**	**290 ± 10** mosmol/L (7.3 atm or 745 kPa or 5600 mm Hg)
5	Blood plasma **oncotic pressure**	**25–30 mm Hg**
6	**Arterial blood pH**	**7.35–7.45**
7	Blood **viscosity** (versus water viscosity, taken for 1.0)	**4.5–5.0**
8	Plasma viscosity (versus water viscosity)	**1.8–2.2**
9	Relative blood density	1.050–1.062 g/ml
10	Relative plasma density	1.029–1.032 g/ml
11	**Platelets** count in peripheral blood	**(150–450) × 10^9/l**
12	**Osmotic resistance of red blood cells** ***minimal:*** ***maximal:***	**0.46–0.48 %** NaCl **0.32–0.34 %** NaCl
13	Plasma **protein content** **Total:**	**60–85 g/l**
14	Albumins: Globulins: Fibrinogen:	38–50 g/l 20–36 g/l 2–4 g/l
15	Plasma **glucose content**	**3.3–5.5 mmol/l**

Indices of RBC in adults.

Table 9

Group	Total red blood cells count × 10^{12}/л	Reticulocytes, %	Hemoglobin, g/l	Mean RBC volume, fl (MCV)	Mean hemoglobin content in one RBC, pg (MCH)
Newborn	**5.0–7.0**	**12–15**	**192–232**	**101–128**	**25.4–34.6**
Adult men	**3.9–5.1**	**0.5–1.2**	**130–170**	**80–100**	**25.4–34.6**
Adult women	**3.7–4.9**		**120–150**	**79–98**	

RDW (**Red Cell Distribution Width**) — the width of RBC volume distribution curve. It is calculated as the coefficient of RBC volume variation according to the formula (where SD is a standard deviation of RBC volume from its mean value, MCV):

$$\text{RDW} = \frac{\text{SD} \times 100\ \%}{\text{MCV}}$$

Normal RDW value is **11.5–14.5 %**. An increase of RDW shows wider range of RBC volume (size), or ***anisocytosis*** (RBC inequality). To evaluate RBC volume both indices — MCV and RDW — should be taken into account, as MCV characterizes the *mean* value of cells volume, and RDW — the degree of their volume variability.

At a RBC distribution curve where number of cells is plotted against their corresponding volume on the horizontal axis (fig. 1, a — normal RDW) the increase of RDW is seen as widening of the area under curve (fig. 1, b — anisocytosis):

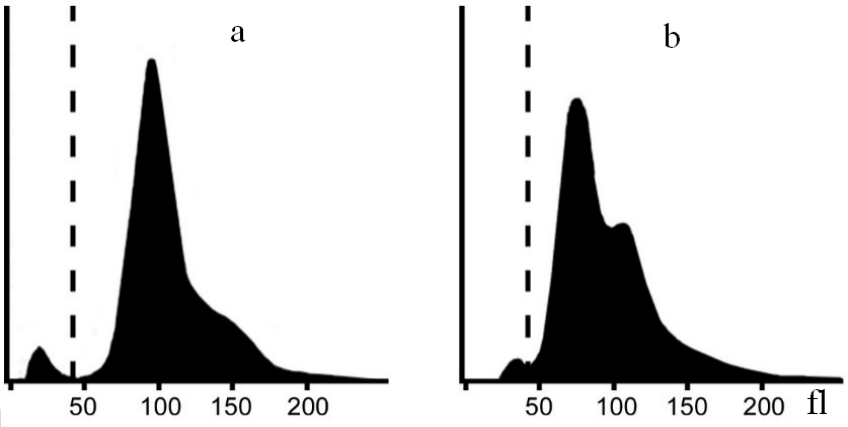


Fig. 1. Distribution curves for RBC and platelets. The dashed lines at 35 fl is a division between platelets (left parts of the curves) and RBC (right parts of the curves):
a — normal curve (MCV — 96 fl, RDW — 13.6 %); *b* — anisocytosis, two RBC populations (microcytes predominance)

The increase of RDW is characteristic for the anemias accompanied by anisocytosis, such as folic acid and vit B_{12} deficiency anemias.

LEUKOCYTE FORMULA

(% proportion of different types of leukocytes)

Table 10

Granulocytes					Agranulocytes	
Neutrophils			Basophils	Eosino-phils	Lymphocytes	Monocytes
Young	Band neutrophils	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 %)

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

PHYSIOLOGY OF ENDOCRINE SYSTEM

Lesson 5. BASES OF INFORMATION EXCHANGE OF THE CELL WITH THE ENVIRONMENT: CHEMICAL SIGNALING. GENERAL PHYSIOLOGY OF ENDOCRINE SYSTEM

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. General characteristic and mechanisms of ligands (hormones) action.
5. Basic ways of signal transmission involving membrane receptors. Second messengers, their function. Ligands (hormones) acting through membrane receptors.
6. Signal transmission involving intracellular receptors. Ligands (hormones) acting through intracellular receptors.
7. 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.
8. Basic ways of signal transmission to the cells for the main types of hormones. Physiologic effects of hormone-receptor interaction at a cellular level.
9. The structure and functions of the pituitary gland (hypophysis). Associations between the pituitary gland and hypothalamus. Hormones of the pituitary gland and hypothalamus, their role. Interaction of nervous and humoral mechanisms of functional regulation at a hypothalamic level.
10. Regulation of the pituitary and hypothalamic hormones secretion. The most common manifestations of pituitary and hypothalamic endocrine function disorders: diabetes insipidus, acromegaly, etc.

***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 perform?
5. Why do the effects of thyroid and corticoid hormones develop slowly as compared to the effects of protein and peptide hormones?
6. What is the metabolic effect of hormones?

7. What is the permissive effect of hormones?

8. What are first and second messengers of hormonal action?

9. What are the ways of the endocrine gland functional state evaluation?

10. What are the feedback mechanisms of pituitary and hypothalamic secretion regulation?

11. What are the effects of adrenocorticotropic hormone (ACTH)? What are the factors inhibiting its secretion?

12. What do the excess and insufficiency of ACTH result in?

13. 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?

14. What are the stimuli for secreting vasopressin (antidiuretic hormone)?

15. What are the common symptoms of diabetes mellitus and diabetes insipidus? What are the causes of these two different diseases?

PRACTICAL WORKS

Work 5.1. 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 (antagonist of **β**-adrenoreceptors), then 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 5.2. 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. 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 <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. **Somatotropin** (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 pituitary 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:

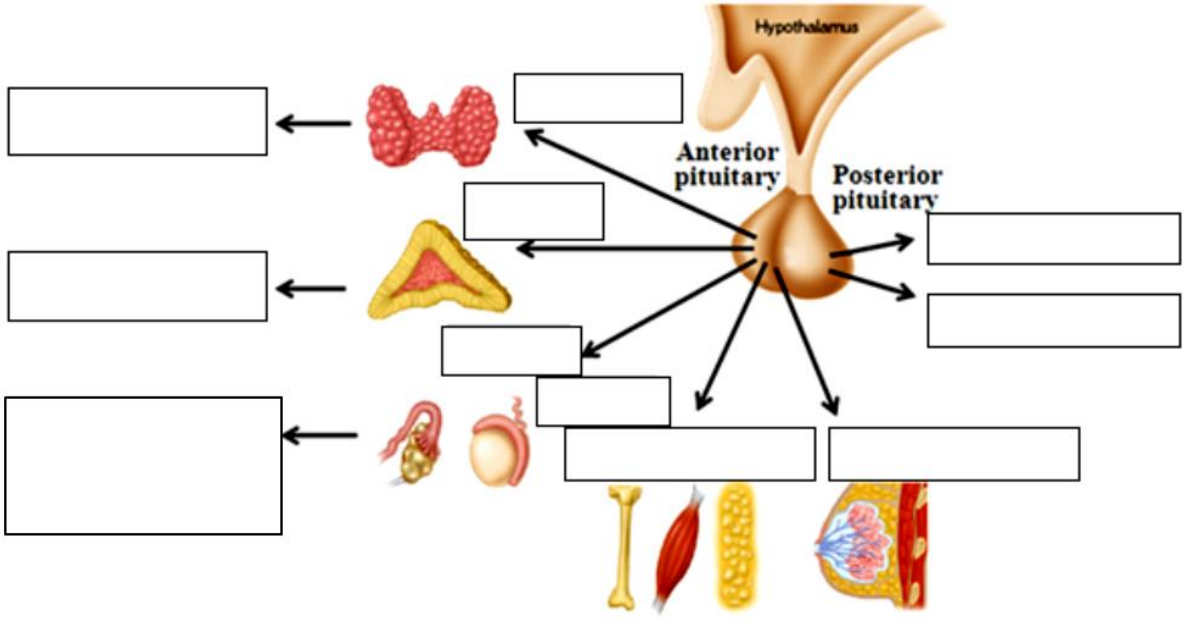
1. Measure the height of the examined with the height meter.
2. Calculate a predicted height of the examined.
3. Evaluate the measured height versus the predicted height of the person.
4. Fill in the gaps in the sentences about hormones influence on the height.

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.

Work 5.3. STUDYING HORMONES OF ANTERIOR AND POSTERIOR PITUITARY GLAND AND THEIR ACTION ON PERIPHERAL ENDOCRINE GLANDS

Using materials of lectures and textbook fill in the respective names of pituitary hormones and hormones of peripheral glands regulated by anterior pituitary gland.



Lesson 6. PHYSIOLOGY OF ENDOCRINE SYSTEM. ESSENTIAL HORMONES, THEIR MECHANISMS OF ACTION AND EFFECTS

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. Glucocorticoids. Effects and mechanisms of cortisol action. Regulation of secretion. Manifestations of insufficient and excessive cortisol secretion. The role of glucocorticoids in stress.
3. Mineralocorticoids. Effects and mechanisms of aldosterone action. Regulation of secretion. Manifestations of insufficient and excessive aldosterone secretion.
4. Hormones of the adrenal medulla. Effects and mechanisms of hormone action. Regulation of hormone secretion.
5. The role of calcitonin, parathyroid hormone and vitamin D_3 in regulation of homeostasis of calcium and phosphorus in the organism. Requirements in calcium, factors affecting it.
6. 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.
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.
8. Functions and hormones of the epiphysis.
9. The concept of hypothalamic-pituitary-adrenal and sympathoadrenal systems.
10. Participation of endocrine glands in adaptive activity of the organism. General adaptation syndrome and stress: nervous and hormonal mechanisms of their development.
11. The thymus gland and its hormones. The concept of APUD system of the intestines. The endocrine function of the heart, liver and kidneys.
12. 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 necessary?
3. In what way do glucocorticoids increase the level of blood glucose?
4. In what way the level of glucocorticoid hormones is regulated?

5. What is the stimulating factor for aldosterone secretion?

6. 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?

7. What processes does the blood calcium concentration depend on?

8. List the contra-insular hormones (hormones that increase blood glucose level).

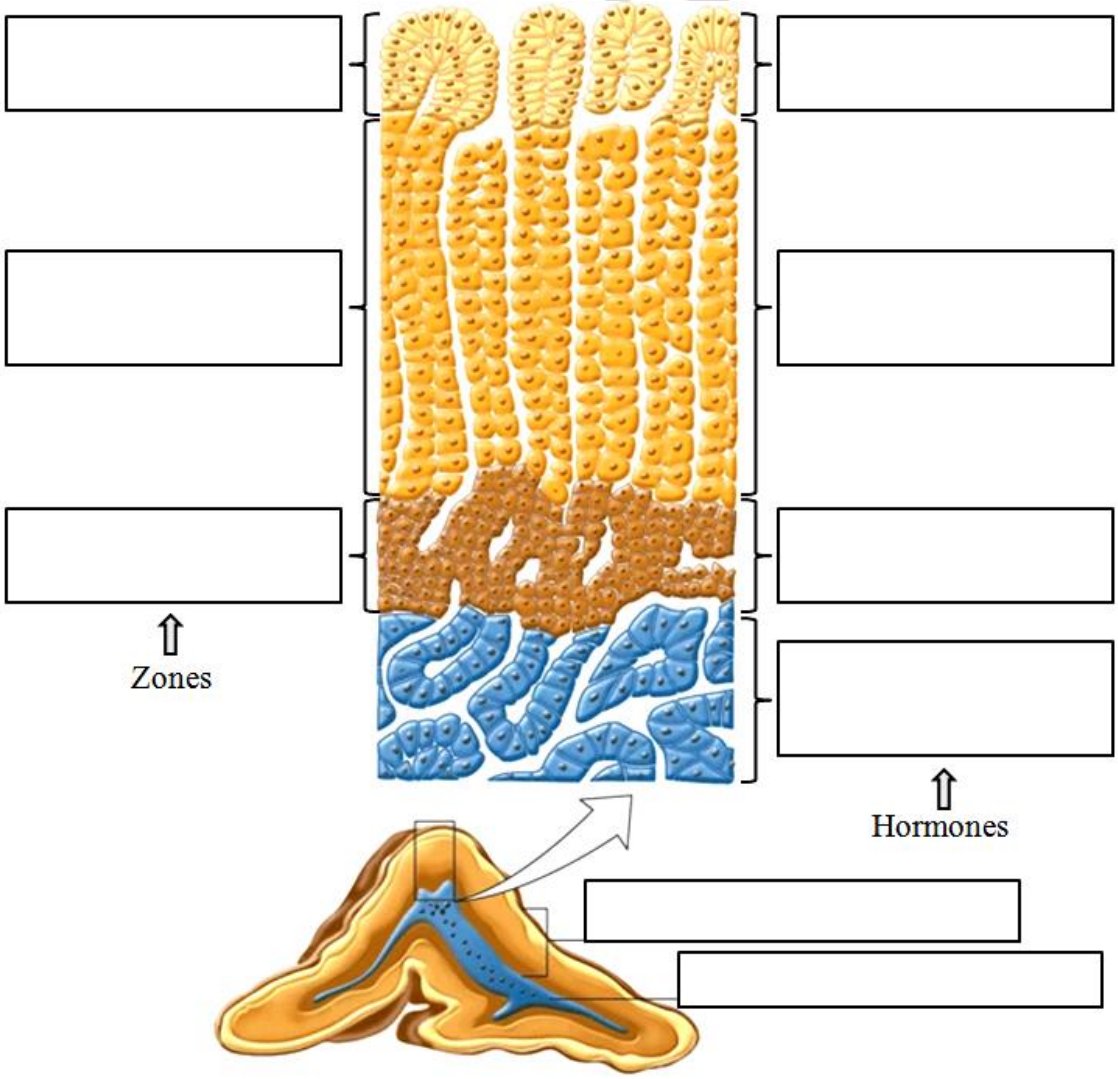
9. What hormones are most important for stress reaction development?

10. What are the mechanisms and the results of hypothalamic-pituitary-adrenal system activation?

PRACTICAL WORKS

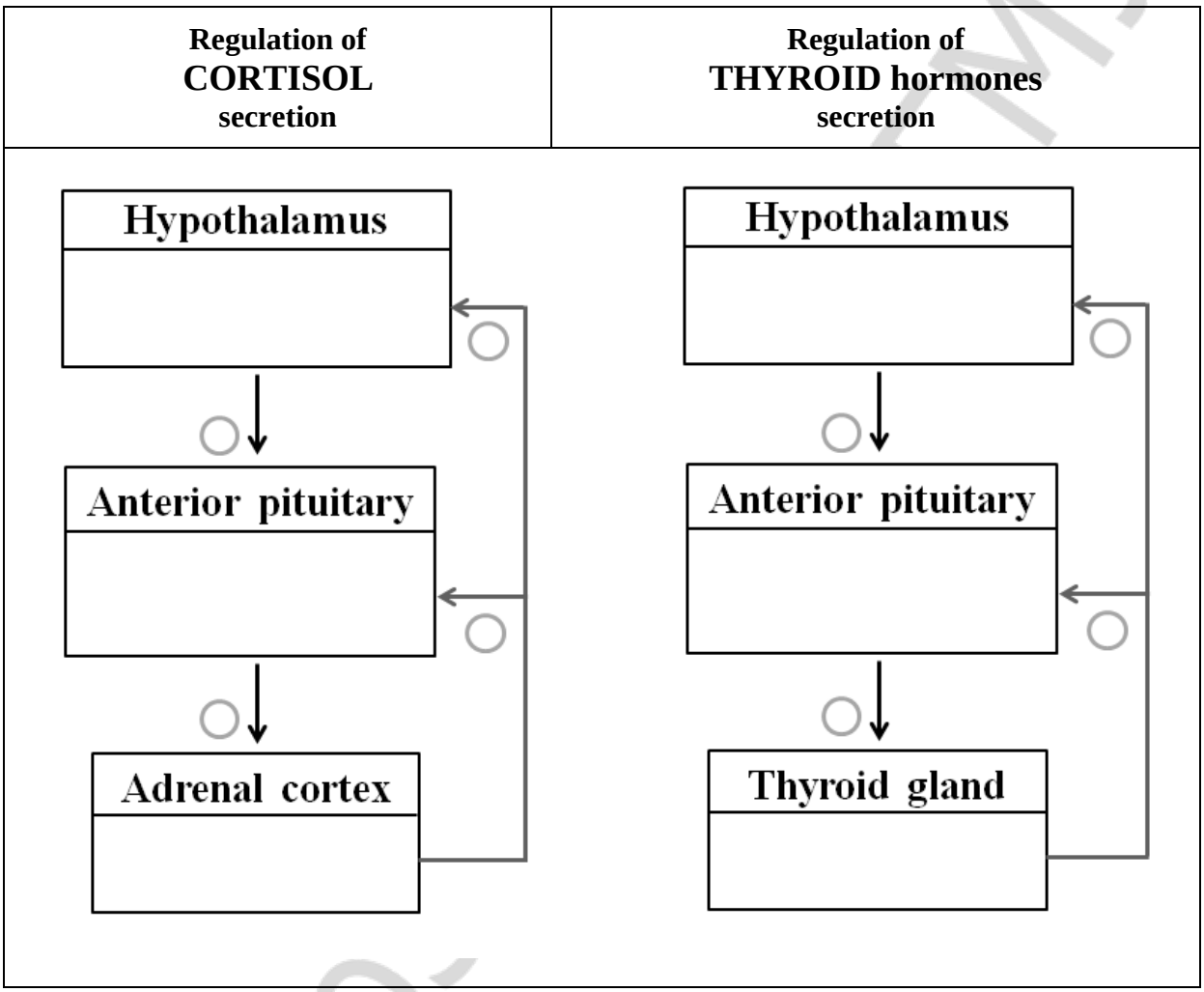
Work 6.1. PARTS OF ADRENAL GLAND AND THEIR HORMONES

Using materials of lectures and textbook fill in the parts of adrenal gland, names of cortex zones and the names of adrenal gland hormones.



Work 6.2. STUDYING THE MECHANISMS OF PERIPHERAL ENDOCRINE GLAND HORMONES REGULATION AND THEIR NEGATIVE FEEDBACK INFLUENCE ON HYPOTHALAMIC AND PITUITARY HORMONES

Using materials of lectures and textbook fill in the names of respective hormones and indicate stimulating or inhibitory effects by inserting signs "+" or "–" into circles.



THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

Lesson 7. PHYSIOLOGY OF BLOOD AND ENDOCRINE SYSTEM (THE CONCLUDING LESSON)

The list of questions for studying:

1. The internal environment of the organism. Homeostasis.
2. The main fluid compartments of the body, their composition.
3. The osmotic pressure of the body fluids, its significance for fluid exchange between cells and extracellular space. Influence of osmotic pressure changes on the cells state: hyper- and hypohydration. Isotonic solutions.
4. The oncotic pressure of blood plasma and its significance for fluid exchange between intravascular and interstitial spaces.
5. Blood functions. Composition of blood.
6. Blood proteins and their functions.
7. Red blood cells (erythrocytes). Normal amount of red blood cells and their specific properties. Erythrocytopenia and erythrocytosis.
8. Red blood cells formation (erythropoiesis) and destruction. The role of erythropoietin, vitamins and other factors. Anemias. Types of hemolysis. Osmotic resistance of red blood cells.
9. Hemoglobin and its types. Structure, properties and functions of adult hemoglobin (Hb A). Normal amount of hemoglobin in men and women. Color index and its calculation. Mean hemoglobin content in one red blood cell (MCH). Role of iron for hemoglobin formation. Daily requirement in iron and its main sources for the organism.
10. White blood cells (WBC), their total amount. Properties of WBC. Types of leucocytes, their functions. Leucocytosis and leucopenia. Physiological and absolute leucocytosis.
11. Percentage of leucocytes types (leucocyte formula). Shift of the leucocyte formula. Granular and agranular leucocytes, their functions. Phagocytosis. The concept of cellular and humoral immunity.
12. Platelets, their structure and functions. Normal amount of platelets. Concept of primary and secondary hemostasis.
13. Blood types. ABO system antigens and antibodies, their characteristics.
14. Blood typing in ABO system using standard and monoclonal sera. Transfusion reactions resulting from mismatched blood transfusion. Tests performed before blood preparations transfusion.
15. Rhesus system of blood antigens, its characteristics. The difference of Rh system from ABO system. Possible reasons of anti-rhesus antibodies formation. Consequences of the first and subsequent transfusions of blood mismatched in Rh system. Blood typing in the Rh system.
16. Information exchange between the cell and the environment. Concepts: information, signal. Types of signals.
17. Chemical signaling. Basic types of intercellular communication involving signal molecules, their characteristics.

18. Classification of molecular receptors. Types of signal molecules (ligands).

19. Ligand-receptor interactions. Basic ways of signal transmission involving membrane receptors. Second messengers, their function. Ligands acting through membrane receptors.

20. Intercellular signal transmission involving intracellular receptors. Ligands acting through intracellular receptors.

21. Basic physiological effects of ligand-receptor interaction at a cellular level.

22. 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.

23. General characteristic and mechanisms of hormone action. The types of hormone mechanism of action depending on hormone's chemical structure. Receptors for hormones and basic ways of signal transmission to the cell.

24. The structure and functions of the pituitary gland (hypophysis). Associations between the pituitary gland and hypothalamus. Hormones of the hypothalamus and pituitary gland, their role. Interaction of nervous and humoral mechanisms of functional regulation at a hypothalamic level.

25. Regulation of the pituitary and hypothalamic hormones secretion. The most common manifestations of pituitary and hypothalamic endocrine functions disorders: diabetes insipidus, acromegaly, etc.

26. Thyroid gland. Thyroid hormones, mechanisms of their action and their effects. Influence of thyroid hormones on the CNS growth and development. Regulation of hormone secretion. Characteristic manifestations of excessive and insufficient secretion of hormones.

27. Adrenal glands. Hormones of the three zones of adrenal cortex. Effects and mechanisms of hormones action. Regulation of hormones secretion. The role of glucocorticoids in stress.

28. Hormones of the adrenal medulla. Effects and mechanisms of hormone action. Regulation of hormone secretion.

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

30. 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.

31. Endocrine function of sex glands. Mechanism of hormone action and their effects. Characteristic manifestations of hormones excess and insufficiency.

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

GENERAL PHYSIOLOGY

Lesson 8. 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. Basic laws of excitable tissues response to the stimulus action.
4. 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 unit of information transfer in the nervous system. Phases and ion mechanisms of AP generation.
8. Excitability alteration during action potential.
9. Comparative characteristics of the receptor potential and action potential.

***Self-check*:**

1. What factor allows comparing excitability of various cells? Compare the excitability of the nervous and striated muscle tissue.
2. Why does the cardiac muscle response to the stimulus according to the "all-or-none" law, and a skeletal muscle — according to the law of force?
3. What kind of membrane channels do participate in formation of the resting potential and what type of channels is necessary for generation of the action potential?
4. What is the effect of an increase of extracellular potassium ions concentration on the resting potential value?
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 8.1. THE EFFECT OF Na^+ AND K^+ IONS ON THE MEMBRANE RESTING POTENTIAL AND ACTION POTENTIAL

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

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

The initial parameters of 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 affects mainly 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:

Fill in tables of the protocol and 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

Effect of K^+ on the membrane potential

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

Effect of Na^+ on the action potential

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

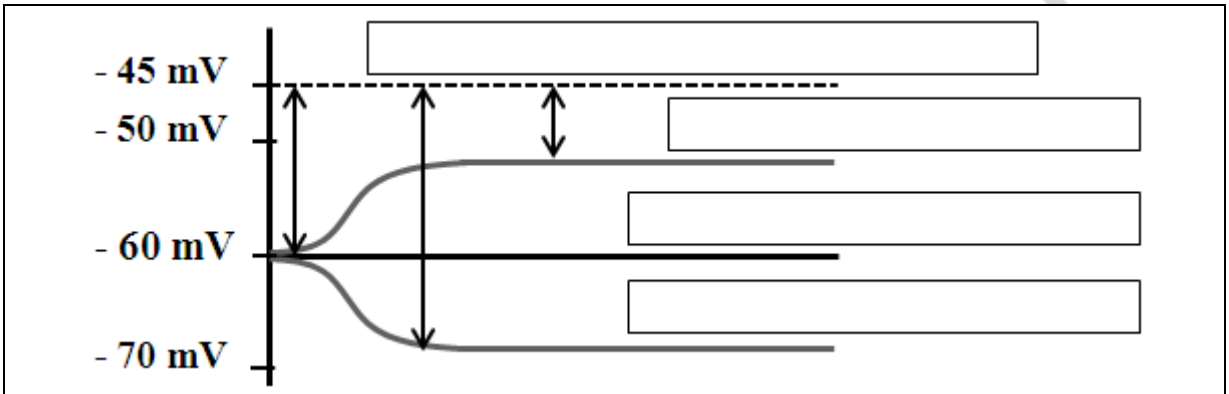
Conclusions: _____

_____

_____

Work 8.2. STUDYING THE RESTING MEMBRANE POTENTIAL, TYPES OF ITS CHANGES AND THEIR INFLUENCE ON MEMBRANE EXCITABILITY

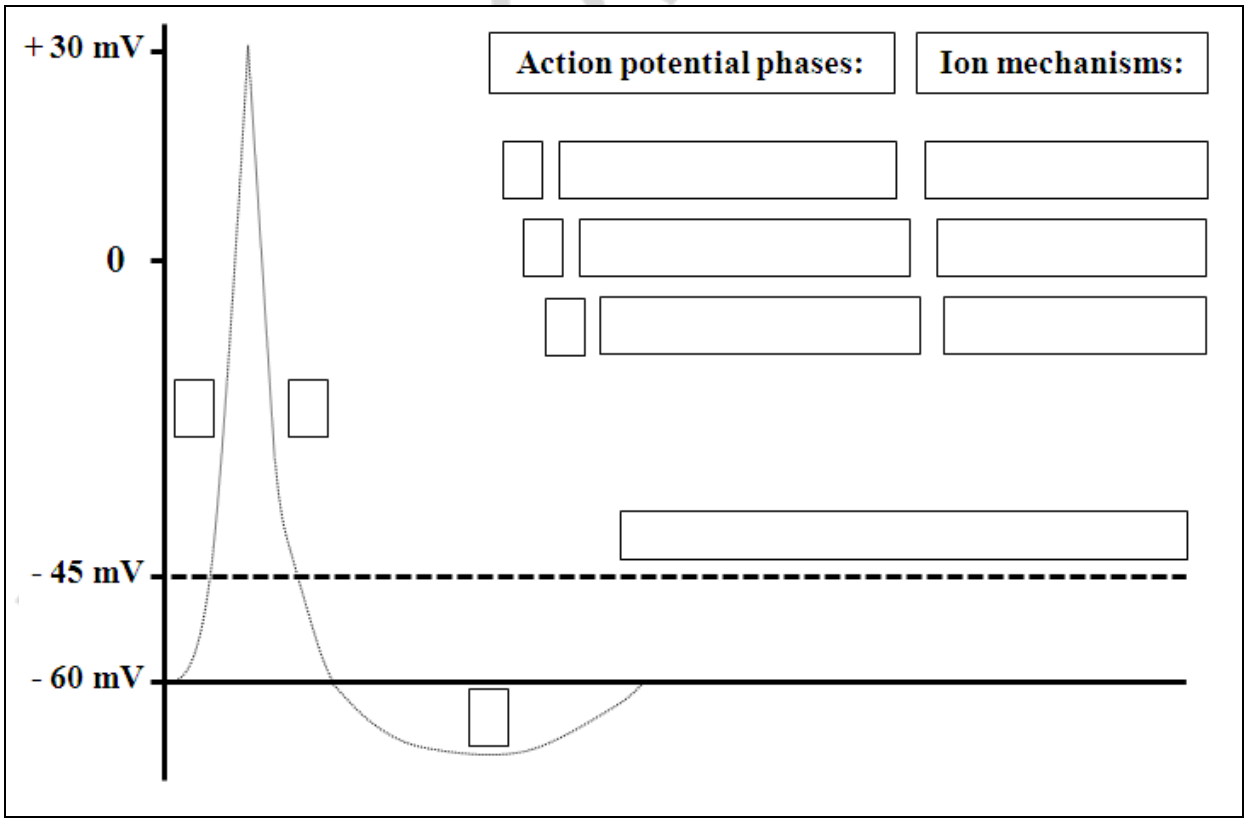
Fill in the types of membrane potential changes into boxes, then fill in the table.



Deviation of resting potential	Change of the threshold level	Change of membrane excitability
Depolarization		
Hyperpolarization		

Work 8.3. STUDYING THE ACTION MEMBRANE POTENTIAL MECHANISMS

Draw a figure of action potential using different colors for its phases; indicate names of AP phases and their ion mechanisms in respective boxes.



Lesson 9. 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 excitation conduction by myelinated and unmyelinated nerve fibers. The rates of excitation conduction.
4. Synapses, their physiologic role. Classification of synapses. The structure of a chemical synapse.
5. The mechanisms of excitation conduction in neuromuscular junction. An End Plate Potential (EPP), its transformation into an action potential. Acetylcholinesterase, its role. Types of channels in synaptic membranes.
6. Functional properties of synapses.
7. The possibilities of pharmacological influence on the process of signal transmission in synapses.

***Self-check*:**

1. What is the mechanism of local anesthetics blocking effect on excitation conduction by nerve fibers?
2. What advantages have myelinated fibers as compared to unmyelinated ones?
3. What is the reason of neurotransmitter release into the synaptic cleft?
4. Is it possible to conduct a signal through the synapse in calcium-free medium?
5. Which channels are located on the postsynaptic membrane? What type of the receptors are these channels?
6. What potential is generated on the postsynaptic membrane?
7. Why does the organism die of oxygen insufficiency in poisoning with curare, a poison blocking neuromuscular junctions?
8. In what way does the signal transmission in neuromuscular synapse change under the influence of acetylcholinesterase inhibitors?

PRACTICAL WORKS

Work 9.1. DEMONSTRATION OF LOCAL ANESTHETICS EFFECT DEVELOPMENT DEPENDING ON THE DURATION OF ACTION

The local anesthetics effect develops due to 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 sensation is not formed. Blockade of sodium channels is a process that requires certain 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 on 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

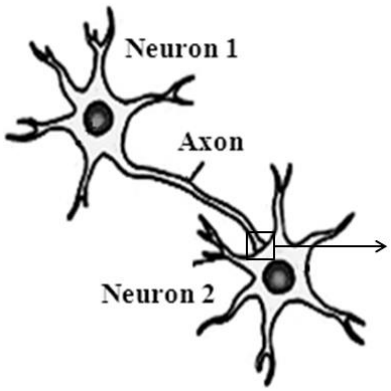
Ways of affecting the synaptic transmission at a neuromuscular synapse

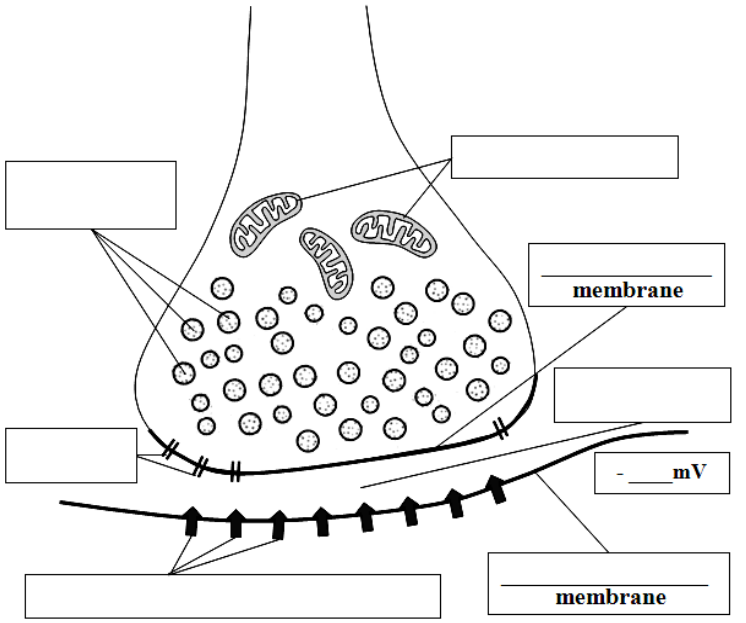
Types of influence	Result	Substance example
Blocking of acetylcholine (ACh) **release**	Complete blockade of synaptic transmission, muscle paralysis	Botulinum toxin
Blocking of postsynaptic membrane **receptors**	Blockade of synaptic transmission, muscle paralysis	Curare and curariform substances (muscle relaxants)
Inhibition of **acetylcholinesterase**	***Reversible inhibitors*:** Enhancement and prolongation of ACh action, **facilitation** of impulses conduction through synapse	Anticholinesterase 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

Work 9.2. COMPARISON OF THE STRUCTURE OF CENTRAL (INTERNEURONAL) SYNAPSE AND PERIPHERAL SYNAPSE (NEUROMUSCULAR JUNCTION)

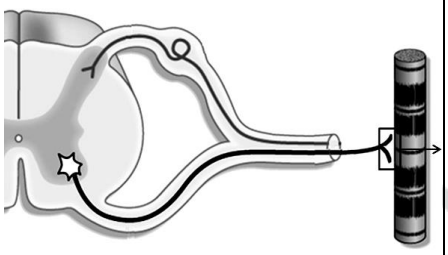
Fill in the names of the main synaptic structures for an interneuronal central synapse and for neuromuscular junction. Indicate the main functional difference of neuromuscular junction as compared to the central synapse.

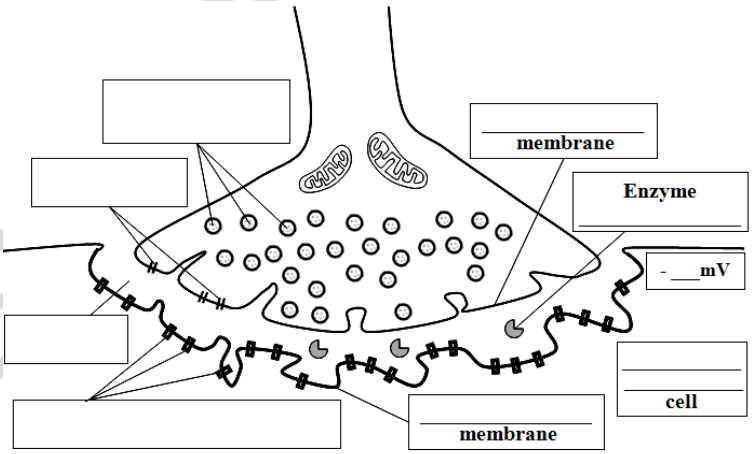
Interneuronal synapse





Neuromuscular junction





The main functional distinctive feature of neuromuscular junction is that a single End Plate Potential is _____ for action potential generation in this type of synapse while in the central interneuronal synapse action potential generation requires at least _____ Excitatory Postsynaptic Potentials summated in a way of spatial or temporal summation. Thus, impulses from _____ neurons to the _____ muscles are always transmitted precisely according to the rate of stimulation from CNS.

Lesson 10. PHYSIOLOGY OF SKELETAL AND SMOOTH MUSCLES

Basic questions:

1. The types of muscle tissue, differences in their structure.
2. Physiologic properties of skeletal muscles. The structure of muscle fibers. Sarcomere. Main proteins of myofilaments, their functions.
3. Mechanisms of contraction and relaxations of a single muscle fiber and a whole muscle. Excitation-contraction coupling.
4. Factor affecting the force skeletal muscles contraction. Tetanic muscle contractions. Muscle tone. Muscle fatigue.
5. Motor units, their types, structural and functional properties.
6. Physiologic properties and peculiarities of smooth muscles.
7. Contraction and relaxation mechanism of smooth muscles. Smooth muscle tone.

***Self-check*:**

1. The duration of muscle shortening in single muscle contraction is 0.03 s, while the relaxation period is 0.04 s. Determine the type of this muscle contraction when the frequency of its stimulation 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 are the sources of calcium ions for the contractions of skeletal and the smooth muscles?
6. What is the type of motor units that are able to prolonged contractions?
7. 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 10.1. 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:

$$\mathbf{HSI} = \frac{\mathbf{Muscle\ strength\ in\ kg} \times \mathbf{100}}{\mathbf{Body\ mass\ in\ kg}}$$

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:

$$\textbf{BSI} = \frac{\textbf{Muscle strength in kg}}{\textbf{Body mass in kg}}$$

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

Muscles	Muscle strength	Muscle strength index (in units)
Right hand		
Left hand		
Back extensors		

Conclusion: _____
_____

Work 10.2. 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.

Fill in the table of the Protocol.

PROTOCOL

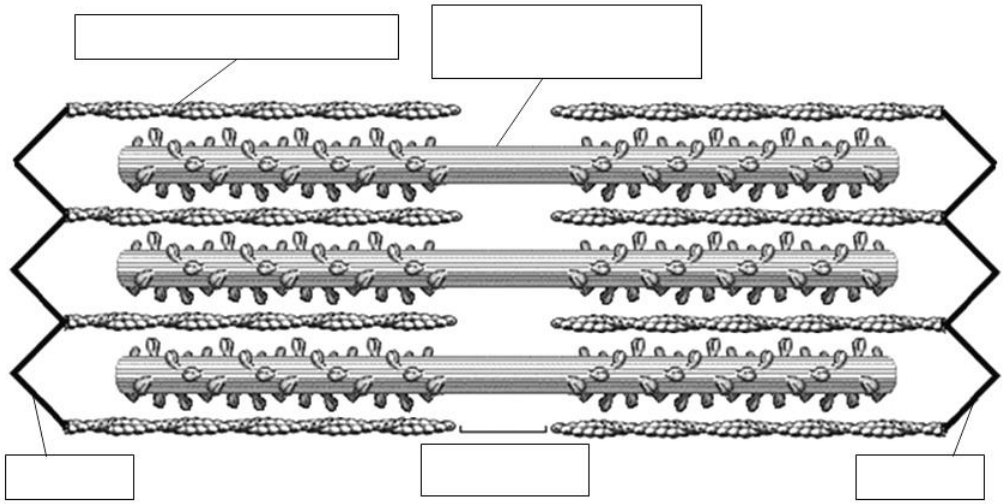
Factors that affect MUSCLE TENSION (force of muscle contraction)

Factor	Effect of the increase of a factor on muscle tension
The frequency of stimulation	
The number of motor units recruited	
The starting length of the muscle	

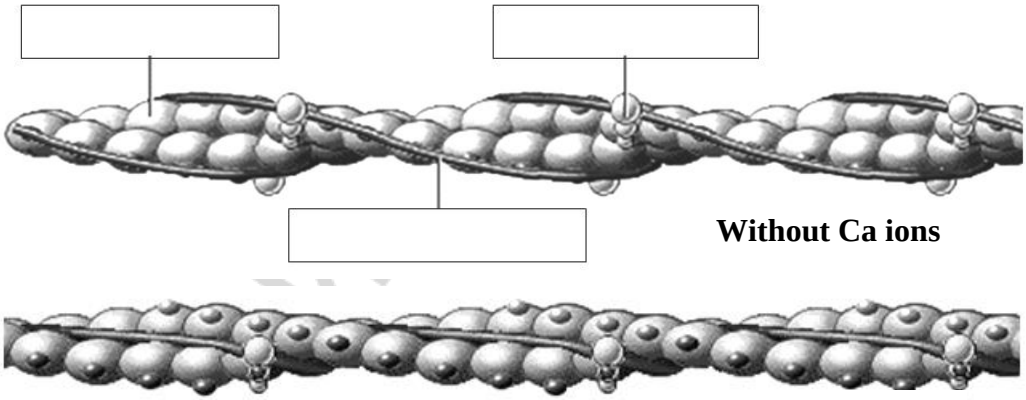
Work 10.3. STUDYING THE STRUCTURE OF SARCOMERE, SKELETAL MUSCLE FILAMENTS AND THEIR PROTEINS

Fill in the names of the main sarcomere structures and proteins of skeletal muscle filaments into the respective boxes.

SARCOMERE



ACTIN filaments and their proteins



Without Ca ions

With Ca ions

Fill in the respective names of **actin filaments'** proteins:

Protein	Function
	Main structural protein possessing binding sites for myosin heads and participating in relative movement during muscle shortening
	Regulatory protein that covers binding sites for myosin heads and prevents myosin binding to actin filaments in unstimulated muscle
	Regulatory protein that is able to bind Ca ions and to move aside another protein from binding sites for myosin on actin filaments, thus exposing binding sites and initiating muscle fiber contraction

MYOSIN filaments consist of the only one protein type, _____.

Lesson 11. 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 main 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. Resuscitation 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 is the purpose and function of reciprocal inhibition?

5. What are the basic functional differences between neuromuscular junctions and neuronal synapses?

6. What is the difference between the primary and secondary inhibition?

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

8. What is time duration that limits brain cortex survival under hypoxia (anoxia)? What is the time for the spinal cord neurons survival under anoxia?

PRACTICAL WORKS

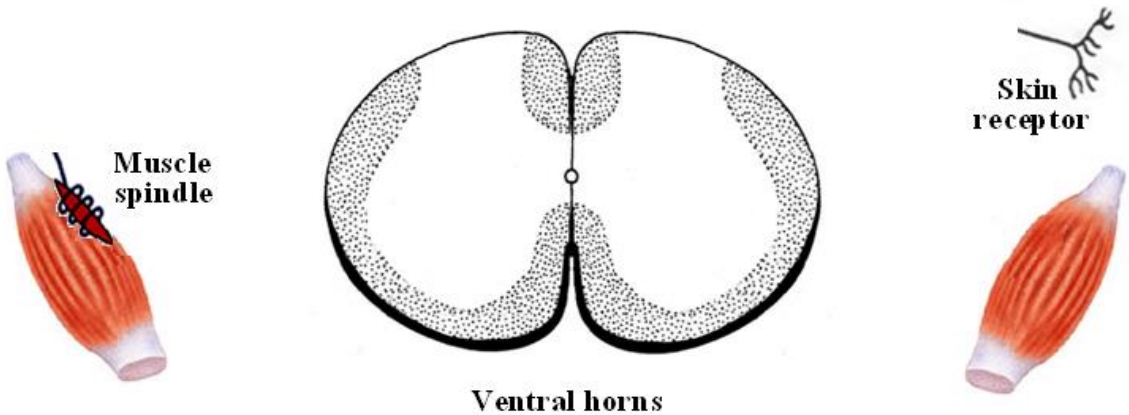
Work 11.1. Schemes of reflex arches consisting of 2 neurons (tendon reflex) and 3 neurons (reflex from skin receptors)

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 the reflex arches at the sides of spinal cord cross section.
2. Indicate numbers of corresponding reflex arch neurons.

PROTOCOL



1 — afferent neuron (pseudounipolar neuron of the spinal ganglion); 2 — motor neuron in the ventral horns	1 — afferent neuron (pseuidounipolar); 2 — interneuron; 3 — motor neuron in the ventral horns

Work 11.2. 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 11.3. 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.

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 11.4. 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.

<table>
<tr><td colspan="4">PROTOCOL
1. EMG drawing of the biceps under various conditions</td></tr>
<tr><td>Rest</td><td>Arm flexion</td><td>Arm extension</td><td>Under tension (holding the load)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

Work 11.5. 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 arm**	**Extension of the arm**	**Synergic tension**
biceps				
triceps				
Conclusion. Activity of motor centers innervating biceps and triceps muscles at rest is _____; in flexion and extension of the arm activity of the center that stimulates muscle contraction is _____, and activity of the center of the muscle-antagonist is _____; under synergic tension of the shoulder muscles _____.				

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

Lesson 12. GENERAL PHYSIOLOGY OF THE EXCITABLE TISSUES (THE CONCLUDING LESSON)

The list of questions for studying

1. Types of the excitable tissues. Excitation and its forms in different tissues. Excitability, the indices that allow evaluation of its level. Basic laws of excitable tissues response to the stimulus action.
2. Types of membrane ion channels. Membrane ion permeability. Main concentration gradients across the cell membrane. Active and passive types of substances transport through the cell membrane.
3. Resting membrane potential of excitable cells and mechanisms of its maintaining.
4. Main factors determining resting potential level. Chang es of resting potential under influence of these factors — depolarization or hyperpolarization, their effects on membrane excitability.
5. Action potential, its phases and ion mechanisms of development. Changes of the state of channels that participate in action potential generation.
6. Excitability alteration during action potential. Refractory periods, their reasons and physiological significance.
7. Sensory receptors, their functions. Receptor potential, mechanism of its origin (in mechanoreceptors as the example). Properties of the receptor potential. Comparison of action potential and receptor potential. Types of stimulation strength encoding in receptors. Adaptation of receptors.
8. Nerve fibers and their structural elements. Types of nerve fibers. Mechanisms of action potential propagation along myelinated and unmyelinated nerve fibers. Velocities of excitation conduction.
9. Classification of synapses. Structure of synapse. Channels of pre- and postsynaptic membranes. Specific proteins of vesicle and postsynaptic membranes involved in exocytosis.
10. Mechanism of synaptic transmission through neuromuscular junction. Postsynaptic excitatory potential (End Plate Potential). Role of acetylcholinesterase. Properties of synapses.
11. Possible mechanisms of neuromuscular junction blockade. Inhibition of nicotinic cholinergic receptors in postsynaptic membrane. Inhibition of acetylcholinesterase. Consequences of neuromuscular junction blockade.
12. Main properties of skeletal muscles. Structure of skeletal muscle tissue and cells. Sarcomere. Structural proteins of myofilaments and their functions.
13. Mechanism of skeletal muscle contraction. Single cross bridge cycle. Excitation-contraction coupling. Relaxation of skeletal muscle.
14. Whole muscle contraction. Periods of the single muscle twitch. Summation of contractions (tetanus), its types.

15. Factors determining the force of contraction. Motor units. Fast and slow muscle fibers, their comparison. Muscle tone.

16. Smooth muscles, their physiological properties. Main factors causing smooth muscle contraction. Ways of intracellular Ca^{2+} concentration increase.

17. The smooth muscle contraction and relaxation mechanisms. Comparison of smooth muscle contraction to the skeletal muscle one.

18. The central nervous system, its structure and functions. Role of the central nervous system in integration of body functions and interaction of an organism with the environment.

19. Neuron, its physiological properties and functions. Functions of neuron's structural elements (soma, axon, dendrites). Functions of glial cells.

20. Integration of neurons into neuron chains. General principles of excitation conduction in neuron chains (divergence, convergence, reverberation). Types and functions of neural chains (networks).

21. Reflex principle of the nervous system functioning. A reflex arch, its components. Types of reflexes. The feedback and its significance. Multilevel organization of a reflex.

22. Inhibition processes in the nervous system. Inhibitory neurotransmitters. Mechanisms of inhibitory synapses functioning. Inhibitory postsynaptic potential (IPSP).

23. Types of inhibition in the central nervous system. Primary inhibition (pre- and postsynaptic) and secondary (pessimal and inhibition after excitation). Types of postsynaptic inhibition.

24. Physiologic principles of coordination in the central nervous system (divergence, convergence, reciprocal inhibition, common final way, dominance, feedback).

25. Nervous centers, their functions and properties (temporal and spatial summation, rhythm transformation, tone of nervous center, plasticity, rapid fatigability). The tone of nervous centers, factors affecting it.

SPECIAL PHYSIOLOGY
OF THE CENTRAL NERVOUS SYSTEM

Lesson 13. THE ROLE AND FUNCTIONS OF THE SPINAL CORD, MEDULLA, MIDBRAIN, CEREBELLUM AND RETICULAR FORMATION

Basic questions:

1. Structure of the spinal cord, its parts. Functions of the spinal cord.
2. Muscle tone. The spinal mechanisms of muscle tone regulation.
3. Basic spinal reflexes important in clinical practice. Consequences of the injuries of the spinal cord and its ventral or dorsal roots.
4. The medulla. The main medullar centers regulating basic functions of the organism. Integration of autonomic and somatic functions.
5. The midbrain 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 muscle tone, posture and movements. Consequences of the brainstem injury.
7. Cerebellum, its structure and functions. Participation of the cerebellum in mechanisms of muscle tone, posture and movements regulation. Basic symptoms of the cerebellar function disorder.
8. Reticular formation of the brainstem, 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, biceps and triceps (flexion and extension) reflex of the upper extremity? What type of reflexes are they referred to?
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 lumbar parts?
3. Why does the dorsal roots damage result in the significant decrease of muscle tone?
4. What are the basic causes of decerebrate rigidity?
5. What is a *spinal shock*? When does this state occur?
6. What are basic functions of quadrigeminal bodies?
7. What kind of a symptom is *ataxia*?
8. What is the name of a symptom that appears as inability to perform quickly alternating opposite movements (such as flexion and extension, pronation and supination)?
9. What type of a tremor is characteristic for cerebellum disorders?
10. What is the influence of reticular formation on the cerebral cortex?

PRACTICAL WORKS

Work 13.1. STUDYING OF SOME TENDON REFLEXES (MANDIBULAR, UPPER EXTREMITY FLEXION AND EXTENSION)

Tendon reflexes are studied for evaluation of 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 centers (neurons) for the biceps and triceps muscles reflexes are located in the _____ (CNS department).

Work 13.2. 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 are _____ (expressed, impaired).
2. **Conclusion:**

Work 13.3. 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. **Conclusion:** the state of tactile sensitivity in the examined _____.

Work 13.4. 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 13.5. 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 muscle tone (**dystony**); finger trembling at rest (**tremor**); movement impairment revealed as excessive or insufficient movement (**dysmetry**); coordination impairment (**ataxia**) that is manifested as "drunk" (swaying) gait and etc.; speech motor disorders (**dysartria**); swinging rhythmic twitching of eye-balls (**nystagmus**); impairment of alternating 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

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 posture 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 14. 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. Encephalography (EEG).

2. Thalamus. The main groups of thalamic nuclei, their functions. Role of the thalamus in pain sensations formation, sensory and motor functions.

3. Hypothalamus. Main centers of hypothalamus and their functions. Integration of somatic, autonomic and endocrine functions. Hypothalamus participation in mechanisms forming higher psychic functions.

4. Basal nuclei. The main structures of basal nuclei, their functions. Participation of basal nuclei in mechanisms of the muscle tone, posture and movements regulation. The role of dophamine and acetylcholine neurotransmitter systems. Consequences of basal nuclei disorder.

5. Limbic system. The main structures of the limbic system, its functions. Participation in formation of motivation and emotions.

6. Cerebral cortex. The main cortical areas. Sensory and motor functions. Integration of sensory, motor and autonomic functions of the organism.

7. The cerebral cortex role in the performance of movements.

8. Modern concepts of localization of functions in the cortex. Consequences of the damage of various regions of the cerebral cortex.

***Self-check*:**

1. In what way does the animal feeding behavior change in case of damage of lateral or ventro-medial nuclei of the hypothalamus?

2. List the main centers of hypothalamus and the functions that it 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 nuclei disorder.

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

6. List basic functions of the limbic system.

7. What brain parts do suffer in the first place 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 alpha rhythm is recorded on ECG? What is its frequency?

10. Which rhythm of EEG is considered synchronized? What is the desynchronization reaction?

11. Which gyrus of the cerebral cortex is the somatosensory cortical area?

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

PRACTICAL WORKS

Work 14.1. ELECTROENCEPHALOGRAPHY

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

Accomplishment. To record an EEG 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 head regions on both sides.

During EEG 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 EEG 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.

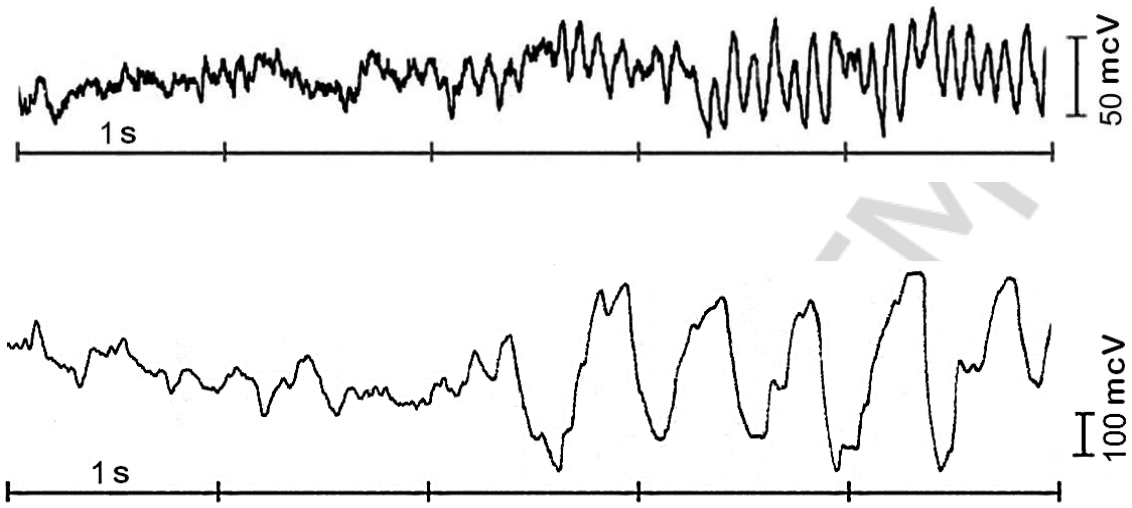
Directions for recording the Protocol:

1. Sign the types of EEG rhythms in the given EEG fragment.

2. Fill in the table.

PROTOCOL

1. EEG fragment.



2. **Normal values** of EEG rhythms

Rhythm	Frequency (Hz)	Amplitude (mcV)
Alpha (α)		
Beta (β)		
Theta (θ)		
Delta (δ)		

Lesson 15. 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. The tone of autonomic centers.
3. Sympathetic and parasympathetic parts 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 postganglionic neurons of the sympathetic and parasympathetic system on effector cells, their neurotransmitters and receptor mechanisms.

6. The effects of sympathetic and parasympathetic parts of ANS on the body organs and systems. Relative antagonism and synergism of their effect. Basic autonomic reflexes.

7. The principles of ANS effector cells functions correction by affecting the receptors in ANS ganglia and of the effector cells.

8. Basic indices for evaluation the functional state of ANS parts.

***Self-check*:**

1. What are the peculiarities of ANS innervation of the adrenal glands medulla?

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; 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; GIT motility; GIT sphincters tone; vessels of skeletal muscles; secretion of gastric juice; bladder sphincter; sweat glands?

7. List possible effects of atropine taking into account that this medicine is an antagonist of muscarinic cholinergic receptors.

PRACTICAL WORKS

Work 15.1. 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.

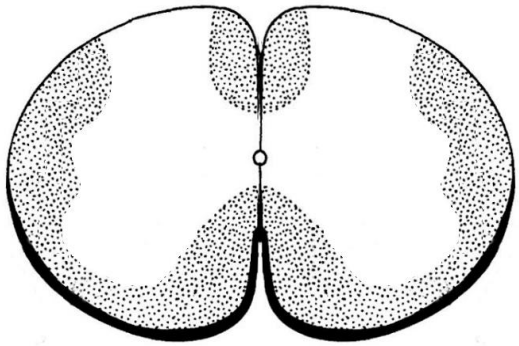
Directions for recording the Protocol:

1. Draw the scheme of a somatic reflex arch at the left side of a spinal cord section, and the scheme of an autonomic (in particular, sympathetic) reflex arch at the right side; indicate the structural parts of reflex arches with numbers.

2. Fill in the table.

PROTOCOL

Scheme of somatic reflex **Autonomic (sympathetic) reflex**



Parts of a somatic reflex arch:	**Parts of an autonomic (sympathetic) reflex arch:**
1. Receptor part may be presented by the following receptors: 1.1. _____ 1.2 _____	1. Receptor part is presented mainly by _____ receptors.
2. Afferent part is presented by _____, which are located in _____	2. Afferent part is presented by _____, which are located in _____
3. Interneurons	3. Interneurons
4. Efferent part is presented by _____ or _____ motor neurons, which are located in _____	4. Efferent part consists of 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 _____ m/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 neuro-effector junction is _____, which binds to ____ and ____ types of _____ receptors.

Work 15.2. CLINOSTATIC REFLEX

Reflex study allows determining the functional state of parasympathetic and sympathetic centers regulating the heart function. When a person 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, beats/min		
In standing position	**In lying**	**Pulse difference [PR standing – PR lying]**

Conclusion: _____

Work 15.3. 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, beats/min		
In lying position	**In standing**	**Pulse difference [PR standing – PR lying]**

Conclusion: _____

Work 15.4. 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 inspiration, the tone of nuclei *n. vagi* increases, and heart 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 inspiration 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 inspiration. 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, beats/min		
Before breath holding	**During breath holding after inspiration**	**Pulse difference [PR breath holding – PR initial]**

Conclusion: _____

Work 15.5. ASSESSMENT OF NEUROTRANSMITTER MECHANISMS OF THE EFFECT OF SYMPATHETIC AND PARASYMPATHETIC PARTS 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, **BPmean** — Mean Hemodynamic Blood Pressure.

2. Draw a picture of BP changes under injection of noradrenaline and acetylcholine.

3. Make a conclusion about the effect of the ANS sympathetic and parasympathetic parts on the heart rate and the force of heart contractions as well as about neurotransmitter mechanisms of these effects.

PROTOCOL

Effects of the heart	**BP_{sys}**	**BP_{mean}**	**BP_{diast}**	**HR**
Initial values				
Stimulation Symp. Nerves to heart T_1				
Injection of noradrenaline, 5μg/kg				
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				
Stimulation Vagus Nerve to heart				
Injection of acetylcholine, 5μg/kg				
Atropine $^{(\text{M-cholineblocker})}$, 10.0 mg/kg + StimulationVagus Nerve to heart				

NORADRENALINE effect **ACETYLCHOLINE effect**

Conclusion: _____

_____

_____

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

PHYSIOLOGY OF SENSORY SYSTEMS

Lesson 16. 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 nonspecific 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 light action. Functions of pigment, horizontal, bipolar and ganglionic cells of the retina. Mechanisms of visual system adaptation.
9. Eye movements and their role in 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 16.1. EVALUATION OF VISUAL ACUITY

Visual acuity is the ability to see clearly surrounding objects placed at various distances. Vision acuity is evaluated by a minimal angle of vision, under which the eye is capable to discriminate two points as separate. A normal eye is capable to discriminate 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 size appears while looking 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. To the left from each line a distance is indicated (D), 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 meters from the table. The study is performed for every eye separately. The examined covers one his 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 — usually 5 m); D — distance, from which a normal eye must clearly see letters of the given line. Normal value of visual acuity is 1.0. Corresponding values of V (visus) are indicated to the right from each line of the table, from 0.1 at the top till 2.0 in the bottom (visual acuity higher than normal).

Directions for recording the Protocol:

Evaluate visual acuity of both eyes and compare it with the norm.

PROTOCOL

1. Visual acuity of the right eye _____, left eye _____.
2. **Conclusion:** Visual acuity of the right eye is _____
   Visual acuity of the left eye is _____
   (normal, increased, or decreased)

Work 16.2. STUDYING THE COLOR VISION

The human eye can discriminate 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.

Conclusion: (if there are any color perception disorder in the examined).

Work 16.3. EVALUATION OF VISUAL FIELD BOUNDS (PERIMETRY)

Visual field is the space seen by a human eye, when the sight is fixed at one point. The size of visual field is not identical in different people and depends on the functional state of the retina, depth of the eye-ball position, 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 rods (necessary for black-and-white vision) distribution in retina predominantly on its periphery. 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 — 65º.

Materials and equipment: Forster's perimeter, objects of various colors, a ruler, colored pencils.

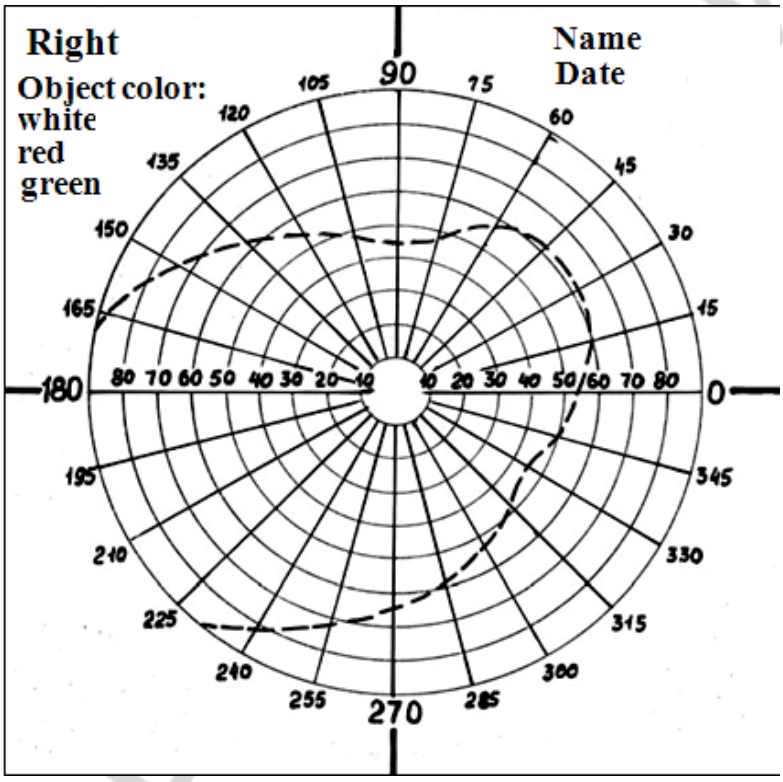
Accomplishment. The study is performed using Forster's perimeter that is a stand-holder with a movable calibrated (in degrees) metal arch with divisions on a lateral side. The examined must be seated with his back to light and put his chin on a rest of the stand-holder at the right (while examining the 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

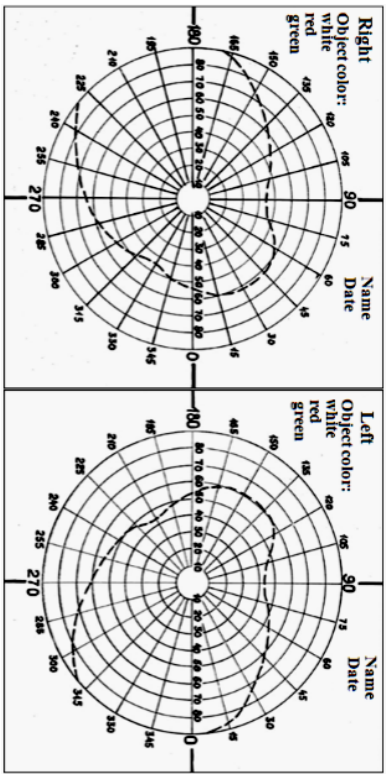
field and name its color. Repeat the study in a vertical and two oblique positions of the perimeter for objects of white, green or blue color. Insert the results (in degrees) into the table.

Directions for recording the Protocol:

Fill in the table with measured angle values for visual field bounds at 8 points (4 axes) for white color, then for the other (green, blue or red) color. Using the obtained results draw a diagram of visual fields for white and other colors.

Direction of axes	Bounds of visual field of the __RIGHT__ eye in degrees	
	for white color	for _____ color
90° (upwards)		
270° (downwards)		
0° (outwards)		
180° (inwards)		
45° (outwards above)		
45° (inwards down)		
45° (outwards down)		
45° (inwards above)		





Conclusion: _____

_____

_____

_____

Work 16.4. SENSITIVITY EVALUATION OF THE RETINA CENTRAL REGIONS

Sensitivity evaluation of central parts of the retina is important as it determines visual acuity level in many aspects. Sensitivity depends not only on the functional state of neurons in the center of the retina but on its blood supply, the state of the optic nerve, visual pathways, visual cortex and other factors.

Accomplishment. The work is performed using computer 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. One after another fluorescent points appear in various parts of the screen. Each point intensity increases gradually, and at some moment it becomes sufficient to be seen on a dark screen. As soon as the point becomes visible, 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.

The test results are presented as a colored distribution of points in accordance with the color scale. 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.

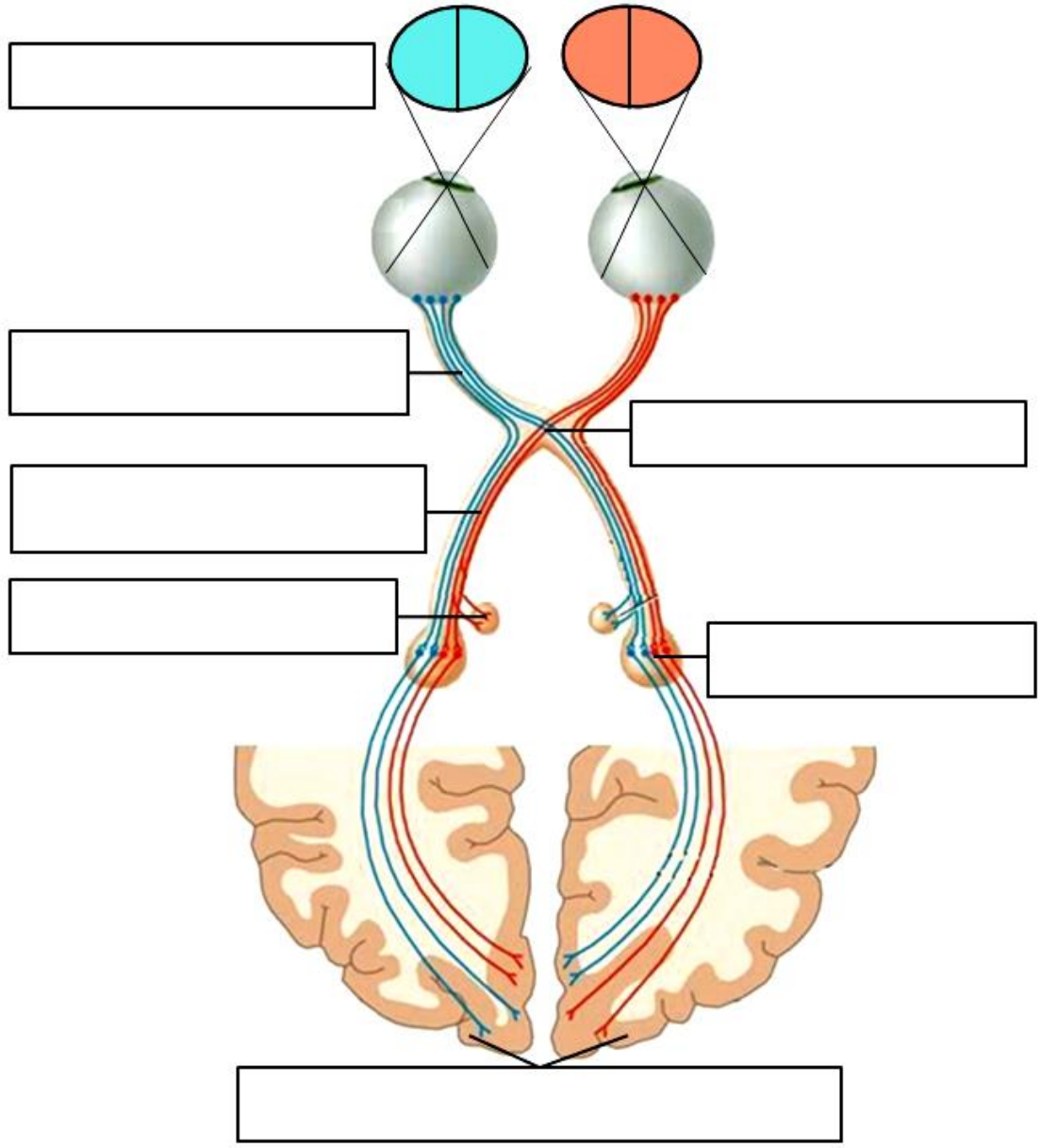
A considerable impact on the results of the study produces the degree of darkening and time of preliminary darkness adaptation. But while performing the work in conditions similar for the whole group the results of different examined students can be compared even in short times of darkness adaptation.

PROTOCOL

1. Points of _____ colors predominate on the screen.
2. The area of decreased sensitivity (scotoma) at 20–25^{o} outward shows the projection of the _____.
3. **Conclusion:** Sensitivity of the examined eye retina is _____.
(normal, high or decreased)

Work 16.5. OPTIC PATHWAYS GENERAL SCHEME

Using materials of lectures and textbook fill in the structures names on scheme of the visual pathways starting from the visual fields up to the visual cortex.



Work 16.6. VELOCITY EVALUATION OF SIMPLE SENSOR-MOTOR REACTION

The velocity of sensory-motor 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 triangle appears in the center of the screen. Each time after the triangle appears on the screen press key *Enter* as soon as possible. After every its appearance (except the 1st one) the screen shows a *mean* value of your sensory-motor reaction.

PROTOCOL

1. Mean time of sensory-motor reaction (from 5–6 evaluations) is _____ ms.

Lesson 17. 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 interoreceptors. 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 do 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 hair 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 tuning fork (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 pass through 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. List the main antinociceptive systems.

PRACTICAL WORKS

Work 17.1. EVALUATION OF SOUND SOURCE DIRECTION

Humans and animals possess spatial hearing that allows determination of localization of 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 combining the 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.

Directions for 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.

PROTOCOL

1. In investigation of sound source localization using phonendoscope having tubes of different length the examined localizes the source of sound to the side of _____.

2. **Conclusion:**

The reason of the sound shift to the side _____ is the _____ difference in the right and left organ Corti receptors activation by sound wave coming to both ears.

Sound sensation shifts to the side that becomes activated _____.

Work 17.2. STUDYING BONE CONDUCTION

WEBER's test

Sound can be conducted to the internal ear receptors by the way of usual air conduction (through the middle ear) and by bone conduction. Bone conduction is the transmission of sound waves directly to the internal ear involving into oscillations cranial bones (the temporal bone) and internal ear fluids, resulting in the oscillation of the basilar membrane and excitation of receptors.

Materials and equipment: a tuning fork (camertone), a stop-watch, cotton pads.

Accomplishment. Apply the handle of the vibrating tuning fork 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 the damaged (poorly hearing) ear. Repeat the experiment covering the one auditory canal with cotton.

PROTOCOL

1. Lateralization of sound is _____
(absent or is found and directed to …).
2. At the closure of one auditory canal, lateralization of sound occurs to the side of _____.
3. **Conclusion.** The reasons of sound lateralization are:
   a) _____
   b) _____

RINNE's test (comparison of air and bone sound conduction).

Accomplishment. Press the handle of the oscillating tuning fork to a mastoid bone at one side and measure the time till sound sensation disappears (the time of bone conduction). Then bring the same tuning fork with its still vibrating branches closer to an external auditory canal and continue to count

time. In norm the examined continue to hear sound of the tuning fork that is still oscillating because of the better sound conduction through the middle ear that amplifies sound. The total time, during which the sound is heard is 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***).

PROTOCOL

Ear	Time of conduction, s	
	Bone conduction	**Air conduction**
Right		
Left		

Conclusion: Rinne's test is _____

Work 17.3. 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.

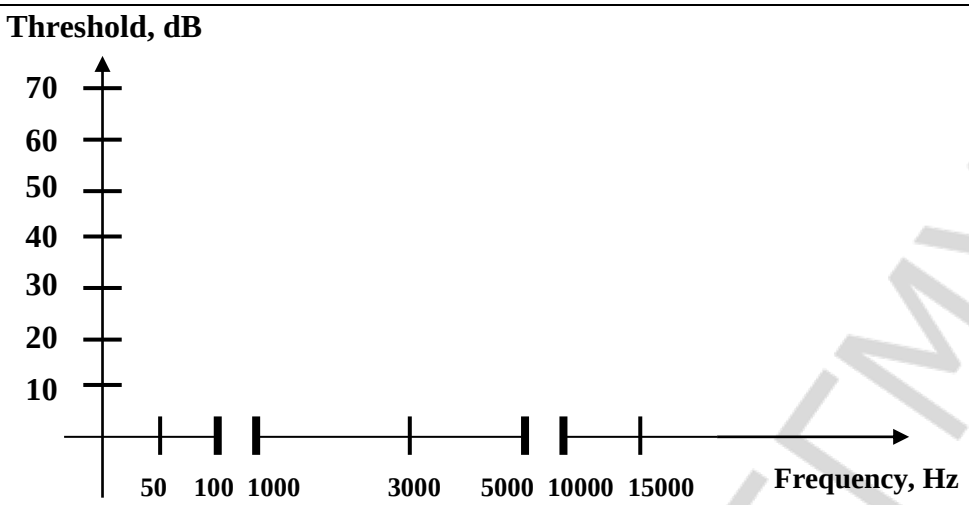
Sensitivity of the auditory analyzer is evaluated by a minimal value of sound pressure sufficient for a sense perception to appear; i. e. by **hearing threshold**. To determine this minimal sound pressure audiometer is used. They permit precisely dosing sound oscillations frequency in the range from 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 given frequencies, fill in the table and draw a figure of hearing thresholds.

PROTOCOL

Frequency, Hz	**50**	**100**	**1 000**	**3 000**	**5 000**	**10 000**	**15 000**
Threshold, dB							



Conclusion: The area of the highest auditory sensitivity is:_____ Hz.

Work 17.4. 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 sensation 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.

PROTOCOL

Skin surface	Spatial threshold (in mm)
Internal side of the forearm	
External side of the forearm	
Tip of index finger	
Cheek	
Forehead	
Lip	

Conclusion: the minimal values of spatial thresholds of skin tactile sensitivity are received _____

The reason of this is _____

Work 17.5. STUDYING THE FUNCTIONAL STATE OF THE VESTIBULAR ANALYZER

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 is always directed towards the side ***opposite to rotation***, and a ***faster*** one that follows it and is characterized by the movement of the eyeball (jump) in the direction ***of rotation***. The slow nystagmus component occurs at the beginning of the movement, when endolymph moves towards ampoule more slowly under the action of acceleration. 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, a photoplethysmograph, eye-bandage, a stop-watch.

Accomplishment.

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 a stationary object. The character the observed eyeballs nystagmus depends on predominant stimulation of these or other semicircular 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.

PROTOCOL

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 nystagmus	Duration of nystagmus (sec)
Inclination forward by 15º	Horizontal canals	Horizontal	
Inclination forward by 90º	Vertical canals	Rotary	
Head inclination to the shoulder	Sagittal canals	Vertical	

Conclusion: (compare the nystagmus duration to normal values)

_____

_____

Work 17.6. 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. The 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.

PROTOCOL

Substance	Threshold concentration, %
Bitter (quinine)	
Sweet (sugar)	
Salty (common salt)	
Sour (citric acid)	

Conclusion: (compare thresholds of taste sensitivity to various substances)

_____

_____

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

Lesson 18. SPECIAL PHYSIOLOGY OF THE CENTRAL NERVOUS SYSTEM. PHYSIOLOGY OF SENSORY SYSTEMS (THE END-OF-TERM LESSON)

The list of questions for studying:

1. Spinal cord, its general structure and functions. Main spinal cord reflexes. Consequences of the spinal cord damage. Spinal shock.
2. The spinal level of muscle tone maintaining. Muscle tone changes in case of damage of various parts of reflex arch.
3. Medulla and pons. The vital centers of medulla. The main nuclei of medulla and pons, their functions.
4. Midbrain. The main midbrain structures and nuclei, their functions. Decerebrate rigidity and reasons of its origin.
5. 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.
6. Cerebellum, its functions. Participation of the cerebellum in muscle tone, posture and movements regulation. Basic symptoms of the cerebellum function disorder.
7. Thalamus, its functions. Functional characteristics of thalamic nuclei. Its role in pain sensation formation, sensory and other functions.
8. Hypothalamus. Main centers of hypothalamus and their functions. Integration of somatic, autonomic and endocrine functions.
9. Basal nuclei, their main structures and functions. Participation in execution of complex movements.
10. Limbic system, its structures and functions. Participation in formation of motivations and emotions.
11. The autonomic nervous system. General structure and functions. Characteristics of afferent, central and efferent parts of autonomic nervous system reflex arch in comparison with the somatic nervous system.
12. Sympathetic and parasympathetic parts of the autonomic nervous system, peculiarities of their reflex arches. Preganglionic and ganglionic autonomic neurons, their neurotransmitters. Receptor types of ganglionic neurons and effector cells.
13. The effects of sympathetic and parasympathetic parts of autonomic nervous system on functions of organs and systems. Synergism and relative antagonism of their effects. Autonomic nervous centers, their tone.
14. The concept of sense organs, analyzers, sensory systems. I. P. Pavlov's theory of analyzers. General principles of analyzers structure, their classification.

15. Peripheral (receptor) part of analyzer. Types of sensory receptors. Analog and discrete encoding in receptors. Adaptation of receptors. Fast and slow adapting receptor types.

16. Visual system. General structure and functions. Peculiarities of the structure and properties of the eye. The optic system of the eye. Accommodation and its mechanisms.

17. Normal refraction of the eye and errors of refraction. Principles of correction. Types of the eye abnormalities associated with age. Visual acuity.

18. The structure and functions of the eye retina. Photochemical processes in photoreceptors of the retina under the action of light. Functions of pigment, horizontal, bipolar, amacrine and ganglion cells of the retina.

19. Conducting pathways of the visual system. Primary and secondary visual cortex. Basic principles of color vision. Main types of color vision disorders.

20. The auditory system. Basic characteristics of the sound and their perception. The sound-conducting apparatus. The structure and properties of the outer and middle ears.

21. The sound-perceiving apparatus. The structure and functions of the inner ear. Organ of Corti. Mechanism of hair cells excitation.

22. Mechanisms of sound perception and analysis. Primary and secondary auditory cortex. Tonotopical representation of sounds in auditory system.

23. The vestibular system, its structure and functions. Mechanisms of detection of linear and angular accelerations. Vestibular-ocular reflexes (nystagmus).

24. The olfactory system. Reception of smells. Conducting pathways and central parts of the olfactory system. Steps in transduction in the olfactory receptor neurons.

25. The taste system. Taste reception. Conducting pathways and central parts of the taste system. Taste perception. Basic types of taste.

26. The somatosensory system. Skin sensitivity. Types of receptors. Somatosensory cortex.

27. Pain. Nociceptors. Neurotransmitters. Fast and slow pain, nervous fibers carrying sensations of fast and slow pain. Referred pain.

PHYSIOLOGY OF CARDIOVASCULAR SYSTEM

Lesson 19. 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 contributing to blood flow in vessels.
4. The basic law of hemodynamics — correlation between blood pressure, volume velocity of blood flow and peripheral vascular 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-related 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 and 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. In what way deep inspiration and expiration do affect the venous return to the heart?
4. In what way will venous return change after veins' constriction or dilation? In what way will it affect stroke volume (SV)?
5. What is the basic reason of age-related systolic blood pressure increase?

6. What factors do the pulse filling and pulse tension depend on?

7. What is the difference between the concepts of "pulse rate", "pulse wave propagation velocity" and "linear blood flow velocity"?

8. What kind of transport through a capillary wall is characteristic of O_2, CO_2, water, hydrophilic low-molecular substances; lipids; proteins?

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 for filtration (or reabsorption) of fluid in the capillary.

10. List main factors that may result in interstitial edema.

PRACTICAL WORKS

Work 19.1. STUDYING THE ARTERIAL PULSE PROPERTIES BY PALPATION

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 unstable 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 factor subjectively evaluated by the height of arterial wall elevation during palpation of pulse wave passing (it corresponds to sphygmogram amplitude). 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 VELOCITY is a factor subjectively assessed by palpation as the velocity of reaching the maximum amplitude of the arterial wall dilation. 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, as it is observed in stenosis of the artery.

Pulse filling and pulse velocity (but not pulse tension) 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.

PROTOCOL

Pulse property	Norm	Deviation variants	Examination data
Rhythm	Rhythmic	Arrhythmic	
Rate	60–90	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 ____, mean_____ .			

Conclusion: (compare the results with the norm) _____
_____

Work 19.2. ARTERIAL BLOOD PRESSURE MEASUREMENT BY KOROTKOFF'S AUSCULTATIVE 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.

PROTOCOL	
Results: **Systolic** (maximal) pressure — _____ (norm — 110–139 mm Hg) **Diastolic** (minimal) pressure — _____ (norm — 60–89 mm Hg)	Thus, **Blood Pressure** is _____/_____ **mm Hg**
Conclusion: Blood pressure is _____ (normal, high — hypertension, low — hypotension)	

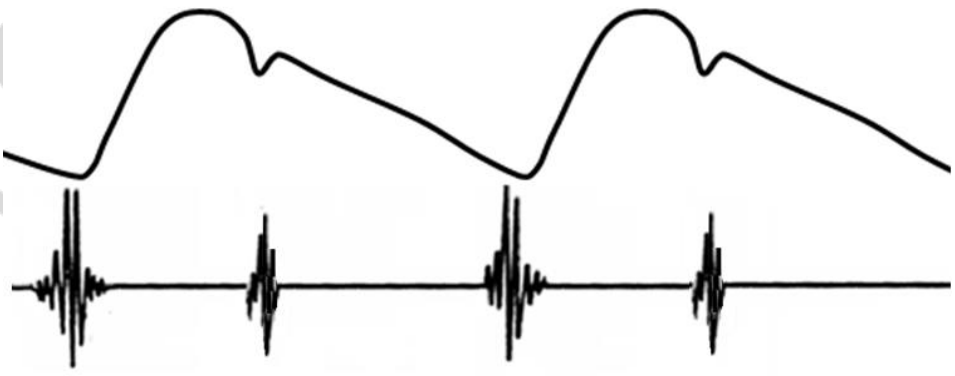
Work 19.3. PULSE ASSESSMENT BY SPHYGMOGRAM ANALYSIS

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 notch. 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.

Directions for recording the Protocol:

1. Indicate anacrota, katacrota, incisura and dicrotic notch on the sphygmogram.
2. Indicate the I and the II heart sound of the phonocardiogram.
3. Fill in the gaps in the text below related to the sphygmogram.

PROTOCOL



1. Blood pressure increase in the aorta and carotid artery starts just after the _____ heart sound. This blood pressure increase is seen on a sphygmogram as _____.
2. The appearance of a dicrotic notch on the sphygmogram coincides with the appearance of the _____ heart sound. Dicrotic notch is caused by _____.
3. The pulse velocity (shown by the slope of anacrotic wave) in aortic stenosis is _____ due to _____; the slope of the anacrota in aortic insufficiency is _____ due to _____

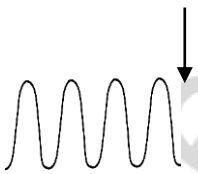
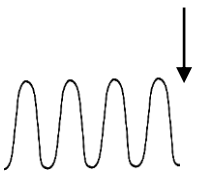
Work 19.4. ANALYSIS OF ARTERIAL BLOOD PRESSURE CHANGES UNDER THE ACTION OF ADRENALINE AND NORADRENALINE

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 purpose of the work is to compare the effects of catecholamines — adrenaline (epinephrine) and noradrenaline (norepinephrine) on the indices of hemodynamics.

Directions for recording the Protocol:

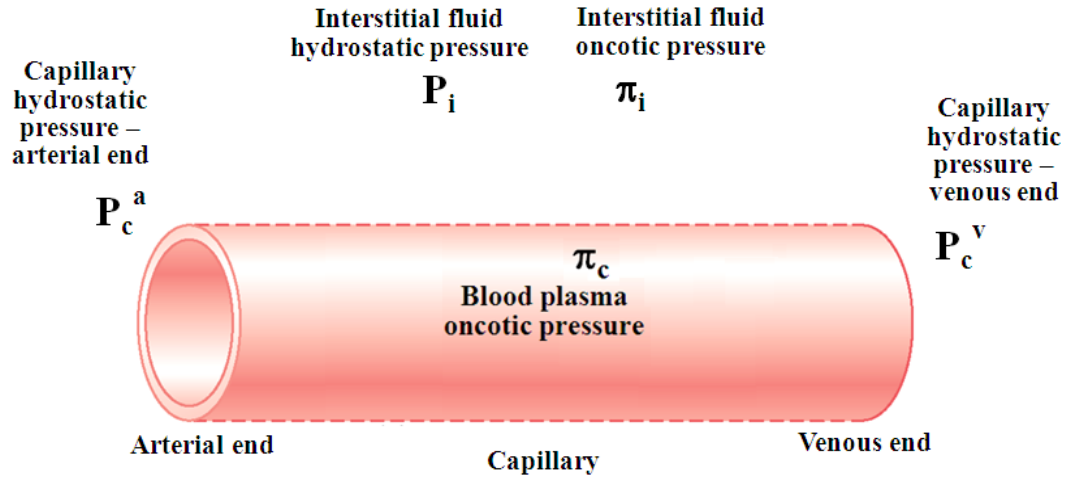
1. Fill in the table.
2. Draw the figures of blood pressure changes under catecholamines action.
3. Compare the effects of adrenaline and noradrenaline.

PROTOCOL

Factor	Initial value	Noradrenaline 20 μg/kg	Adrenaline 20 μg/kg
HR			
BP_{syst}, mm Hg			
BP_{diast}, mm Hg			
BP_{mean}, mm Hg			
Pulse pressure, mm Hg			
Noradrenaline		**Adrenaline**	
			
Conclusion:			
Noradrenaline increases BP _____ and BP _____ because it stimulates mainly _____ adrenergic receptors.		Adrenaline increases BP _____ and _____ as it stimulates _____ _____ adrenergic receptors.	

Work 19.5. VIDEO "MICROCIRCULATION"

Using materials of the video and lectures show by arrows directions of all pressures participating in transcapillary exchange and indicate their values in mmHg. Write the Starling equation for calculation of resulting pressure below.



Net filtration pressure =

Fill in the gaps in the text:

1. Blood flow in arteries is _____ than in venules.
2. Mean linear velocity of blood flow in capillaries is _____.
3. List the mechanisms of transcapillary exchange of substances in microcirculatory blood vessels:

1) _____; 2) _____;
3) _____; 4) _____.

4. Fill in the main types of transport through the capillary wall for:

oxygen and carbon dioxide _____;
water _____;
glucose _____;
lipophilic substances _____;
high-molecular substances _____.

5. Main factors that can result in the development of interstitial edema are:

_____
_____
_____
_____

Lesson 20. 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 heart muscle metabolism and blood supply at a relative rest and at exercise. The coronary blood supply in the right and left ventricles during the systole and diastole.

3. The structure and functions of the heart conducting system. Propagation of excitation through the heart conducting system. Automaticity mechanisms. 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 heart muscle cells.

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 concepts 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. What part of the conductive system of the heart has the highest ability to automatic excitation? And what part has the lowest ability? What can be used as an index of the automaticity?

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 20.1. 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 automatic excitation. The ability to 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 "Automaticity 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 nodes? _____
_____
_____.

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

3. Temperature effect on the heart automaticity

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 does the AP rate of pacemaker's cells change in cooling: _____ and in warming of the heart's pacemaker _____.

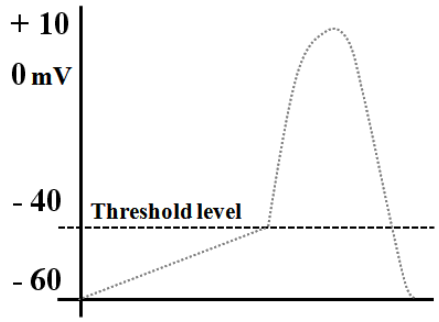
Hence, in human hypothermia one can expect _____ of HR, and in hyperthermia — _____ of HR.

Work 20.2. Mechanisms of generation of action potentials (AP) of pacemaker cells (sinoatrial node) 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); indicate AP phases and excitability phases.

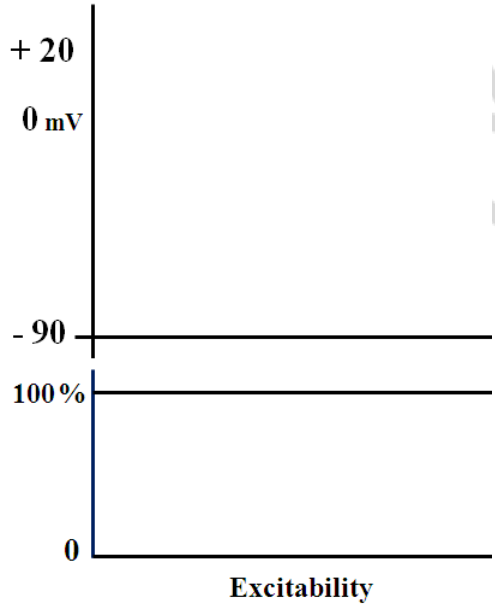
AP of a pacemaker's cell



Action potential phases:

Phase №	Phase name

AP and excitability state of a contractile heart muscle cells



Action potential phases:

Phase №	Phase name

Fill in the following points:

The basis of the pacemaker cells ***automaticity*** is the _____ _____ phase of their action potential. Its ion mechanisms are based on the following changes of membrane permeability:
_____
_____
_____
_____

The reason of the **phase 0** is the opening of _____ channels and movement of these ions _____ the cell.
The reason of **phases 1** and **3** is the _____ of _____ ions _____ the cell.
The reason of **phase 2** is the opening of _____ and approximate balance of _____ _____ and _____ _____.
Phase 4 corresponds to the _____ _____.

Lesson 21. 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 blood at rest and at exercise. Indices of myocardial contractility.

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

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

***Self-check*:**

1. At what pressure in the left ventricle does the ejection period of the heart start, 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)

- Stroke Volume — **55–90** ml
- End-Diastolic Volume — **90–140** ml
- End-Systolic Volume — 50–60 ml
- Ejection Fraction — **50–75 %**

Mean limits of pressures in the ***atria***:

- Left atrium — +4 – +12

• Right atrium — -1 – +8.
• Main pressures developed in the heart ventricles

Ventricular pressures	Left ventricle	Right ventricle
End-systolic pressure	**90–140** mm Hg	**15–30** mm Hg
End-diastolic pressure	4–12 mm Hg	0–8 mm Hg

PRACTICAL WORKS

Work 21.1. RECORDING AN ECG AND ITS ANALYSIS

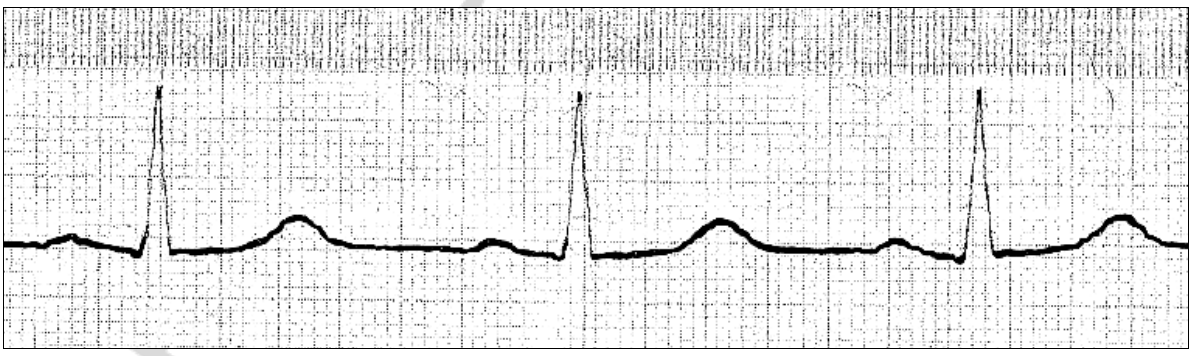
Accomplishment. While recording an ECG the patient is lying. Electrodes are applied to the extremities in accordance with accepted color marking of wires: the **right arm** — **red** color; **left arm** — **yellow** color; **left leg** — **green** color; **right leg** (grounding the patient) — **black** 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.

All waves amplitudes and intervals durations are measured in the standard lead II.

Electrocardiogram **(standard lead** II**)**



ECG Analysis

1. 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.

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

Put down characteristics of given ECG:

calibrating signal: 1 mV = _____ mm;

paper movement speed: _____ mm/sec; 1 mm = _____ sec.

2. 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.

Fill in the table:

Presence of P waves on ECG	
Shape of P waves	
Direction of P waves	
Location relative to QRS complexes	
PQ mean duration	
Duration variability	

Conclusion: the source of the rhythm is: _____.

3. 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.

Fill in the table:

Duration of 5 RR intervals (in seconds)				

Mean RR value _____; deviation from mean value_____ %.

Conclusion: the rhythm is _____.

4. Determination of heart rate (HR)

Mean duration of RR interval 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.

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

Mean RR =

HR = 60 : RR = _____beats/minute.

Conclusion:

5. Assessment of conductivity

Evaluation of excitation conduction through the heart (conductivity) waves and intervals duration is used. To assess the time of excitation conduction **through atria** the duration of **P** wave is measured (norm is 0.08–0.1 sec), for assessment of the time of excitation conduction **from atria to ventricles**) the duration of **PQ** (**PR)** interval is measured (from the beginning of P wave till the beginning of Q wave (R, if Q is absent), norm is 0.12–0.2 sec), and excitation conduction **through ventricles** is estimated by measurement of the total duration of **QRS** complex (from the beginning of Q wave till the end of S wave, norm is 0.06–0.1 sec). If the duration of these intervals exceeds the upper limit of the norm, it means that excitation conduction is slowed down. Thus, the ***conductivity is decreased***.

Fill in the table:

P wave duration	
PQ (PR) interval	
Duration of QRS complex	

Conclusion (compare the values with the norm and make a conclusion about conductivity of different parts of the heart):

6. Assessment of ECG waves and intervals *duration* in the lead II:

Table 13

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	

7. 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	

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

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

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

waves _____ are sharp,
waves _____ are smooth,
presence of other wave shapes (2-phase and others) _____.

10. Segment ST analysis:

Deviation of ST segment from an **isoelectric line** is one of basic signs of the ***heart ischemia*** (insufficient blood supply to the myocardium). In norm ST segment deviation from the isoelectric line upwards or downwards must 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:

Cardiac **rhythm** is _____, **heart rate** is _____, **conductivity** is _____ , **waves** and **intervals** are _____, the signs of the **heart ischemia** are _____.

Task: draw **normal ECG (II lead)** using given isoelectric line:

_____

Work 21.2. 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 noises.

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 (pulmonary artery component);

– On the left edge of the sternum, 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 the pulmonary artery are listened to.

3. Open: ***Introduction of Auscultation → Normal First and Second Sounds at Apex and Base → First Sound – Mitral and Tricuspid Valve Closure***. Observe the dynamics of mitral and tricuspid valves closing and their contribution to the formation of the 1st heart sound 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. **The first** heart sound occurs in the beginning of _____ _____ period of the cardiac cycle. The basic cause of the first heart sound is _____.
In ***synchronous*** recording of ECG, phonocardiography and sphygmography the 1st heart sound appears after _____ **wave** of **ECG** and precedes the _____ of **sphygmogram**.

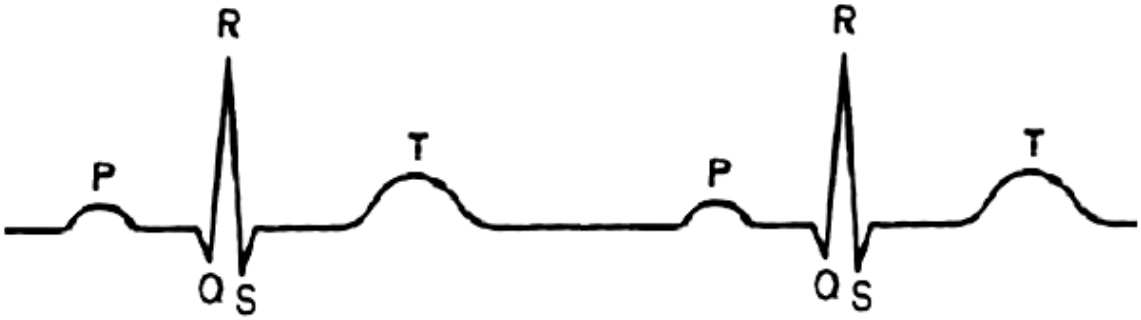
2. **The second** heart sound occurs during _____ phase of the cardiac cycle and coincides with the occurrence of _____ on sphygmogram. 2nd heart sound appears after the end of _____ wave of ECG. The basic cause of the 2nd heart sound is _____.

3. **Pressure** in the ventricles during the interval between the **1st** and **2nd** heart sounds _____, while blood **volume** in ventricles _____; during the interval between the **2nd** and **3rd** heart sounds ventricular **pressure** _____, while blood **volume** in ventricles _____.

Work 21.3. 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 after expiration. The speed of paper movement of the cardiograph is usually 50 mm/sec.

Electrocardiogram and Phonocardiogram (draw it synchronous to ECG)



_____

PCG analysis (of the given phonocardiogram):

1. Presence of sounds: _____ and murmurs:_____.
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 21.4. BASES OF ULTRASOUND EXAMINATION OF THE HEART (ECHOCARDIOGRAPHY) — DEMONSTRATION

Demonstration is performed using the computer program "Heart Sounds".

1. Open: ***Heart Sounds → General Tutorials → Introduction to Cardiac Imaging Modalities → Transthoracic Echocardiogram.*** Video image appears on the screen showing the heart cross-section, the dynamics of heart contraction and respective changes of ventricular cavities volumes and position of the mitral and aortic valves. The left part of the image represents the M-mode of heart ultrasound investigation that shows the dynamics of valve leaflets movements and changes of the interventricular septum thickness during cardiac cycle.

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 (ultrasound) 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 22. REGULATION OF THE CIRCULATION 1 (REGULATION OF THE HEART FUNCTION)

Basic questions:

1. The most important indices of the heart function (HR, SV, and contractility). Cardiac output, blood pressure and organ blood flow dependence on the heart function.
2. Classification of mechanisms of heart function regulation. Intracardial mechanisms of heart function regulation.
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 the effects of neurotransmitters and hormones on the rate and force of heart contractions.
5. Reflex mechanisms of heart regulation. The tone of nervous centers regulating heart function.
6. Characteristics of basic reflex reactions of the heart to the stimulation of vascular and non-vascular reflexogenic zones.
7. Humoral mechanisms of heart regulation: the effects of catecholamines, angiotensine II, electrolytes and metabolites on heart function.
8. Characteristics of heart functioning under physical activity and emotional stress (HR, SV, CO, contractility, coronary blood flow, metabolism).

***Self-check*:**

1. Give the equation that expresses the association of Blood Pressure, Total Peripheral Resistance, and Cardiac Output (or Heart Rate and Stroke Volume of the heart).

2. Under the increase of parasympathetic system activity in what way do the following factors change: K^+ ions outflow from cells, cardiomyocytes excitability, heart rate, duration of PQ and RR intervals, end-systolic volume, heart contractility, cardiac energy expenditures, cardiac output, and BP?

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. myorelaxant d-tubocurarine), antagonists of muscarinic cholinergic receptors (e. g. atropine)?

4. Under the increase of sympathetic system activity in what way do the following factors change: cardiomyocytes adenylate cyclase activity, Ca^{2+} entry to the cell, cardiomyocytes excitability, heart rate, duration of PQ and RR intervals, end-systolic volume, heart contractility, energy expenditures and oxygen consumption by the heart, cardiac output, and BP?

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

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

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

8. Why is reflex 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 does the heart function change under the influence of: significant increase of K^+ ions extracellular concentration; excess of Ca^+ ions in blood; overdose of calcium channels blockers; angiotensine II?

PRACTICAL WORKS

Work 22.1. OCULOCARDIAC REFLEX (DAGNINI–ASCHNER REFLEX)

In norm, when pressure is applied to the eyeballs, the heart rate decreases by 4–10 beats/min as this reflex involves the increased vagal activity.

Accomplishment. Heart 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 heart rate is counted again during 20 seconds.

Results: heart rate (HR) was:

in lying position before pressing _____ beats/min;

during the pressing the eyeballs _____ beats/min;

HR difference is _____ beats/min;

after pressing discontinuation_____ beats/min.

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

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

Conclusion: _____

What HR 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 22.2. 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.

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

Explain the mechanism of an orthostatic change of pulse rate, following the ***successive changes*** of given factors (use arrows ↑or ↓):

Passing to a standing position →

hydrostatic pressure in leg veins _____, veins diameter ____, →
blood pooling in veins _____, venous return _____, →
end-diastolic blood volume _____, heart stretching _____, →
force of the heart contraction ____, stroke volume and blood pressure ____, →
activity of baroreceptors _____, →
afferent input from baroreceptors to vagus nuclei _____, →
activity of efferent vagus fibers to the heart _____, →
final effect of vagus nerve on the heart rate _____.

Work 22.3. 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), Ca^{2+} ions (4) on heart work.

Mechanocardiogram

1 **Acetylcholine**	2 **Adrenaline**
3 **K^+ ions excess**	4 **Ca^{2+} ions excess**

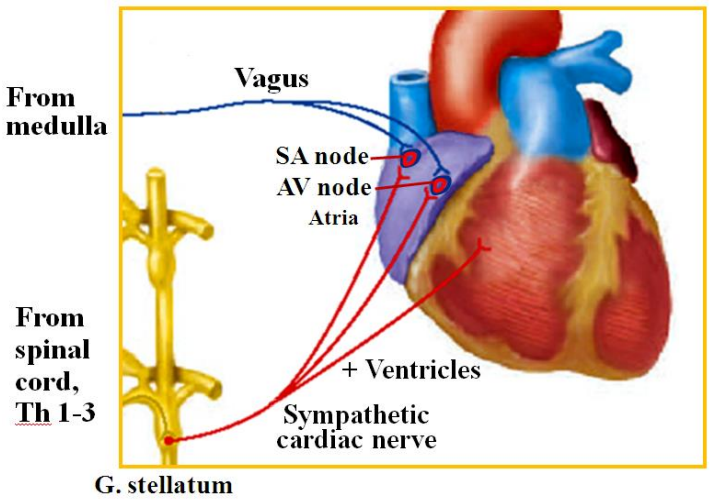
Answer the following questions:

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

2. In what way do the blockers of slow calcium channels act on the velocity of the slow diastolic depolarization 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, end-systolic volume _____, heart contractility _____, cardiac output _____, BP _____, myocardial energy expenditures _____, and oxygen consumption in the heart muscle _____?

Work 22.4. EFFECT OF PARASYMPATHETIC AND SYMPATHETIC PARTS OF THE AUTONOMOUS NERVOUS SYSTEM ON HEART FUNCTION



Using the lecture and textbook materials, 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 parts of the heart _____ _____	5. Predominantly innervated parts of the heart _____ _____
6. Type of the myocardial receptors _____	6. Type of the myocardial receptors _____
7. Intracellular mechanisms of the signal transmission _____ _____	7. Intracellular second messenger of the signal transmission _____ _____
8. Main changes in the cell under receptors stimulation _____ _____ _____	8. Main changes in the cell under receptors stimulation _____ _____ _____
9. Effects on the main indices of the heart function: HR _____; Stroke Volume _____; CO _____; excitability _____; conductivity _____; contractility_____.	9. Effects on the main indices of the heart function: HR _____; Stroke Volume _____; CO _____; excitability _____; conductivity _____; contractility_____.

Lesson 23. REGULATION OF BLOOD CIRCULATION 2 (REGULATION OF THE ARTERIAL BLOOD PRESSURE)

Basic questions:

1. Reflex mechanisms of blood circulation regulation. Vasomotor center, its afferent and efferent connections. Main reflexogenic zones.
2. Short-term reflex mechanisms of BP regulation by modifying the heart function and peripheral resistance.
3. Intermediate and longterm neurohumoral mechanisms of BP regulation. Renin-Angiotensin-Aldosterone System (RAAS). The role of excretory organs in longterm 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. Local mechanisms of circulation regulation. The effect of nervous, metabolic, myogenic mechanisms and factors secreted by endothelium on the tone of smooth muscle cells of vessel walls.
6. Peculiarities of blood circulation and its regulation in coronary, cerebral, pulmonary and renal vessels.
7. 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 does 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 do 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 these effects?
5. What are the stimuli for renin secretion increase? Does renin produce the constriction of vessels itself? What component of RAAS does cause vasoconstriction? List the main effects of RAAS activation.
6. What is the difference between basal vessels tone and their resting tone?
7. In what way does the vascular tone of skeletal muscles, skin, myocardium, and digestive organs vessels change on exercise?
8. In what way does the tone of smooth muscle cells of coronary vessels change when calcium permeability of their plasma membrane decreases?
9. List the vasoconstricting and dilating factors formed by endothelium.
10. What is the myogenic autoregulation mechanism of the kidney blood flow? 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 23.1. ANALYSIS OF RECEPTOR AND ION MECHANISMS OF BLOOD PRESSURE AND HEART FUNCTION REGULATION

Fill in the gaps to compare the peculiarities of innervations and effects of parasympathetic and sympathetic parts of the ANS on vascular tone:

Parasympathetic innervation (only a few exclusions!)	**Sympathetic innervations**
1. Preganglionic fibers neurotransmitter _____	1. Preganglionic fibers neurotransmitter _____
2. Type of receptors on the membrane of postganglionic neuron _____ _____	2. Type of receptors on the membrane of postganglionic neuron _____ _____
3. Postganglionic fibers neurotransmitter _____	3. Postganglionic fibers neurotransmitter _____
4. Innervated vessels _____ _____	4. Innervated vessels _____ _____
5. Type of the receptors of endothelial cells in the vessels wall _____	5. Types of the receptors of smooth muscle cells in the vessels wall 1. _____ 2. _____
6. Intracellular second messenger _____	6. Intracellular second messenger 1. _____ 2. _____
7. Changes in the smooth muscle cell state under stimulation of muscarinic cholinergic receptors of endothelial cells _____	7. Changes in the smooth muscle cell state under stimulation of α adrenoreceptors _____ β adrenoreceptors _____

Effect of some vasoactive substances on BP and heart function

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

Calcium channels blockers (such as nifedipine, verapamil and others) and nitrogen oxide donors (nitroglycerin, isosorbide dinitrate) are widely used in medical practice. This practical work is intended to study the effects of these medicines on the heart function and blood pressure.

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

Conclusion: Ca^{2+} channels blocker nifedipine causes _____ (↑↓) of HR through _____ of the conductive system cells Ca^{2+} channels. BP_{syst}, BP_{diast} and BP_{mean} ____ (↑↓) occurs due to _____ of Ca^{2+} channels of heart muscle cells and smooth muscle cells of vessels. Isosorbide dinitrate (source of NO) produces _____ (↑↓) of BP_{syst}, BP_{diast} and BP_{mean} due to ____(↑↓) of vessels tone.

Fill in the missing parts in the text:

Sources of calcium ions for smooth muscle cell contraction are:

_____

Increase of smooth muscle cells plasma membrane permeability for Ca^{2+} ions results in _____ of the vessels tone, decrease — in _____. Opening of smooth muscle cells endoplasmatic reticulum calcium channels results in _____ of the tone of vessels.

Put down a sequence of intracellular signal transmission in activation of α and β adrenergic receptors of vascular smooth muscle cells:

Noradrenaline+α_1 adrenoreceptor → …

Adrenaline+β_2 adrenoreceptor → …

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

Vasoconstricting substances	Vasodilatating substances

Fill in the table:

Effect of adrenergic receptors activation in vessels of some organ

Vessels of organs	Predominating receptors type	Vascular response
Myocardium Skeletal muscles		
Skin Intestines		

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

Lesson 24. PHYSIOLOGY OF CARDIOVASCULAR SYSTEM (THE CONCLUDING LESSON)

The list of questions for studying

1. Hemodynamics. Circles of blood circulation. Functional classification of vessels.

2. Main factors contributing to the blood flow in vessels.

3. 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.

4. Blood pressure, its types. Blood pressure in different parts of vascular system. Main factors that determine arterial blood pressure (BP) level. Normal values of BP, age-related BP changes.

5. Volume and linear velocities of blood flow in different parts of the vascular system. Factors determining these velocities.

6. Arterial pulse, its origin and main characteristics (rate, rhythmicity, filling, tension and velocity). Sphygmography; sphygmogram analysis. The velocity of pulse wave propagation.

7. Microcirculatory system, its structural and functional characteristics. Mechanisms of transcapillary exchange of fluid and various substances between blood and tissues. Starling's equation. Fluid filtration and reabsorption in capillaries.

8. Mechanisms of lymph formation and outflow. Functions of the lymphatic system. Factors contributing to the predominance of filtration over reabsorption and to the development of interstitial edema.

9. Peculiarities of metabolism and blood supply of the myocardium at rest and at exercise. The coronary blood flow in the myocardium of the right and left ventricles during the systole and diastole.

10. The structure and functions of the heart conducting system. Automaticity of the heart. Action potential of the conducting system cells, its phases and ion mechanisms. The role of the slow diastolic depolarization phase, ion currents during this phase.

11. Physiologic properties of the heart muscle cells. Action potential of cardiomyocytes, its phases and ion mechanisms. Excitation-contraction coupling, the role of Ca^{2+} ions.

12. Temporal relationships of excitation, excitability and contraction of the heart muscle. The role of long absolute refractory period of myocardium. The concept of an extrasystole.

13. Laws of the heart muscle contraction (Frank-Starling and Anrep's laws, "all-or-nothing" law, positive (or Bowditch) staircase). The concept of preload and afterload.

14. Sequence of phases and periods of the cardiac cycle. Functions of atria, ventricles and valves of the heart. The state of valves, blood pressure and blood volumes in heart chambers during the phases of cardiac cycle.

15. Systolic (stroke) volume and minute volume (cardiac output) of blood at rest and at exercise. Indices of myocardial contractility (the ejection fraction and the velocity of pressure increase during isovolumetric contraction).

16. Electrocardiography. Electrocardiographic leads. The origin of ECG components. Order of ECG analysis, basic standards (waves sequence and duration, PQ, QRS intervals duration, ST segment position). Calculation of heart rate using mean duration of RR interval.

17. Heart sounds, their origin. Auscultation and phonocardiography, their diagnostic significance. Polycardiography (synchronous recording of ECG, phonocardiogram and sphygmogram).

18. Classification of mechanisms of the heart function regulation. Intracardial mechanisms of regulation of the heart function.

19. Extracardial mechanisms of heart regulation. Effects of sympathetic and parasympathetic nerves on the heart function. Receptors, ion and molecular mechanisms of autonomic system neurotransmitters and hormones effects on the heart rate and force of heart contractions.

20. Reflex mechanisms of heart regulation. Reflectory changes of the heart function in response to the stimulation of vascular (aortic arch and carotid sinus) and other reflexogenic zones.

21. Humoral mechanisms of heart regulation: the effect of catecholamines, acetylcholine, Ca^{2+} and K^{+} ions and other substances.

22. Reflex mechanisms of blood circulation (blood pressure) regulation. Vasomotor center, its afferent and efferent connections. Main reflexogenic zones. Influence of baro- and chemoreceptors on vasomotor center activity and blood pressure level.

23. Short-term (fast) reflex mechanisms of blood pressure regulation by changing the heart function and peripheral resistance.

24. Long-term mechanisms of blood pressure regulation. Renin-Angiotensin-Aldosterone System (RAAS). The role of kidneys in long-term regulation of the circulating blood volume and blood pressure.

25. Systemic humoral regulation of blood circulation by catecholamines, angiotensin II, vasopressin, natriuretic hormone and other vasoactive substances.

26. 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.

27. Peculiarities of blood circulation and its regulation in coronary, cerebral, pulmonary and renal vessels (effects of pCO_2, pO_2, metabolic factors, O_2 utilization coefficient).

PHYSIOLOGY OF RESPIRATION

Lesson 25. LUNG VENTILATION AND BASIC TYPES OF ITS DISORDER. LUNG VENTILATION INDICES

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. Tiffeneau's test. 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 the lung residual volume and functional residual capacity (FRC), if the total lung capacity is 7 l, 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 surfactant insufficiency?
6. In what way does the pressure in the pleural cavity change in case of 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 Tiffeneau's index and make a conclusion.
8. Make a conclusion on the following indices of lung ventilation:
   Vital Capacity (VC) = 92 %,
   Peak Expiratory Flow (PEF) = 84 % of the norm;
   Maximal Expiratory Flow at 25 % of VC (MEF_{25}) = 93 %,
   MEF_{50} = 81 %,
   MEF_{75} = 62 % of the norm;
   Tiffeneau's test = 63 %.

Table 15

Normal values of respiration indices

VC (Vital Capacity)	men — **4–7** l; women — **3–5** l
TV (Tidal Volume) at rest	300–800 ml (**500 ml** on average)
RR (Respiration Rate) at rest	**9–20** /min (14–15/min on average)
PEF (Peak Expiratory Flow) **$PEF^{due} = 1.25 \times VC$**	men — **5–10** l/s; women — **4–8** l/s
Tiffeneau's test (**FEV1/FVC×100 %**)	**70–85 %**

PRACTICAL WORKS

Work 25.1. SPIROMETRY

Materials and equipment. A water spirometer, disposable or repeatedly sterilized mouth-pieces, masks, connection hoses.

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 due vital capacity (DVC) is its determination using Harris-Benedict tables. On the basis of body mass, height and age the basal metabolic rate due value is taken from the tables. Then it is multiplied be coefficient the following way:

for **men**: $VC^{due} = BMR \times$ **2.6**

for **women**: $VC^{due} = BMR \times$ **2.2**.

Results: VC = _____, VC^{due} = _____ ml.

VC^{due}–VC= _____, that is _____ % of VC.

Evaluate the measured VC comparing it with its due value. The difference between the measured VC and VC^{due} **should not exceed 20 %**.

Conclusion:

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 velocity on VC value (Votchal's test).

Determine VC in the examined, then forced VC (FVC). 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:

Determination of the lung volumes.

The examined must make 5 quiet expirations into the spirometer. To find 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 – TV = _____ (the norm is 55–66 % of VC).

Conclusion (compare the obtained data with the norm):

Work 25.2. SPIROGRAPHY (teaching video)

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

To determine the main respiratory volumes and capacities by spirography, initial quiet respiration of the examined is recorded, then the examined must make a maximal deep inspiration and immediately a maximal expiration — to determine VC. Then quiet breathing is recorded again. For the determination of maximal ventilation of the lungs (MV) per 1 min the examined should make a maximum hyperventilation during 12–15 sec.

Spirogram: indicate TV, IRV, ERV, and VC.

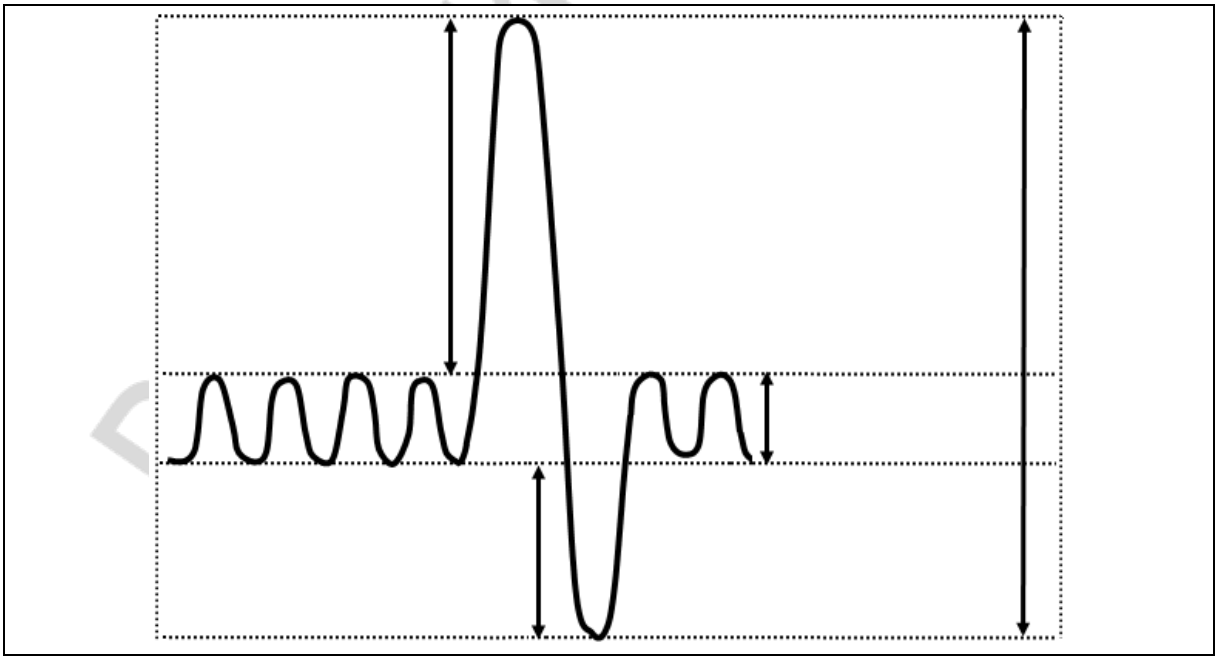


Table 16

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	2100 ml (……%)	55–66 % of VC
5. Expiratory reserve volume	1100 ml (……%)	20–33 % of VC
6. Vital capacity	……	3–7 liters
7. Minute ventilation	……	4–9 l/min
8. Alveolar ventilation	…….	AV = 65–80 % of MV

Conclusion (compare the obtained data with the norm):

Work 25.3. PNEUMOTACHOMETRY (PEAKFLOWMETRY)

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

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

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** (maximal) **Expiratory Flow** (**PEF**) in adults is 4–10 l/sec. To find the due PEF value the following formula is used:

$$\mathbf{PEF^{due} = 1.25 \times VC}$$

The difference between due PEF value and real measured PEF 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. PEF decrease shows the presence of **obstructive** lung type of disturbances. In marked bronchial obstruction PEF is significantly reduced.

Obtained results:

Due Peak Expiratory Flow, PEF^{due} =

Peak Expiratory Flow: PEF =

Peak Inspiratory Flow =

Conclusion (if any signs of obstructive impairments revealed):

Work 25.4. STUDYING OF LUNG VENTILATION INDICES USING COMPUTER SYSTEM CARDIOVIT CS-100

Table 17

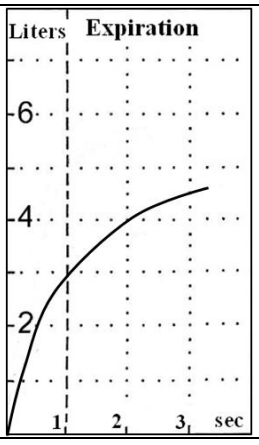
Basic ventilation indices and their abbreviations used in lung ventilation evaluation

Abbreviation	Measurement unit	Full name
VC	Liter, l	Vital Capacity
FVC	l	Forced Vital Capacity
TV	l	Tidal Volume
FEV_1	l	Forced Expiratory Volume for the 1st sec
$FEV_1/FVC \times 100$ %	%	Tiffeneau's test = Tiffeneau's index
PEF	l/sec	Peak Expiratory Flow
MEF:		Maximum (instant) Expiratory Flow
MEF_{25}	l/sec	--//--//-- at the moment of 25 % FVC expiration
MEF_{50}	l/sec	--//--//-- at the moment of 50 % FVC expiration
MEF_{75}	l/sec	--//--//-- at the moment of 75 % FVC expiration
$MEF_{25–75}$	l/sec	Mean Expiration Flow from 25 % to 75 % FVC
$MEF_{75–85}$	l/sec	--//----//----//----//----//-- from 75 % to 85 % FVC
MV	l/min	Minute Ventilation
MVV	l/min	Maximal Ventilation

Accomplishment. When the signal "Ready" appears on the monitor, the examined makes a maximal deep inspiration and then he makes a forced maximal 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.

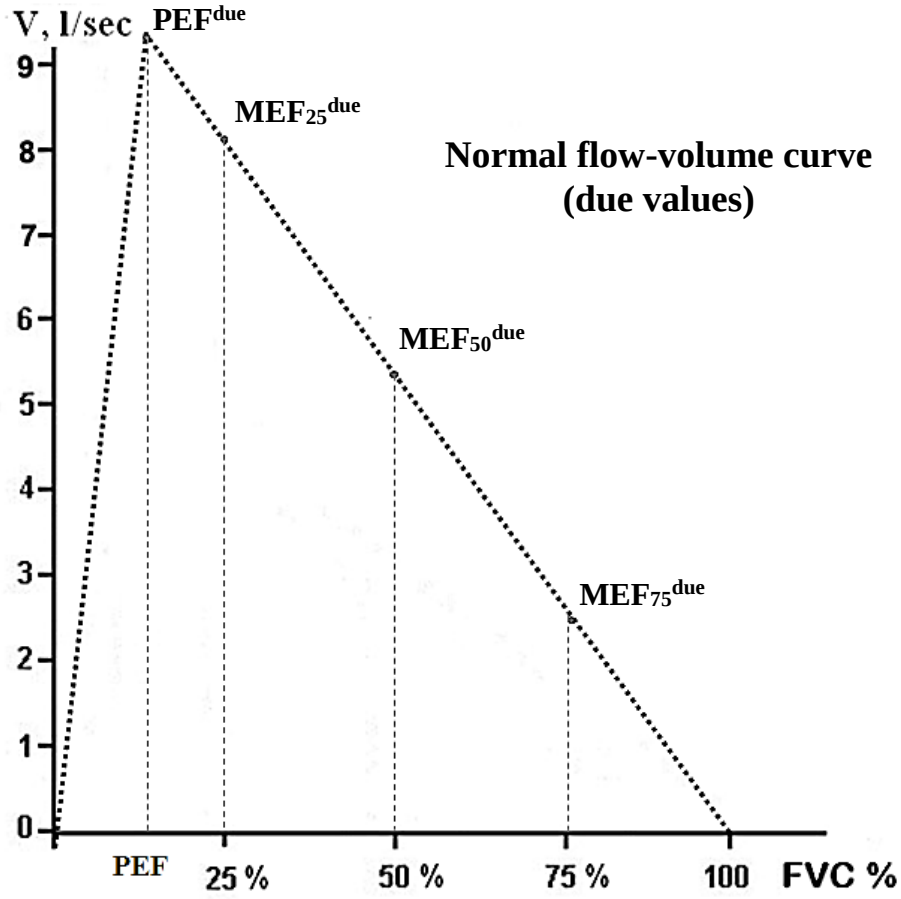
Test results of one of the examined are given for analysis. The missing values are necessary to determine using expiration figure and/or calculate.

Table 18

Indices	Measured values	Due values	% of the norm	
FVC	_____	5.25 l	_____	
FEV_1	_____	4.2 l	_____	
FEV_1/FVC	_____	80 % (70–85 %)	–	
PEF	**7.21 l/sec**	9.47 l/sec	**76**	
MEF_{25}	**4.74 l/sec**	8.21 l/sec	**58**	
MEF_{50}	**1.96 l/sec**	5.27 l/sec	**37**	
MEF_{75}	**0.53 l/sec**	2.03 l/sec	**26**	
$MEF_{25–75}$	1.52 l/sec	4.26 l/sec	36	
$MEF_{75–85}$	0.36 l/sec	1.00 l/sec	36	

On the basis of obtained results (**PEF, MEF_{25}, MEF_{50}**, and **MEF_{75}**) draw the **"flow-volume" curve for the measured values** of expiration flow volume velocity. Take into consideration that at the start and by the end of expiration (100 % FVC) the flow velocity is 0. Use color pencil or pen.

«Flow-volume» curve



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.

Results evaluation:

FVC of the tested person is _____
(within normal limits, increased or decreased)

FEV_1/FVC ration in % (Tiffeneau's test) is _____
(within normal limits, increased or decreased)

PEF makes ____% of the norm, i. e. it is _____
(within normal limits, increased or decreased)

MEF_{25} makes _____ % of the norm, i. e. it is _____
MEF_{50} makes _____ % of the norm, i. e. it is _____
MEF_{75} makes _____ % of the norm, i. e. it is _____
Among indices of MEF the most significant _____ is observed in _____, therefore it testifies for the most significant _____ of _____.

Conclusion:

Lesson 26. 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 the 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 expired 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. Calculate 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 oxyhemoglobin percentage 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. The measured values of P_{50} (pO_2 level at which oxyhemoglobin percentage is 50 %) are 34, 25 and 17 mm Hg. Determine the presence or absence of oxyhemoglobin dissociation curve shifts for each case.
8. 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?
9. 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 130 g/l, oxygen content in venous blood is 8 vol.%.
10. Calculate the cardiac output (minute blood volume) if the O_2 consumption by a man is 250 ml/min, Hb content in the blood is 90 g/l, oxygen content in venous blood is 9 vol.%.

Normal values of gas exchange indices

Diffusion capacity of the lungs for oxygen (at rest)	15–30 ml/min/mm Hg
Partial pressure of oxygen in arterial blood, pO_2	85–100 mm Hg
Partial pressure of CO_2 in arterial blood, pCO_2	35–45 mm Hg
Oxyhemoglobin of arterial blood, HbO_2 %	95–98 %
Oxygen utilization coefficient (mean): at rest	30–40 %
at exercise	50–60 %
Oxygen volume, bound by 1 g of hemoglobin	1.34 ml

PRACTICAL WORKS

Work 26.1. EVALUATION OF ALVEOLAR AND EXPIRED AIR CONTENT. CALCULATION OF FUNCTIONAL DEAD SPACE VOLUME (demonstration of a teaching video)

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:

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

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

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

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 ($\%CO_{2\ ex}$) is determined in the collected expired air.

To determine the content of carbon dioxide in alveolar air ($\%CO_{2\ alv}$) 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 lung ventilation efficiency and abnormal ventilation/perfusion ratio.

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

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

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

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

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

PDS index is used for calculation of ***effective*** alveolar ventilation (AV_{ef}) of the examined: AV_{ef} = MV – (RR × PDS).

Conclusion: (assess PDS value):

Physiological dead space is (give the definition):

Work 26.2. 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.

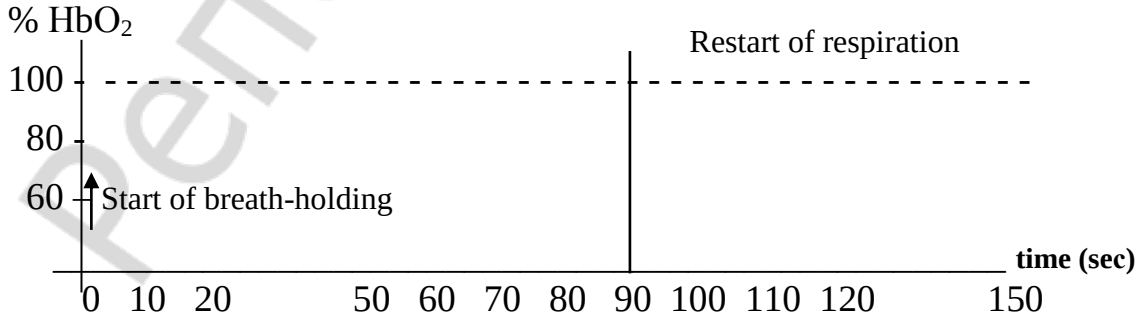
Effect of breath-holding on blood oxygen saturation

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?)

During the breath-holding the oxyhemoglobin blood content (HbO_2 %) _____ with a significant _____ only after _____.
(↑ or ↓, quickly or slowly) (increase or decrease) (indicate time)
Restoration of blood O_2 saturation after the restart of respiration occurs _____.

Work 26.3. MODELING A MISMATCH OF VENTILATION AND BLOOD FLOW IN THE LUNGS, ITS EFFECT ON RESPIRATION AND GAS EXCHANGE

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

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

Factors used in work 26.3:

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

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

SaO_2 — saturation of hemoglobin 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 — physiologic DS/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/perfusion 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 the 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 lobes of the lung. Such situation may occur in marked hypovolemia, in blood loss, pulmonary artery embolism,

etc. Stop the process in 2 minutes (**File**, **Pause**). (The necessary indices are already filled in the table).

Compare the changes of indices caused by hyperventilation and by decreased pulmonary blood flow, observe the similarity and differences.

Table 19

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

Fill in the gaps, using arrows (↑ or ↓) and symbols (= or ≈).

Hyperventilation results in:

PAO_2 _____, PaO_2 _____, $PACO_2$ _____, $PaCO_2$ _____, $PaCO_2$–$PACO_2$ ____, Vd/VT _____, pH _____. SaO_2 _____.

Decrease of pulmonary blood flow results in:

PAO_2 _____, PaO_2 _____, $PACO_2$ _____, $PaCO_2$ _____, $PaCO_2$–$PACO_2$ _____, Vd/VT _____, pH _____. SaO_2 _____.

Fill in the following points:

1. **Hyperventilation** effect on the composition of alveolar air and gases content in the blood:

2. Unfavorable changes that may occur in the organism as a result of excessive ventilation in the lungs:

3. Indices that give most information for revealing a mismatch of ventilation and pulmonary blood flow and help to determine that the decrease of alveolar pCO_2 is caused by hyperventilation and not by decrease of pulmonary blood flow:

Lesson 27. REGULATION OF RESPIRATION

Basic questions:

1. Respiratory center, its parts. Mechanisms providing respiratory periodicity.
2. Central and peripheral receptors for O_2, CO_2 and H^+ ions (pH) 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 the respiratory ways regulation.
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 does the spinal cord rupture between C_1 and C_2 segments produce? between C_8 and Th_1?
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 that flows 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 does respiration change if arterial blood pO_2 is 82 mm Hg, pCO_2 51 mm Hg, and pH 7.30?
5. In what way does pH of the blood change in hyperventilation? In what way does respiration change in alkalosis?
6. What change of respiration (hyper- or hypoventilation) can result in pCO_2 of arterial blood is 25 mm Hg?
7. Where are the central chemoreceptor located and what are the stimulating factors for these receptors?
8. In what way does respiration change under stimulation of j-receptors (juxta-capillary)? What is the stimulus for these receptors?
9. What effect do acetylcholine, histamine and adrenaline produce on respiratory airways?
10. What factors cause pulmonary ventilation increase at exercise?

PRACTICAL WORKS

Work 27.1. TESTING THE STRENGTH OF RESPIRATORY MUSCLES (demonstration of a teaching video)

Evaluation of respiratory muscles strength is important for differential diagnosis of lung ventilation 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 neural pathways 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 imbalance, 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 expiration pressure (MEP)** and **maximum inspiration pressure (MIP)**. The initial position of the thoracic cavity for evaluating muscular strength of an expiration is a maximum inspiration, for evaluating muscular strength on inspiration — a maximum expiration.

Normal values of respiratory muscles strength indices are given in the table 20.

Table 20

Pressure	Men	Women
MEP	**120–230 cm** of water column (12–23 kPa, 85–170 mm Hg)	**80–150 cm** of water column (8–15 kPa, 55–110 mm Hg)
MIP	**40–130 cm** of water column (4–13 kPa, 30–95 mm Hg)	**30–90 cm** of water column (3–9 kPa, 20–65 mm Hg)

Measurement results:

MEP = _____, MIP = _____.

Conclusion:

Evaluate the following results:

The patient VC makes 70 % of the norm, Tiffeneau's index = 70 %, MEP = 40 cm of water column, MIP = 20 cm of water column.

VC is _____

Tiffeneau's index is _____

MEP is _____

MIP is _____

Is it possible to make a conclusion about the presence of restrictive lungs disorder in the patient on the basis of these factors? Why?

Work 27.2. Effect of CO_2 tension increase in alveolar air on external respiration

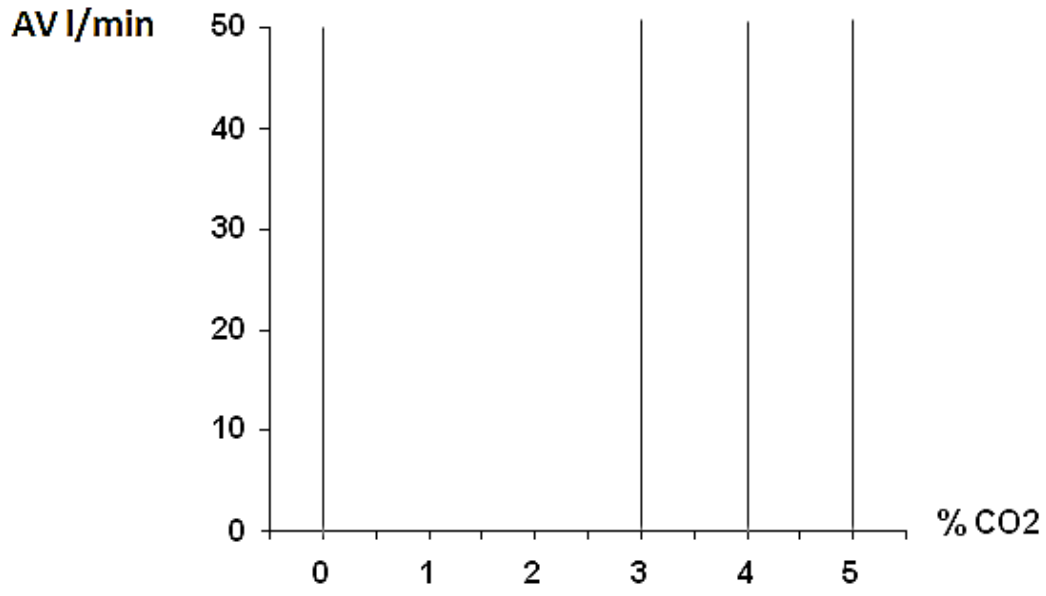
The computer program **PhysioLogy** is used for this work. Full names of the factors were presented in work 26.3, p. 122.

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 21

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 and pH)

Work 27.3. CHEMORECEPTORS AND OTHER RECEPTORS INFLUENCE ON LUNG VENTILATION

Using materials of textbook and lectures fill in a table with description of peripheral and central chemoreceptors.

Kind of receptor	Localization	Factor(s) receptors respond to	Change that increases activity
Peripheral chemoreceptors	1. 2.	1. 2.	
Central chemoreceptors			

Following the pattern present in the first line, assess given values of arterial blood indices and indicate their resulting effect on the lung ventilation (rate and depth of respiration).

Index	Assessment	Effect on lung ventilation
pO_2 124 mm Hg	Hyperoxia	Decrease
pO_2 83 mm Hg		
pCO_2 24 mm Hg		
pO_2 104 mm Hg		
pCO_2 55 mm Hg		
pCO_2 42 mm Hg		
pO_2 77 mm Hg		
pCO_2 63 mm Hg		
pH 7.48		
pH 7.41		
pH 7.32		
pH 7.51		

Fill in a table that describes lung ventilation influence on blood acid-base balance (add corresponding arrows).

Change of lung ventilation	Effect on a level of blood CO_2	Effect on blood H^+ level	Effect on blood pH (name of a type of disorder)
↑V	**CO_2**	**H^+**	**pH ( )**
↓V	**CO_2**	**H^+**	**pH ( )**

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

Lesson 28. TESTING RESERVES OF THE CARDIO-RESPIRATORY SYSTEM

Basic questions:

1. Calculation of functional reserves of lung ventilation for oxygen supply to the lungs in a healthy person.
2. Calculation of oxygen diffusion value in the lungs at rest and at maximal physical 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 %.
7. Calculate O_2 utilization coefficient, if the arterial blood oxygen content is 20 vol.% and venous blood oxygen content is 20 vol.%.
8. Calculate venous blood oxygen content, if the arterial blood oxygen content is 16 vol.% and O_2 utilization coefficient is 25 %.

Normal values of Maximal Oxygen Consumption

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 28.1. TEST OF A 6-MINUTE WALK

The test is based on measurement of maximum distance that the tested person can cover for 6 minutes of intensive walk. The functional blood circulation class (FC) is assessed approximately by table 22.

Table 22

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 28.2. TEST PWC_{170} (BICYCLE ERGOMETRY)

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 **heart rate 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 cardiovascular 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 cardiovascular 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 23). 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 24). 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:

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

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 **700–1100** 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 23

Power of the 1st load (N_1) 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 24

Power of the 2nd load (N_2) 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,

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

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

A complex of devices that permits 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 25 gives data obtained during bicycle ergometer testing.

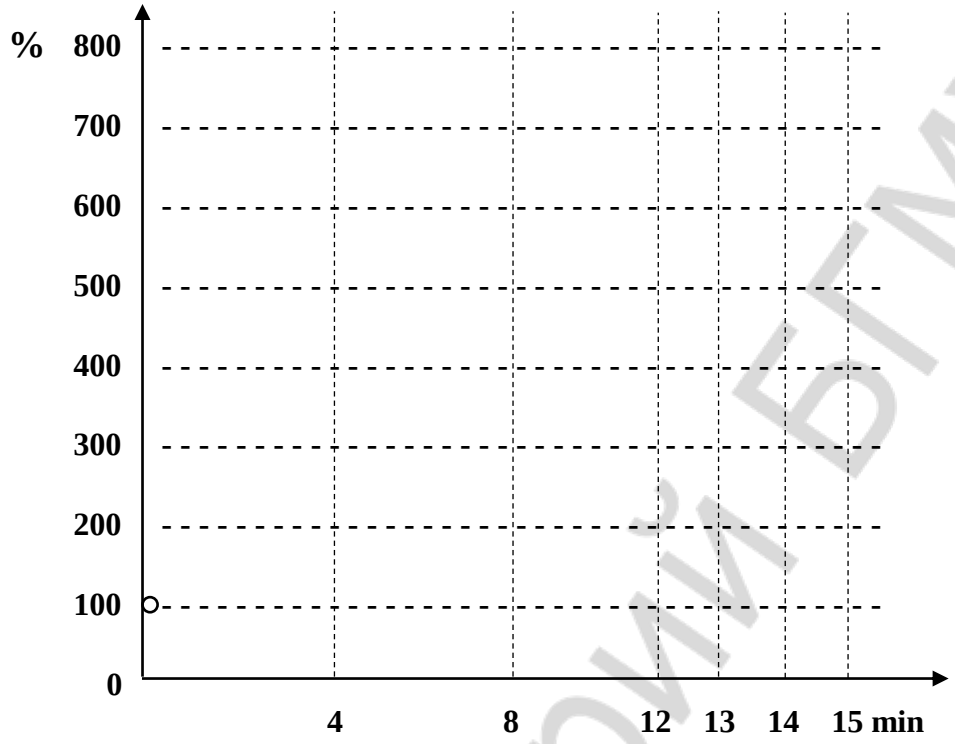
Table 25

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			Time after the load (min)		
		50, 4 min	100, 4 min	150, 4 min	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 dissociation 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 data analysis answer the questions:

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

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

3. Which of the studied factors changes **most** of all on physical exercise? Why it is necessary for physical exercise to change this factor?

Work 28.4. 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, uses moderate physical loads. Using data obtained in that work we'll calculate a number of factors of functional reserves of cardio-respiratory system of the examined.

Evaluation of maximal oxygen pulse

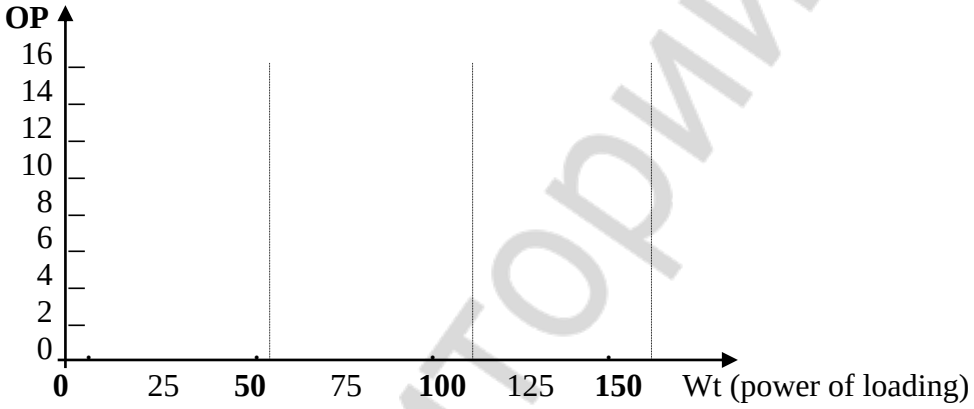
Oxygen pulse (OP) characterizes the oxygen volume consumed from the systolic (stroke) blood volume. It is calculated be the formula:

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

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

Calculate oxygen pulse at exercise and make a graph:

	Before exercise	**1st stage (50 Wt)**	**2nd stage (100 Wt)**	**3rd stage (150 Wt)**
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 (up to the horizontal line), determine the value of ***maximal*** oxygen pulse.

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

Table 26

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 on the maximal 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 = OP^{max} × 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 27

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 28

Functional class of cardio-vascular system by MOC test

Functional class	Consumption of O_2 ml/kg/min	Consumption of O_2 (met)	Working capacity
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 LESSONS ON THE SECTION THEMES ARE PASSED _____

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Lesson 29. PHYSIOLOGY OF RESPIRATION. RESERVES OF THE CARDIO-RESPIRATORY SYSTEM (THE CONCLUDING LESSON)

The list of questions for studying:

1. The main stages of respiration. Functions of respiratory airways and lungs.
2. Nervous and humoral mechanisms of regulation of the respiratory airways.
3. Respiratory muscles. Biomechanics of an inspiration and expiration. Elastic recoil of the lungs and chest wall. Factors creating elastic recoil of the lungs.
4. Intrapleural pressure, its changes during respiration. The reason of negative pressure in intrapleural space. Surfactant, its influence on surface tension and elastic recoil of the lungs, and therefore on intrapleural pressure.
5. Lung volumes and capacities. Spirometry, spirography. Anatomical and physiological dead spaces. Indices of lung ventilation, lung volume (vital capacity); air flow rate indices.
6. Obstructive and restrictive lung disorders, their main causes and influence on lung ventilation. Main indices of obstructive and restrictive lung disorders.
7. Oxygen and carbon dioxide content in atmospheric, expired and alveolar air, pO_2 and pCO_2 of alveolar air and arterial blood. Partial pressures calculation. Relative constancy of alveolar air composition and partial pressure of gases.
8. Gases exchange in the lungs. Factors affecting O_2 and CO_2 diffusion between alveolar air and blood. Diffusion ability of the lungs for oxygen.
9. Inequality of blood flow and ventilation in the lungs due to effect of gravity. Ventilation/perfusion (V/Q) ratio in different zones of the lungs. Blood flow adjustment to the level of ventilation: effect of alveolar pO_2 decrease on the local pulmonary blood flow.
10. Oxygen transport in blood. O_2 capacity of the blood, its calculation using Hb content. Oxyhemoglobin dissociation curve. Factors affecting the affinity of hemoglobin to oxygen (pCO_2; H^+; t; 2,3-DPG). Shifts of the curve to the right and to the left.
11. Carbon dioxide transport in blood. The role of carbonic anhydrase.
12. Gas exchange between the blood and tissues; pO_2 and pCO_2 of venous blood, interstitial fluid and cells.
13. The oxygen utilization quotient of the whole body at rest and at exercise.
14. Respiratory center, its parts and functions. Mechanisms of the respiratory periodicity.

15. Central and peripheral chemoreceptors of H^+ ions, CO_2 and O_2 in the organism. Changes of pO_2, pCO_2 and H^+ ions level resulting in increase of chemoreceptors activity and stimulating the respiratory center. Other factors stimulating the respiratory center of the brainstem. Mechanism of the first inspiration of a newborn.

16. Relationship between lung ventilation and acid-base balance. Influence of pH (H^+ ions) on lung ventilation; influence of ventilation on CO_2 level and therefore blood H^+ ions concentration. The bases of respiratory compensation of acid-base balance metabolic disorders.

17. Receptors of respiratory airways, lungs and respiratory muscles. Reflectory reactions to their stimulation. Hering-Breuer's reflexes.

18. The functional reserves of cardio-respiratory system. Calculation of maximal heart rate and maximal cardiac output. Cardiac output as a limiting factor of cardio-respiratory system reserves in a healthy person.

19. Indices of the heart functional reserves. Coronary blood flow, its maximal level. Oxygen utilization quotient of the heart at rest and at exercise. ECG signs of the heart ischemia.

20. Main indices of gas exchange reserves: maximal oxygen consumption, oxygen debt, threshold of anaerobic exchange.

ENERGY BALANCE AND METABOLISM. THERMOREGULATION

Lesson 30. ENERGY BALANCE AND METABOLISM. THERMOREGULATION

Basic questions:

1. The concept of metabolism in the organism. Characteristic of anabolic and katabolic processes and their correlation at various functional states of the organism.
2. Basal Metabolic Rate, factors that determine its level. Main directions of energy expenditure at the level of basal metabolic rate.
3. Methods of energy expenditure (Basal Metabolic Rate) determination (direct and indirect calorimetry, calculation using tables and formulas).
4. Total metabolic rate, its components. Specific dynamic action of food. Energy expenditure at various levels of working activity.
5. Thermoregulation. Homoiothermal, poikilothermal and heterothermal organisms. Temperature of the human body and its daily range. The core temperature of the body and the shell (skin) temperature.
6. Sources of heat production in the organism. Contractile (shivering) and non-contractile (non-shivering) thermogenesis. Brown fat metabolism. Regulation of heat production.
7. Heat loss of the organism. Heat transfer in the body. Physical and physiologic mechanisms of heat loss. Regulation of heat loss.
8. Thermoreceptors. Thermoregulation center. The concept of "set point" for temperature control. Neural and humoral mechanisms of temperature constancy maintenance in the organism.
9. The concept of hypo- and hyperthermia. Fever and its difference from hyperthermia.

***Self-checks*:**

1. List the standard conditions for basal metabolic rate determination.
2. What is the oxygen caloric equivalent? What substances have the highest oxygen caloric equivalent?
3. Lung ventilation of a person at rest is 5 l/min. The O_2 content in expired air is 16 %. Calculate daily energy expenditures in mixed diet.
4. Will the body temperature of a person change in case of increase of his heat production?
5. What are the mechanisms of a constant body temperature maintaining when heat loss is increased due to the low ambient temperature?
6. What type of heat loss does not require the presence of positive temperature difference between the human skin surface and the environment?
7. What is the difference between physical hyperthermia and fever?

8. Why is high temperature of the environment (30°C) in high humidity tolerated worse than in lower humidity?

9. What is the main way of regulation of heat loss from the skin surface?

PRACTICAL WORKS

Work 30.1. CALCULATION OF DUE VALUES OF BASAL METABOLIC RATE BY TABLES AND FORMULAS

Basal Metabolic Rate means **minimal** energy expenditures necessary for maintaining vital processes of the organism in the **awaken** state. To bring the metabolic rate to its minimal level it is necessary to follow the standard conditions.

Standard conditions that allow excluding additional energy expenditures are the following:

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 emotional **rest, in lying position**;

3) **fasting** state, **no less than 12–16 h after meal** (to exclude its specific dynamic action);

4) thermoneutral conditions (external "**temperature of comfort**", about 22 °C for a person lightly dressed) that doesn't increase body heat production or heat loss.

At the level of basal metabolic rate, energy is spent for renewal of cellular structures, tone of skeletal muscles and contraction of the heart muscle and respiratory muscles, sustaining constant body temperature, functioning of internal organs, etc.

The **due value** of Basal Metabolic Rate (BMR) for a healthy person is easy to calculate by formulas and tables developed by a great number of studies of daily energy expenditures by healthy people of different sex, age, body weight and height. There are many evaluation methods of due Basal Metabolic Rate (due BMR). One of them is calculation by formulas given in table 29.

Table 29

Calculation formulas for human due BMR depending on age, sex and body weight (BW)

Age, years	Due BMR (kcal/24 h)	
	Men	Women
0–3	60.9 × BW – 54	61.0 × BW – 51
3–10	22.7 × BW + 495	22.5 × BW + 499
10–18	17.5 × BW + 651	12.2 × BW + 746
18–40	**1.0 × BW × 24 (formula 1)** **15.5 × BW + 679 (formula 2)**	**0.9 × BW × 24 (formula 1)** **14.7 × BW+ 496 (formula 2)**
40–60	11.6 × BW + 879	8.7 × BW + 829
Over 60	13.5 × BW + 487	10.5 × BW + 596

Method of Harris–Benedict tables for due BMR determination

One of the most widely used methods of evaluating basal metabolic rate is the method using **Harris–Benedict tables** (see **Appendix**, pp. 165–166). 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 weight; and from the second — number B depending on height and age. The sum of these numbers (A+B) gives the value of due BMR.

Dubois's method for due BMR determination

Another widely used method of due BMR evaluation 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 BMR, the value of heat production in kcal/m^2 found in table 30 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 weight and height (see **Appendix**, p. 167).

Table 30

Expenditures for basal metabolism of healthy people depending on age and sex

Age, years	Men, kcal/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

As can be seen from the table, energy expenditures of healthy people per one square meter of the body surface and per hour varies from **36 to 46** kcal (36–46 kcal/m^2·hour) depending of age and sex, is higher in men and declines with age.

The difference between values of due basal metabolic rate determined by different methods does not usually exceed 10 %.

Directions for recording the protocol:

1. Calculate your own due BMR by several methods — by formulas, by tables of Harris-Benedict and by body surface area (Dubois's method).

2. Compare the obtained results. The most precise methods are the method using Harris-Benedict tables and method of Dubois. The results obtained by these two methods usually differ insignificantly (as a rule, no more than by 50–150 kcal).

PROTOCOL

1. Sex _____ (m/f); height _____ cm;
   BW (body weight) = _____ kg; age _____ years.
2. Due BMR = _____ × BW × 24 = _____ kcal/24 hrs;
   (by formula **1** from table 29,
   1.0 × **BW** × **24** for men, or **0.9** × **BW** × **24** for women)
   Due BMR = _____ × BW + _____ = _____ kcal/24 hrs;
   (by formula **2** from table 29,
   15.5 × **BW + 679** for men or **14.7** × **BW + 496** for women)
   Due BMR = A+B = _____ kcal/24 hrs.
   (by **Harris–Benedict** tables)
   Heat production (E) on m^2 per hour (from table 30) = _____ $kcal/m^2 \cdot hour$
   Body surface area (S) by nomogram = _____ m^2,
   Due BMR = $E_{kcal/m^2 \cdot hour} \times S_{м2} \times 24_{\ hour}$ = _____ kcal/24 hrs
   (by **Dubois**)

Work 30.2. MEASUREMENT OF THE METABOLIC RATE USING METHOD OF THE INDIRECT CALORIMETRY BY GAS ANALYSIS

There are two basic ways of metabolic rate measurement, direct and indirect calorimetry. ***Direct calorimetry*** is a direct measurement of the quantity of heat liberated from the body. This amount of energy equals the energy expenditure by the body, as all the energy released by the metabolic processes is finally converted to heat (in case the external work is not performed). To measure the amount of liberated body heat, the person should stay for the certain time in a large, specially constructed heat-insulated chamber. This method is difficult to perform and used mostly for the research purposes.

The other method is ***indirect calorimetry by gas analysis***.

In this method, energy expenditure is determined using the value of **oxygen caloric equivalent** that shows the amount of energy obtained in biological oxidation reactions per 1 liter of O_2 consumed for oxidation. Oxygen caloric equivalent depends on the substrate that is oxidated. Usually the body cells use carbohydrates and/or fats for oxidation. For both fats and carbohydrates, the end products of oxidation are carbon dioxide and water. Carbohydrates possess considerably more oxygen atoms in their molecules than fats; therefore, less oxygen is necessary for their oxidation to the final products. Thus energy yield per one liter of oxygen for carbohydrates oxidation is higher than for fats, regardless to the fact that each gram of fat has caloric value more than 2-fold higher compared to carbohydrates.

The carbohydrates oxygen caloric equivalent value is about 5.05 kcal/l; while fats oxygen caloric equivalent value is 4.69 kcal/l. Usually the body uses

for oxidation both types of the substrates, in various proportions. Therefore, the oxygen caloric equivalent value is usually between its minimal and maximal values.

To determine the exact value of the oxygen caloric equivalent, the ratio of CO_2 produced and O_2 used in biological oxidation reactions is calculated. This ratio is referred to as **respiratory quotient**. The respiratory quotient (RQ) values, similarly to the oxygen caloric equivalent, are minimal for fats and maximal for carbohydrates. The RQ of **fats** is about **0.7**, and of **carbohydrates** is **1.0**. For example, oxidation of one molecule of glucose requires 6 molecules of O_2 and produces 6 molecules of CO_2:

$C_6H_{12}O_6 + \mathbf{6}O_2 \rightarrow \mathbf{6}CO_2 + 6H_2O$ Therefore, RQ = 6 CO_2/6 O_2 = 1.00

Fats require more oxygen for oxidation, so their RQ is less. As for proteins, usually they are not used for oxidation; in case of proteins oxidation the respiratory quotient is 0.8.

Thus, respiratory quotient increases in parallel with the oxygen caloric equivalent, from fats to carbohydrates, so that it is possible to use a respiratory quotient value to find the oxygen caloric equivalent by calculation or simply from the tables where these calculations results are already given:

Table 31

Respiratory quotients and corresponding values of oxygen caloric equivalents

Respiratory quotient	**0.70**	0.75	0.80	**0.85**	0.90	0.95	**1.00**
Oxygen caloric equivalent, kcal/L	**4,686**	4,739	4,801	**4,862**	4,924	4,985	**5,057**

As can be seen from the table, to find the oxygen caloric equivalent value it is necessary to find the respiratory quotient. Then, the oxygen caloric equivalent value should by multiplied by the amount of oxygen consumed by the body per minute. As a result, energy expenditure is calculated in kilocalories per minute:

E expenditure = O_2 caloric equivalent × O_2 consumption

(kcal/min) (kcal/l O_2) (liters O_2/min)

There are two types of the indirect calorimetry, by complete gas analysis and by incomplete gas analysis.

The method with ***complete gas analysis*** involves measurement of both oxygen consumption and CO_2 production. Then real respiratory quotient is calculated and used to find the oxygen caloric equivalent that is multiplied by oxygen consumption. To measure oxygen consumption and CO_2 production the expiratory air O_2 and CO_2 content is measured (*gas analysis*). Then the difference of O_2 and CO_2 content between inspired (atmospheric) and expired air is determined, using known normal values of the atmospheric air. Also, to find oxygen consumption it is necessary to know the Minute Ventilation (MV) of the lung, in L/min. The air volume used per minute, MV, should be multiplied by the percentage of oxygen used. Resulting value is the O_2 consumption in L/min.

Metabolic rate sample calculation by the method of ***complete gas analysis***

Measured values:

Expired air O_2 content 16.93 %, CO_2 content 4.03 %.

Minute Ventilation of the lungs is 5 L/min.

	Atmospheric air	**Expired air**	**Difference**
O_2 content	20.93 %	16.93 %	
CO_2 content	0.03 %	4.03 %	

Calculation of the oxygen consumption:

O_2 consumption = MV (L/min) × % of O_2 used (consumed)

O_2 consumption = 5 L/min × ____% = _____

Calculation of the respiratory quotient:

RQ = % CO_2 produced : % O_2 consumed

RQ = _____

Using the table 31, determine the value of oxygen caloric equivalent corresponding to the calculated RQ.

Then find the energy expenditure per minute (indicate units):

E expenditure = O_2 caloric equivalent × O_2 consumption

E = _____ × _____ = _____

Amount of energy per minute can be converted into energy expenditure per day (metabolic rate), multiplying by 60 minute per hour and 24 hours per day:

Metabolic Rate = E kcal/min × 60 min × 24 hours

Metabolic Rate = _____ kcal/min × 60 min × 24 hours = _____ kcal/day

When measurements are performed in the standard conditions for the person tested, metabolic rate obtained is a Basal Metabolic Rate.

Metabolic rate calculation by the method of ***incomplete gas analysis***

For the incomplete gas analysis method, only **O_2 content** of the expired air is measured, and oxygen consumption is calculated using Minute Ventilation of the lungs. As for the respiratory quotient, it is considered to be at its mean value for the mixed food nutrition (and therefore oxidation of both carbohydrates and fats equally). This mean value is **0.85**, and it corresponds to the O_2 caloric equivalent value **4.862 kcal/L**. Thus, in this method caloric equivalent value is initially, without any measurements, taken as known constant.

Measured values are the same except for the CO_2 content of the expired air that is not measured.

E expenditure = O_2 caloric equivalent × O_2 consumption

O_2 caloric equivalent is taken as **4.862 kcal/L**.

O_2 consumption has already been calculated (see above).

E = 4.862 kcal/L × _____ = _____

Metabolic Rate = _____ kcal/min × 60 min × 24 hours = _____ kcal/day

The difference between the two methods equals to: _____kcal/day

Work 30.3. MEASUREMENT OF THE AXILLARY TEMPERATURE

The normal body temperature (taken in the armpit) for adults in the state of being awake at rest is temperature from 36 °C to 36.9 °C. During sleep from 3 till 5 a.m. body temperature may reach its minimum values — 35.1–36.0 °C. Thus, the norm of axillary body temperature is 36 ± 0.9 °C (**35.1–36.9 °C**). Temperature 37 °C 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 stop-watch, 70 % solution of alcohol, cotton wool.

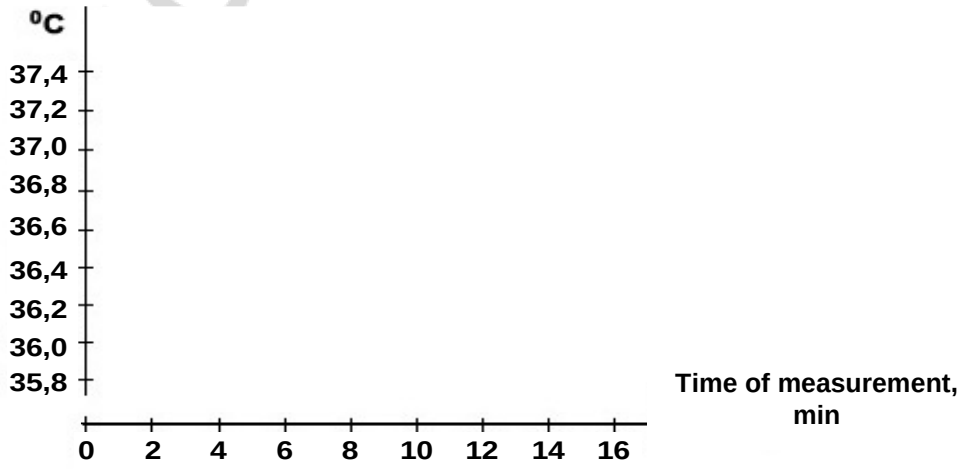
Accomplishment. The skin in the armpit must be dry, because, if the skin is wet, the thermometer shows lower values of temperature due to evaporation of fluid from the surface of mercury reservoir. The examined must keep the thermometer during the whole period of taking temperature tightly clasping the 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 on median-axillary line. 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.

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 30.4. 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 °C) 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.

Conclusion: Heat transfer in the body between tissues and organs is performed by _____.

Therefore in case of an increase of heat production or ambient temperature it is necessary to _____ (↑ or ↓) blood circulation for appropriate heat transfer between body _____ and body _____.

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

PHYSIOLOGY OF DIGESTION

Lesson 31. GENERAL CHARACTERISTICS OF DIGESTION. 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. Mechanisms of gastric juice secretion regulation. Factors stimulating hydrochloric acid and gastric juice secretion.
10. Motor and evacuation functions of the stomach.

***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 true hormones?
4. What consequences may result from prolonged insufficiency of salivation?
5. In what way does 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 do stimulate gastrin secretion in the stomach?
8. Why may non-steroid anti-inflammatory drugs (NSAID) cause lesions of gastric mucosa?

Norms of digestive juices secretion

***Saliva*:**

- Daily secretion — 0.5–2 l.
- Specific gravity — 1.002–1.020.
- pH = 5.6–7.6.

***Gastric juice*:**

- Daily secretion 2–2.5 l.
- Specific gravity of gastric juice— 1.004–1.010.
- Gastric juice secretion on an empty stomach: no more than 50 ml.
- On an empty stomach: total acidity — up to 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.
- pH of pure gastric juice — 1.0–1.8.
- pH of gastric content — 6.0 and more.

PRACTICAL WORKS

Work 31.1. 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 °C).

Materials and equipment: a thermostat or water bath with temperature 37–38 °C, 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 °C; 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 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.

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)		

Conclusion. Starch hydrolysis by saliva occurs due to the presence of the enzyme _____. Saliva boiling or HCl adding result in _____ of this enzyme. Raw starch in contrast to the boiled one _____ by saliva enzymes, therefore vegetable food rich in starch requires _____ processing. Cooling of saliva _____ activity of its enzymes, while restoration of optimal temperature _____ enzymes activity.

Work 31.2. STUDYING ENZYMATIC 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 °C.

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 with the results.

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 + **$NaHCO_3$** solution + fibrin		
4	2 ml of **0.5 % HCl** solution + fibrin		

Conclusion: Proteins hydrolysis by gastric juice occurs due to the presence of both _____ and _____.

Lesson 32. DIGESTION IN SMALL AND LARGE INTESTINE. THE ROLE OF THE PANCREAS AND LIVER FOR DIGESTION. PRINCIPLES OF HEALTHY NUTRITION

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. Liver, its functions. Composition and properties of bile. Bile functions.
4. Regulation mechanisms of bile formation and bile excretion.
5. Digestion in the jejunum and ileum. Composition and properties of intestinal juice, regulation of its secretion. Luminal and parietal digestion.
6. Absorption of products of fats, proteins and carbohydrates hydrolysis in various parts of gastrointestinal tract, its mechanisms. Hydrolysis and absorption coupling.
7. Motor function of small intestine and its regulation.
8. Digestion in large intestine. Motor function of large intestine. The significance of large intestine microflora for the organism.
9. Plastic and energy role of proteins, fats and carbohydrates. Essential substances for the organism. Nitrogen balance.
10. Basic principles of healthy nutrition as a component of healthy life. Principles of compiling diets. Physiological standards of nutrition depending on age, sex, type of working activity and state of the organism.
11. Body mass as an objective factor of income and expenditure balance of energy. Indices for body mass evaluation.

***Self-check*:**

1. In what way does neutralization of acid chyme, coming from the stomach, occur in duodenum?
2. What enzymes of pancreatic juice are secreted in their inactive form?
3. What is the factor activating trypsinogen? Proelastase?
4. What factors do stimulate formation and secretion of bile?
5. What consequences may occur, when bile stops to enter the intestines?
6. Why is evacuation of chyme from the stomach delayed, when fatty food comes from the stomach into duodenum?
7. In what part of the intestines does the absorption of vitamin B_{12} occur?
8. What common transport mechanism is used for absorption of amino acids, glucose, galactose, and bile acids in small intestine?
9. 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.
10. What are the protein minimum and protein optimum and their values?
11. Calculate and assess the body mass index of a man, if his body mass is 86 kg and height is 170 cm.

Norms of digestive juices secretion

Cystic bile (B bile):

- Daily amount — 500–1200 ml
- Specific density — 1.011–1.032
- pH = 5.6–8.0

Hepatic bile (C bile):

- Specific density — 1.008–1.015
- pH = 6.2–8.5

Small intestine juice:

- Daily amount — about 1000 ml
- pH = 5.05–7.07

Large intestine juice:

- Daily amount — 270–1550 ml
- pH = 6.1–731

Pancreatic juice:

- Daily amount — 1500–2500 ml.
- pH = 7.5–8.8

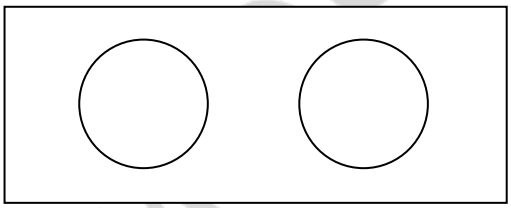
PRACTICAL WORKS

Work 32.1. 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. Draw the distribution of fat in a drop of water and a drop of bile.



Conclusion:

Work 32.2. PARIETAL DIGESTION

Materials and equipment: a piece of rat's small intestine, test-tubes, a stand-holder, glass sticks, threads, water bath, Ringer's solution, Lugol's iodine solution, boiled starch 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 °C, on completion of incubation take the gut out of the test-tube and add one drop of Lugol's solution into both test-tubes.

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

Conclusion:

Work 32.3. 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, Lugol's 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:

Work 32.4. 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 make an appropriate correction to the amount of calories taken with food and modify physical activity level. Insignificant fluctuations of body mass are mainly due to changes of water balance.

Materials and equipment: scales, a height meter.

Accomplishment. Measure 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).

The other **(2)** formulas for calculating DBM:

DBM (for ***men***) = (**height**, cm – **152**) × **1.1** kg/cm + **48**;
DBM (for ***women***) = (**height**, cm – **152**) × **0.9** kg/cm + **48**.

In *asthenic* type of constitution DBM may be decreased by 10 %, in *hypersthenic* constitution — it may be increased by 10 %. After 30 till 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 diet protein-energy insufficiency;
– over 40 % — shows the presence of cachexia (exhaustion).

Body Mass Index (BMI) is calculated by the formula:

$$\mathbf{BMI = BM_{kg}/(height_m)^2.}$$

On the basis of body mass index the risk degree of developing some diseases can be evaluated.

Table 32

BODY MASS INDEX and risk of health impairment

	Hypotrophy(decreased BM)	**Normal BM**	**Increased BM (obesity)**
BMI	<18.5	18.5–25.0	>25.0 (obesity >30)
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

PROTOCOL

Measured body mass (BM) is …….. kg.

DBM_1 =
(by formula 1: height (cm) – **100, or 105, or 110)**

DBM_2 =
(by formula 2: (height, cm – **152**) × **1.1 or 0.9** kg/cm + **48)**

BMI =
(see the formula above)
Conclusion: BM difference from DBM is _____ %.
Thus, Body Mass is _____

THE LESSONS ON THE SECTION THEMES ARE PASSED _____
Teacher's signature

PHYSIOLOGY OF EXCRETION

Lesson 33. PHYSIOLOGY OF EXCRETION

Basic questions:

1. The essence of excretion processes. Excretory organs and 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 morphological and 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. Primary urine composition.
5. Mechanisms of substances reabsorption in various tubules of nephron and collecting ducts.
6. Countercurrent multiplying system and mechanisms of its functioning.
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 capsule hydrostatic pressure is 10 mm Hg, and oncotic blood pressure is 27 mm Hg?
2. In what way the effective filtration pressure does change in case of hypoproteinemia?
3. Will the effective filtration pressure decrease when blood pressure of a person decreases from 120/80 mm Hg to 110/70 mm Hg?
4. What are the factors that prevent albumins passage through the filtration membrane in the kidney glomeruli?
5. What is the renal excretion threshold and what substances are referred to as threshold ones?
6. In what cases may glucose be found in the final urine of a healthy person and why?
7. 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?
8. What changes in the organism does hypo- and hypersecretion of aldosterone result in?

9. What is the mechanism of water reabsorption in the distal tubules and collecting ducts?

10. What factors do increase release of renin by the cells of juxtaglomerular apparatus of the kidney?

Urine analysis indices in norm

Physical properties:	**Chemical composition:**
Color — straw-yellow	Reaction — pH 4.0–8.0
Transparency — transparent	Protein — not found by routine methods
Density — 1.008–1.025	
Daily volume — 0.5–2.0 l/day	Glucose — not found by routine methods
Day : night diuresis ratio — 3–4 : 1	

Microscopy of the sediment:

Erythrocytes — do not occur, or are single in the preparation;
Leukocytes — do not occur, or are single in the preparation;

PRACTICAL WORKS

Work 33.1. 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 properties (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.

2. Assess the obtained result with the norm.

Test		Norm	Result
1. Leukocytes	WBC	Not found	
2. Nitrates	NIT	Not found	
3. Urobilinogen	URO	< 0.2 E.U./dL	
4. Protein	PRO	Not found	
5. pH	PH	4.0–8.0	
6. Occult blood	OB	Not found	
7. Specific density	SD	1.008–1.025	
8. Ketone bodies	KET	Not found	
9. Bilirubin	BIL	Not found	
10. Glucose	GLU	Not found	

Conclusion (compare the results with the norm): _____
_____

Work 33.2. 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. Indicate the changes of the final urine volume and osmolarity:

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 _____
_____

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

Lesson 34. PHYSIOLOGY OF ENERGY BALANCE AND METABOLISM, THERMOREGULATION, DIGESTION AND EXCRETION (THE CONCLUDING LESSON)

The list of questions for studying:

1. General characteristic of nutrition and digestion processes. Nutritional motivations. Physiological mechanisms of hunger and satiety. Appetite.
2. Digestive and non-digestive functions of the digestive system.
3. Peculiarities of functional regulation of the digestive system.
4. Digestion in the oral cavity. Mechanical and chemical food processing. Composition, properties and functions of saliva. Regulation of saliva secretion.
5. Digestion in the stomach. Functions of the stomach. Gastric cells types and their functions. The composition and properties of gastric juice.
6. Functions of hydrochloric acid of gastric juice. Mechanism of gastric HCl secretion. Regulation of HCl secretion. Intrinsic factor. Phases of gastric secretion.
7. Digestion in duodenum. The role of the pancreas in digestion. Composition and properties of pancreatic juice. Pancreatic enzymes, mechanisms of their activation.
8. Regulation of pancreatic juice secretion.
9. The role of liver in digestion. Bile, its main components. Functions of bile. Regulation of bile excretion. Enterohepatic circulation of bile salts.
10. Digestion in the jejunum and ileum. Composition and properties of intestinal juice.
11. Digestion and absorption of nutrients in small intestine. Mechanisms and sites of intestinal absorption of digestion products.
12. Motor function of small intestine and its regulation.
13. Digestion in large intestine. The significance of large intestine microflora for the organism.
14. Energy balance and metabolism. Anabolic and catabolic processes. Plastic and energy role of proteins, fats and carbohydrates.
15. Basal metabolic rate (BMR), its normal level. Main factors which influence BMR. The standard conditions for BMR measurement.
16. Methods of metabolic rate measurement (direct and indirect calorimetry, calculation by tables and formulas).
17. Total metabolic rate, its components. Specific dynamic action of food. Increase of metabolic rate by physical activity. Energy consumption in various kinds of working activity.
18. Body mass as an objective indicator of energy income and expenditure balance. Body mass index.
19. Basic principles of healthy nutrition as a component of healthy life. Compiling diets. Essential nutritional substances.

20. Temperature of the human body. The temperature "core" and the "shell" of the body. Measurement of body temperature. Normal range of core temperature (axillary). Hypo- and hyperthermia. Fever and its reasons; pyrogens.

21. Heat loss of the body. Types of the heat loss and their characteristics. Regulation of heat loss.

22. Sources of heat production in the organism. Contractile and non-contractile thermogenesis. Regulation of heat production.

23. Thermoregulation center. Peripheral and central thermoreceptors. The "set-point" of the temperature control mechanism. Physiological and behavioral mechanisms of body temperature control.

24. The excretory system. The excretory organs: general characteristics of excretion processes in the skin, respiratory system, gastrointestinal tract and kidneys. Excretory and non-excretory functions of kidneys.

25. The structure of a kidney. Nephron as a morphological and functional unit of the kidney. Types of nephrons, their structure and functions. Peculiarities of kidney's blood supply. Basic processes of urine formation.

26. Glomerular filtration. The structure of the glomerular filtration membrane. Net filtration pressure, its calculation. Glomerular filtration rate. The composition of filtrate (primary urine).

27. Reabsorption in proximal tubule of nephron, its mechanisms. The transport maximum and the threshold of excretion (for glucose as an example).

28. Reabsorption in the loop of Henle: countercurrent multiplier system and mechanisms of its functioning.

29. Reabsorption in the distal tubule and collecting duct. Tubular secretion.

30. Regulation of kidney's function by hormones (ADH, aldosterone, atrial natriuretic peptide). Effects of hormones on kidney's function and mechanisms of their action.

31. Regulation of renal blood flow and glomerular filtration rate. The myogenic mechanisms of glomerular blood flow regulation. The tubular-glomerular feedback. Juxtaglomerular apparatus, its role.

32. Mechanisms of regulation of osmotic blood pressure, blood volume and blood pressure by kidney functioning.

INTEGRAL BRAIN ACTIVITY

Lesson 35. 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 neurophysiological 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 classical conditioned reflex?
3. Where the temporary connection is formed in the process of conditioned reflex formation?
4. What kind of inhibition of the formed conditioned reflex is observed, when its reinforcement stops?
5. Give the example of a conditioned reflex inhibition of the type named extinction.
6. What is the difference between conditioned and unconditioned inhibition?
7. What brain structures are most important for memory processes?
8. What is the difference between the mechanisms underlying the processes of short-term and long-term memory?
9. What common features has a sanguine and a phlegmatic person? What features differentiate them from each other (by Pavlov)?
10. What common features has a sanguine and choleric person? What features differentiate them from each other (by Pavlov)?

PRACTICAL WORKS

Work 35.1. 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.). But mistakes may differ from each other. If some words are replaced by other words similar in meaning, and general meaning of word combination is approximately the same, this is a mistake of the word choice, or **simple** mistake. If a word combination is reproduced with entirely different meaning, this is a **sense** mistake. Additionally to the total number of mistakes the sense mistakes (if there are any) should be calculated separately.

Assess the result by the scale:

The assessment of associative (meaningful) memory:

0 mistakes — excellently developed associative memory;
1–3, no sense mistakes — well developed associative memory;
4–6, ≤ 3 sense mistakes — moderately developed associative memory;
7–9, > 5 sense mistakes — low developed associative memory;
10 and more mistakes, among them
> 7 sense mistakes — poorly developed associative memory;

Results: Total number of mistakes — ___, including sense mistakes — __.

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 35.2. 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 (33 and 34) 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 A, E, O) 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 33

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
A E O
E U I A
O U E A Y
E O I A U У
I E U A E O I
U A E У O E A U
A U E O У A E I O
E У A E U O A E I Y

Table 34

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
U A E
I E O Y
E O A U E
O E У E A U
E У A U E I O
A U E У O A E У
U E O A У E U E A
U E U O E У A O E I

Volume of short-term auditory memory:
digits — _____ signs, letters — _____ signs,
Conclusion:

Lesson 36. 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. Aphasia, its main types.

4. Attention and its neurophysiologic mechanisms. The role of attention in processes of perception, learning and memory.

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, and 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) indices differ in the state of wakefulness and sleep in humans?
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 36.1. 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".

Scale

0——1——2——3——4——5——6——7——8——9——10

Always absolutely NO — Always absolutely YES

Point	Score
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 36.2. 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 (300 sec)**.

Instruction for the examined. By a signal you should start looking through attentively every row of table 36 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 accuracy. 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.

TABLE FOR CHECKING OF CORRECTION TEST RESULTS

Table 35 is used to check the number of mistakes in the correction test. The table gives numbers of letters that must be crossed correctly in each line of the standard correction form

Table 35

Line	Letter	Line	Letter	Line	Letter	Line	Letter
1	С, 6	**11**	В, 3	**21**	Л, 5	**31**	Г, 3
2	В, 8	**12**	Е, 4	**22**	О, 3	**32**	А, 7
3	Н, 5	**13**	М, 5	**23**	У, 3	**33**	В, 5
4	Х, 6	**14**	Х, 3	**24**	Б, 3	**34**	Р, 5
5	А, 4	**15**	Н, 5	**25**	М, 3	**35**	Б, 3
6	С, 8	**16**	А, 6	**26**	К, 4	**36**	А, 4
7	У, 4	**17**	Б, 4	**27**	С, 3	**37**	К, 3
8	И, 4	**18**	У, 3	**28**	И, 3	**38**	И, 3
9	Б, 3	**19**	Т, 5	**29**	Х, 2	**39**	Х, 3
10	С, 4	**20**	В, 4	**30**	Е, 2	**40**	Т, 2

Assessment of results

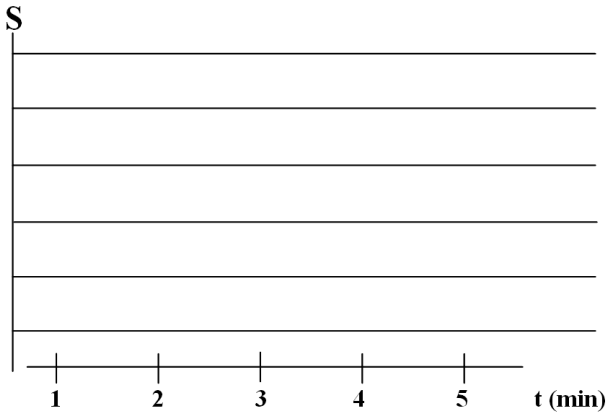
S	Attention productivity and stability
≥ 3.25	very high
2.1–3.25	high
1.6–2.0	medium
1.3–1.5	low
0.0–1.2	very low

PROTOCOL

1st min: N = _____; n= _____; S = _____;
2nd min: N = _____; n= _____; S = _____;
3rd min: N = _____; n= _____; S = _____;
4th min: N = _____; n= _____; S = _____;
5th min: N = _____; n= _____; S = _____;

For 5 min in total — N = _____; n = _____; S = _____.

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 36

Standard letter table for correction test

СХАВСХЕВИХНИСХНВХВКМНАИСЕМВХЕНАИСНПУКСОВ
ВЕНХИВСНАВВСАВСАЕКМАХВКЕОРУМЛПНАВЫВАМПРИ
НХСРОВНВОТКНЛМЧАМОЛТВНЛМИСМГУБВВНСМЛОТЛБ
ХАКИТОНВММБЛЧСХНГХАИХКМИНГСБЧХФИСБЛМОГНХ
АХВСТМОНЕУБСТГАХЫЧНАТНВЛСМНГАХВВЛГМВЕМНМ
СОРНВУЛОНСМСЛНХЧССИОЛКОМГИСМВЛХТСИМНЕПСМ
УХРАОПНИСМИОТУХНГВЛБЯШГВИМТСНУХЛОГНЦСИМУ
ИКНГАЕПВОРСМИТУХЫЖБСИНУХТЯДЛАНТСИМХВУМОЛ
БВАПМИСРОКНЕОЛЭТФОЕУБВОАЖМБНАОПМЮЭХЦШАМ
СИТНЫДАОРЕГСМИТАНЦХЭОАЛСЬМАЫЖЧТСНМКЕАВЭХ
ВАПУЕКАЧМСИТВДЛМТИНФЭЧБГГКПБЯЕХЮЩАНСМВАТ
ЕКНМСИТВДЮБСЕГОВЧБЯЕХЮТГМИОУЕАВСБЮЫХЦТМА
МНГАЕЛИЬЮМПВЕХФЛУЕАСМОЛВГОИБЧСМКЕНГОВМАЕ
ХВАМСИРНКЕГОМЛЭЮБСМИХВАНЕГЛХУЫМСОЛЭТЕТМГ
НГМИТГОЛХИНАПМТИНГОЛЭСВАИНРХВАЛЭЮМИНЕРПМ
АПРВМИСНКМГОАМИВТХИНВЕАПРОЛАИСЕНВХАЭВММА
БВМИЕНКЛОВМАБХМКЕНГИТМАБЛОМНГЕОЭЛАВТММБМ
УИМЕВАРПОТИМТИГОХЮБТИСМУЛОАНЕГИАУФВАСМИА
ТНГОРАМИСПАРВЭМТСАШНКТОВМНГАРМИСТЭХВМИМТ
ВАПНСИМОЛХЭВТОЕНГАМИСВДЛАРПНМГМИТСЮБВАХЭ
ЛНХЧССИОЛКОДЛМТИНБТИСМУЛПРОИСМЕАЛОВБИТЮМ
ОРЕГСМИТАМКМАХВКЕОРУМФЭЧБГГКОРМГСММИИРША
УКЕНАПМСИРВШОРОАПМУЕКНГТСОЭВКЕНВУАЕПИСФМ
БЯЕХЮСМВПАЕВКБЛВРАНГЕИМТБДЮАПОРАОШУОВЛФЕ
МТОНАПСМИВПРАОЭХШКНЕВАСМИФАВКЕНСИАРЕОТИВ
КХАПРСМИТОВПНАКМГОДЛАТСИВПАМКЕГНХЛОЫВАПК
СМММИВПАЕАНКГАРОАИПТСМСВПАЕНУГКНРИМИМЕАТ
ИТОСМШВАЕАУКГНВДЛАОПЭБТСИМПВАМБЛЧСМИВАЭХ
ХВАПРСМИТСФШВХАПКЕНУИТСОЛЭВАТИСРЕВШЛАОЭМ
ЕНГАРПСМИВАПРОИТИСМПВАЕУХЭДВАПРСШМИАПКНВ
ГОВРПАШКНСИТВОГАЭШДАРСМИВАКМНЦГСИТЛВОАРО
АБСРПВАМКЕНГМТИБЛВЭСИВАЕНВЛОАРШАМИАХУФАП
ВОЛСМИАПНШУХЭВТСИАПАМНЕВРЛЕЧСАВКАИСМРАЕВ
РОВНВШТЛМТИРОТИМРШНЭХВАПСРТИМКМПВГКНЕПРА
БВАЕКУМИЦФЭЕАПРСИМХБВАЛОКЕНГМИБЭЛАЮВСМИЕ
АУКШНМИСМАВОРИТБЭВОРАМНКГЛОМИСТЦЯХЭЛАОРС
КНАЕВПСМИМРЛЭЯБСМИКШВПОЛЭХУНВЕКПРВСМИТОР
ИМАКЕНВАЭОЛМТИСПЕАНВШГФХВПАРУЛОСИМТРОАХЕ
ХКЕНИСМПВАМЧСИТВАРПОЛХГНКЕЭФЫВУКЕСИМАПХА
ТОРВМСИПЕУКНВГЛОЭХФЦУЕМСИТМОАРПНЕКХНКШАГ

THE LESSONS ON THE SECTION THEMES ARE PASSED _____

Teacher's signature

Harris–Benedict tables (men)

Table A

KG	KCAL	KG	KCAL	KG	KCAL
3	107	40	617	77	1125
4	121	41	630	78	1139
5	135	42	644	79	1153
6	148	43	658	80	1167
7	162	44	672	81	1180
8	176	45	685	82	1194
9	190	46	699	83	1208
10	203	47	713	84	1222
11	217	48	727	85	1235
12	231	49	740	86	1249
13	245	50	754	87	1253
14	258	51	768	88	1277
15	272	52	782	89	1290
16	286	53	795	90	1304
17	300	54	809	91	1318
18	313	55	823	92	1332
19	327	56	837	93	1345
20	341	57	850	94	1359
21	355	58	864	95	1370
22	368	59	878	96	1387
23	382	60	892	97	1406
24	396	61	905	98	1414
25	410	62	919	99	1428
26	424	63	933	100	1442
27	438	64	947	101	1455
28	452	65	960	102	1469
29	465	66	974	103	1483
30	479	67	988	104	1497
31	498	68	1002	105	1510
32	507	69	1015	106	1524
33	520	70	1029	107	1538
34	534	71	1043	108	1552
35	548	72	1057	109	1565
36	562	73	1070	110	1579
37	575	74	1084	111	1593
38	589	75	1098	112	1607
39	603	76	1112	–	–

Table B

	AGE IN YEARS													
Cm	15	17	19	21	23	25	27	29	31	33	35	37	39	41
92	100	–	–	–	–	–	–	–	–	–	–	–	–	–
96	140	113	–	–	–	–	–	–	–	–	–	–	–	–
100	180	153	128	–	–	–	–	–	–	–	–	–	–	–
104	220	193	168	–	–	–	–	–	–	–	–	–	–	–
108	260	233	208	–	–	–	–	–	–	–	–	–	–	–
112	300	273	248	–	–	–	–	–	–	–	–	–	–	–
116	340	313	288	–	–	–	–	–	–	–	–	–	–	–
120	380	353	328	–	–	–	–	–	–	–	–	–	–	–
124	420	393	368	–	–	–	–	–	–	–	–	–	–	–
128	460	433	408	–	–	–	–	–	–	–	–	–	–	–
132	500	473	448	–	–	–	–	–	–	–	–	–	–	–
136	540	513	488	–	–	–	–	–	–	–	–	–	–	–
140	580	553	528	–	–	–	–	–	–	–	–	–	–	–
144	620	593	568	–	–	–	–	–	–	–	–	–	–	–
148	660	663	608	–	–	–	–	–	–	–	–	–	–	–
152	700	673	648	619	605	592	578	565	551	538	524	511	497	484
156	740	713	678	639	625	612	598	585	571	558	544	531	517	504
160	780	743	708	659	645	632	618	605	591	578	564	551	537	524
164	810	773	738	679	665	652	638	625	611	598	584	571	557	544
168	840	803	768	699	685	672	658	645	631	618	604	591	577	564
172	860	823	788	719	705	692	678	665	651	638	624	611	597	584
176	880	843	808	739	725	712	698	685	671	658	644	631	617	604
180	900	863	828	759	745	732	718	705	691	678	664	651	637	624
184	920	883	848	779	765	752	738	725	711	698	684	671	657	644
188	940	903	868	799	785	772	758	745	731	718	704	691	677	664
192	–	923	888	819	805	792	778	765	751	738	724	711	697	684
196	–	–	908	839	825	812	798	785	771	758	744	731	717	704
200	–	–	–	859	845	832	818	805	791	778	764	751	737	724

Harris–Benedict tables (women)

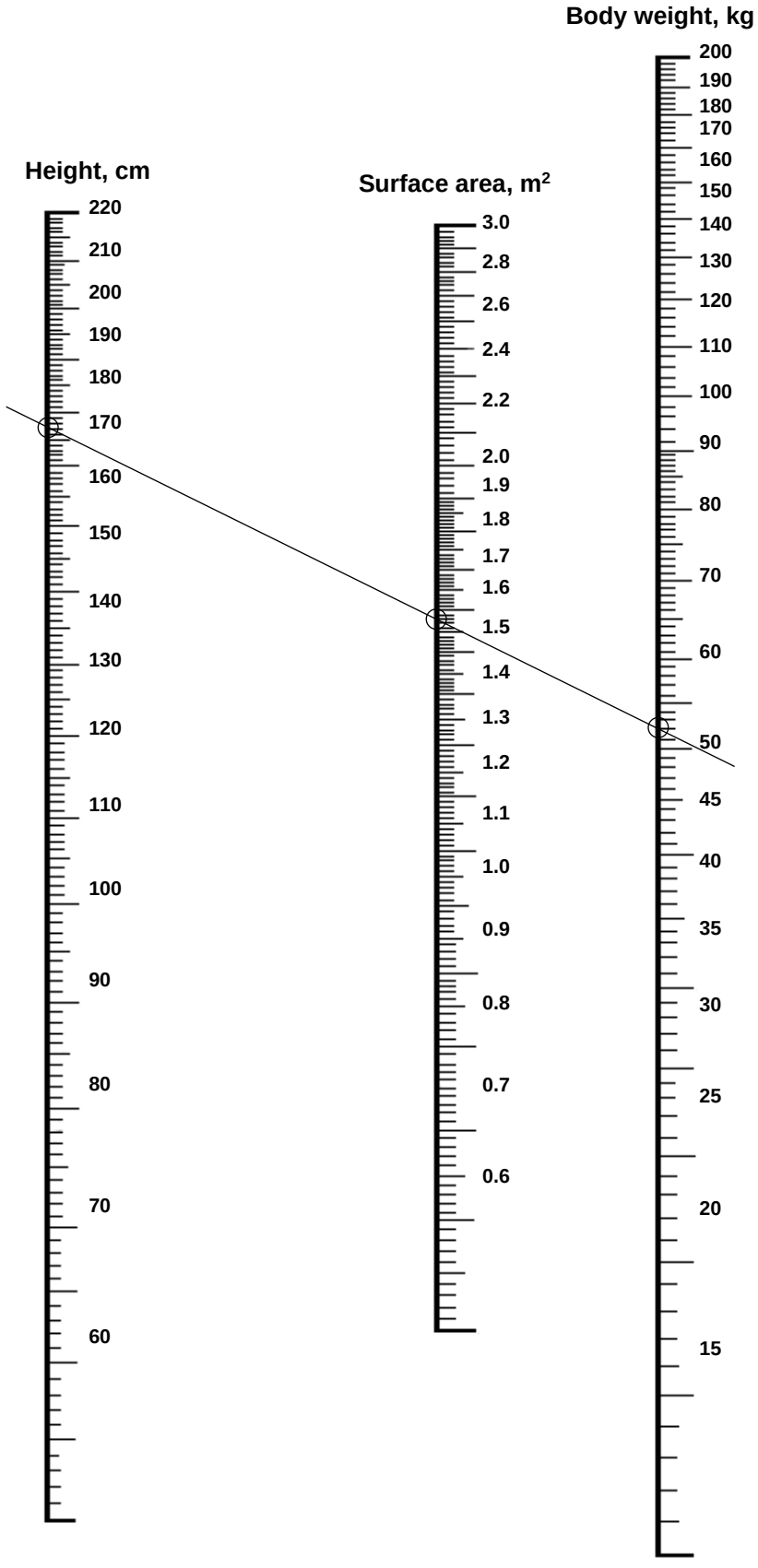
Table A

KG	KCAL	KG	KCAL	KG	KCAL
3	683	41	1047	79	1411
4	693	42	1057	80	1420
5	702	43	1066	81	1430
6	712	44	1076	82	1439
7	721	45	1085	83	1449
8	731	46	1095	84	1458
9	741	47	1105	85	1468
10	751	48	1114	86	1478
11	760	49	1124	87	1487
12	770	50	1133	88	1497
13	779	51	1143	89	1506
14	789	52	1152	90	1516
15	798	53	1162	91	1525
16	808	54	1172	92	1535
17	818	55	1181	93	1544
18	827	56	1190	94	1554
19	837	57	1200	95	1564
20	846	58	1210	96	1573
21	856	59	1219	97	1583
22	865	60	1229	98	1592
23	875	61	1238	99	1602
24	885	62	1248	100	1611
25	894	63	1258	101	1621
26	984	64	1267	102	1631
27	913	65	1277	103	1640
28	923	66	1286	104	1650
29	932	67	1296	105	1650
30	942	68	1305	106	1669
31	952	69	1315	107	1678
32	961	70	1352	108	1688
33	971	71	1334	109	1698
34	980	72	1344	110	1707
35	990	73	1353	111	1717
36	999	74	1363	112	1725
37	1009	75	1372	113	1736
38	1019	76	1382	114	1745
39	1028	77	1391	115	1755
40	1038	78	1401	-	-

Table B

	AGE IN YEARS													
Cm	15	17	19	21	23	25	27	29	31	33	35	37	39	41
88	43	–	–	–	–	–	–	–	–	–	–	–	–	–
92	27	–	–	–	–	–	–	–	–	–	–	–	–	–
96	11	21	–	–	–	–	–	–	–	–	–	–	–	–
100	5	5	14	–	–	–	–	–	–	–	–	–	–	–
104	21	11	2	–	–	–	–	–	–	–	–	–	–	–
108	37	27	18	–	–	–	–	–	–	–	–	–	–	–
112	53	43	34	–	–	–	–	–	–	–	–	–	–	–
116	69	59	50	–	–	–	–	–	–	–	–	–	–	–
120	85	75	66	–	–	–	–	–	–	–	–	–	–	–
124	101	101	82	–	–	–	–	–	–	–	–	–	–	–
128	117	107	98	–	–	–	–	–	–	–	–	–	–	–
132	133	123	114	–	–	–	–	–	–	–	–	–	–	–
136	140	139	130	–	–	–	–	–	–	–	–	–	–	–
140	165	151	146	–	–	–	–	–	–	–	–	–	–	–
144	181	171	162	–	–	–	–	–	–	–	–	–	–	–
148	197	187	178	–	–	–	–	–	–	–	–	–	–	–
152	212	201	192	183	174	165	165	146	136	127	117	108	99	89
156	227	215	206	190	181	172	162	153	144	134	125	116	106	97
160	242	229	220	198	188	179	170	160	151	142	132	123	114	104
164	257	243	234	205	196	186	177	168	158	149	130	121	123	112
168	271	255	246	213	203	194	184	166	156	158	147	138	128	119
172	285	267	253	220	211	201	192	183	173	164	154	145	136	126
176	299	279	270	227	218	209	199	190	181	171	162	153	143	134
180	313	291	282	235	225	216	207	197	188	179	169	160	151	141
184	327	303	294	242	233	223	214	205	195	186	177	167	168	149
188	–	313	304	250	240	231	221	212	203	193	184	175	165	156
192	–	323	314	257	248	230	229	220	210	201	191	182	173	163

NOMOGRAM FOR DETERMINATION OF THE BODY SURFACE AREA



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Северина Татьяна Геннадьевна
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