Ministry of Education and Science of Ukraine
SHEE «Uzhgorod National Univercity»
Medical Faculty №2
Department of Basic Medical Sciences

Feketa V.P., Kivezhdi K.B., Patskun S.V.,
Nemesh M.I., Palamarchuk O.S., Kostenchak O.Y.

Physiology of visceral systems

METHODOLOGICAL DEVELOPMENT
Educational material
for second year medical students
(“Health Care”, 1201 Medicine)

Uzhgorod – 2020

УДК 612 + 591.1
Ф 36

Фізіологія вісцеральних систем. Навчально –методичні матеріали з фізіології для студентів ІІ курсу / Уклад.: Фекета В.П., Ківежді К.Б., Пацкун С.В., Немеш М.І., Паламарчук О.С., Костенчак О.Є.

Навчально-методичні рекомендації з дисципліни «Фізіологія» розраховано на вивчення фізіології іноземними студентами. Мета – подати перелік питань, ключові слова та терміни, питання-відповіді та приклади тестових завдань за системою «Крок 1» для самостійної роботи та засвоєння предмету студентами у процесі підготовки до практичних занять з фізіології.

Укладачі:
Фекета В.П., д.б.н., професор, зав. кафедри фундаментальних медичних дисциплін
Ківежді К.Б., к.б.н. доцент, кафедри фундаментальних медичних дисциплін
Асистенти кафедри: Пацкун С.В., Немеш М.І., Паламарчук О.С., Костенчак О.Є.

Рецензенти:
Горленко О. М., д.м.н., професор кафедри дитячих хвороб медичного факультету ДВНЗ «Ужгородський національний університет»
Ганич Т.М., д.м.н., професор кафедри факультетської терапії медичного факультету ДВНЗ «Ужгородський національний університет»

Затверджено і рекомендовано до друку:
Кафедрою фундаментальних медичних дисциплін (протокол №5 від 21.01.2020)

Contents

Recommended literature

1. Volodymyr Feketa, Marianna Nemesh, Olga Palamarchuk / Human Physiology for doctors - ТОВ «НВП Інтерсервіс», 2019

2. K. Sembulingam, Prema Sembulingam / Essentials of medical physiology 6th edition, 2012

3. John E. Hall / Guyton and Hall Textbook of medical physiology, 2016

4. Phillip Tate / Seeley's principles of anatomy and physiology, 2011

5. Lauralee Sherwood / Human Physiology: From Cells to Systems, 2015

6. Linda S. Constanzo / Physiology, 2017

METHODOLOGICAL DEVELOPMENT №1

Topic: General characteristics of blood. The chemical composition of the plasma.
The number of hours: 2 hours
The object of learning:
To know: blood function, characteristic of organic substances, plasma electrolytes, hematocrit values, homeostasis, homeokinesis.
To be able: to evaluate a blood sample, determine hematocrit index

Theoretical questions for self-preparation

1. Conception of the internal environment.
2. Homeostasis. The notion of norm, constants, homeokinesis.
3. General characteristics of blood. Blood functions.
4. Hematocrit and its clinical evaluation.
5. The chemical composition of plasma. Characteristic of organic substances.
6. The electrolytes of plasma.

Keywords and terms: the internal environment, homeostasis, homeokinesis, hematocrit, notion of norm, constants, normovolemia, hypervolemia, normocythemia, polycythemia, oligocythemia.

APPLICATION №1

Definition of main terms and conceptions:

Internal environment include fluid complex: blood, lymph, intracellular fluid, liquor, pleural and joint fluid.
Blood functions: respiratory, trophic, excretory, thermoregulatory, regulatory, protective.
Blood volume - 6-8% of body weight.
Hematocrit - is the percentage of total blood volume composed of erythrocytes (it ranges from 40% to 54% in men and from 38% to 47% in women). There are arterial, venous and capillary hematocrit, since the volume of erythrocytes is uneven in different parts of the bloodstream. Lowest blood hematocrit is in the arterial blood.
Hematocrit is a relatively rigid homeostatic constant and its long and stable change is possible only in high altitudes, when adaptation to low partial pressure of oxygen enhances erythropoiesis and increases the part of the volume of cellular elements of blood.
An increase in the hematocrit index may be due to an increase in red blood cells (polycythemia, altitude rise, blood transfusion), or a decrease in plasma volume (dehydration). The consequences are: the increase of blood viscosity and the load on the cardiac muscle, the increase of total peripheral resistance of vessels, and a deterioration of the microcirculation.
The decrease in the hematocrit index is due to a decrease in red blood cells (blood loss, anemia), or an increase in plasma volume (infusion of blood substitutes, hydration). Consequences - reduction of the oxygen's transport systems volume, impairment of microcirculation conditions.
The norm is the average value of the parameters of the organism at different levels in practically healthy individuals and the optimal correlation between them.
The norm as the limits of optimal functioning of the living system, is interpreted differently:
1. as an average value, characterizing a set of events, phenomena, processes;
2. as the average value;
3. as a generally accepted rule, a sample.

Physiological norm is a biological optimum of living, the most consistent and effective combination of all life processes in real environmental conditions.

Electrolyte composition of blood is important for maintenance of its osmotic pressure, ABB, functions of cellular elements of blood and vascular wall, activity of enzymes, processes of blood clotting and fibrinolysis. Since blood plasma is constantly exchanged by electrolytes with the cellular microenvironment, the content in it of the electrolytes largely determines the fundamental

properties of cellular elements of the organs - excitability and contractility, secretory activity, permeability of membranes, bioenergetic processes.

APPLICATION №2

Control questions and answers on the topic: "General characteristics of blood. The chemical composition of the plasma."

1. What is the internal environment of an organism?
   A set of liquids (blood, lymph, tissue fluid) that take direct part in metabolic processes and maintain the homeostasis of the organism.
2. What is homeostasis? What biological significance is maintaining the homeostasis of the organism?
   Dynamic constancy of the internal environment of the organism; provides relatively independent changes in the external environment of the organism's existence.
3. What does the blood system concept by Lang include?
   Set of hematopoietic organs, peripheral blood, hemorrhages, neurohumoral apparatus that regulates the system of blood.
4. Name the main features of blood .
   Blood is a liquid tissue, there is no mechanical connection between the blood cells, it is in constant motion, the components of the blood are formed and destroyed outside of it.
5. What amount of blood is in the human body (in liters and in the percentage of body weight)?
   4,5-6,0 liters, which makes about 6-8% of the weight of the body.
6. What two phases form the blood? What is hematocrit? For what purpose and how is it used?
   From plasma and formed elements. Hematocrit is a device that is a glass capillary with 100 divisions. With its help is possible to determine the percentage of plasma and blood elements by centrifugation.
7. What is the index of hematocrit? Specify its normal value.
   Its percentage ratio of formed elements and plasma. The share of formed elements accounts for 40-50% of the blood, the share of plasma - 55-60%.
8. List the main functions of the blood.
   1) transport function (transfer of nutrients, exchange products, gases, water, regulatory substances, heat); 2) protective; 3) maintenance of pH constancy.
9. What is the protective function of blood?
   Protection of the body from infectious agents and toxic substances that enter into the bloodstream.
10. What percentage of water, organic compounds, mineral salts are in blood?
    Water 90-92%, organic substances 7-9%, mineral salts 0,9%.
11. What nitrogenous and non nitrogenous organic substances are in the blood plasma?
    Nitrogenous organic substances: proteins and non-protein nitrogen-containing compounds (amino acids and polypeptides, products of decomposition of proteins and nucleic acids - urea, creatinine, etc.), non nitrogenous organic substances: carbohydrates, lipids (triglycerides, phospholipids, cholesterol).
12. What are the main cations and anions of blood plasma?
    Cations: Na +, K +, Ca2 +, Mg2 +, anions Cl, HCO3-, HPO4-.
13. What is the physiological significance of mineral substances in plasma?
    Participate in maintenance of pH, osmotic pressure, transport of gases in the process of blood clotting
14. How does excess potassium and calcium affect the activity of an isolated heart?
    Excess of potassium reduces cardiac contractions, up to a heart stop in diastole, excessive calcium enhances heart contraction.

Tasks for self-control:

1. Name the main possible causes of change in the hematocrit number.
2. The concept of homeokinesis. Give examples that would indicate the restoration of changed constants in the body.

An ambulance arrives at the scene of an automobile accident, and finds a hemorrhaging, unconscious young woman. Which of the following is a sign of hemorrhagic shock?

1. Low hematocrit *
2. Metabolic alkalosis
3. Dry skin
4. Polyuria
5. Bradycardia

A man weights 80 kg, after long physical activity his circulating blood volume is reduced down to 5,4 l, hematocrit makes up 50%, whole blood protein is 80 g/l. These blood characteristics are determined first of all by:

1. Water loss with sweat *
2. Increased number of erythrocytes
3. Increased protein concentration in plasma
4. Increased circulating of blood volume
5. Increased dieresis

A 65-year-old slightly cyanotic male came to his physician complaining of itch and nose bleeds. A blood test reveals a hematocrit of 62, leading to the diagnosis of polycythemia vera. Treatment includes aspirin to prevent thromboses and periodic phlebotomy to reduce the hematocrit. The reduction of hematocrit is beneficial because of which of the following function?

1. Reduces blood viscosity *
2. Increases arterial oxygen saturation
3. Reduces blood velocity
4. Increases cardiac output

METHODOLOGICAL DEVELOPMENT №2

Topic: Plasma proteins. Physical and chemical properties of blood and plasma.
The number of hours: 2 hours
The object of learning:
To know: the function of plasma proteins, physical and chemical properties of blood and methods for their research.
To be able: to determine the osmotic resistance of erythrocytes, sedimentation rate of erythrocytes (ESR) and evaluate these indicators.

Theoretical questions for self-preparation

1. Characteristics of plasma proteins and their functions.
2. The physiological significance of albumin. Clinical evaluation of ESR
3. Characteristics of globulin, fibrinogen, and their significance.
4. Blood viscosity, colloidal stability of the plasma.
5. Osmotic and oncotic blood pressure.
6. Hemolysis. The osmotic resistance of erythrocytes.
7. The concept of physiological saline and colloid substitutes.

Keywords and terms: hemolysis, osmotic resistance of erythrocytes, osmotic and oncotic blood pressure, physiological saline, colloidal blood substitutes, albumin, alpha-globulin, beta-globulin, gamma-globulin, plasma electrolytes.

APPLICATION №1
Definition of main terms and conception:

Functions of plasma proteins:

1. Reserve amino acids. The plasma contains about 200 grams of protein. If necessary, the cells of the body use it.
2. Transport. The molecules of various substances are binding with specific plasma proteins, in the process of their transporting from the intestine or depot to the place of consumption. Nonspecific transport: plasma proteins bind cations of blood, so they are not diffused through the membranes. Thus, about 2/3 of calcium is nonspecifically bound to plasma proteins, and physiologically active is ionized calcium.
3. Participation in the created colloid-osmotic pressure. The contribution of proteins to total osmotic pressure is minor due to low molecular concentration. But the oncotic pressure that is created by them (most of all by albumins) plays an important role in regulating the distribution of water between plasma and intercellular fluid. The walls of capillaries are relatively permeable for small molecules. Proteins of blood plasma hardly pass through the walls of capillaries and therefore between them and the intercellular fluid creates a concentration gradient of proteins. Decreasing of albumin concentration in plasma (starvation, loss of proteins with urine due to kidney pathology, etc.) leads to water retention in the interstitial space and the development of oncotic edema. Due to this, artificial blood substitutes will have such oncotic and colloid-osmotic pressure as plasma. Polysaccharides (dextran) and polypeptides (gelatin) are often used as colloids in such solutions.
4. Buffer function. It is related to the amphoteric properties of proteins, their ability to bound H + and OH- depending on the pH.
5. Prevention of blood loss. The process of blood clotting involves a chain of reactions in which a number of plasma proteins are involved as enzymes, and ends with the conversion of fibrinogen dissolved in plasma into insoluble fibrin.

Hemolysis is the process, which involves the breakdown of red blood cells (RBCs) and release of hemoglobin. There are osmotic, mechanical, toxic and immune types of hemolysis depending on the cause.

Osmotic resistance of erythrocytes is their stability to hypotonic saline.There is a minimum and maximum osmotic resistance. At concentration of a solution of sodium chloride 0,46% in norm occurs hemolysis by only the least stable red blood cells (minimum resistance). With a decrease in the concentration of sodium chloride solution to 0,33%, the most stable red blood cells (maximum resistance) are destroyed.

Viscosity of the blood is a parameter that characterizes the internal friction of the liquid.If you take the viscosity of water for 1, then the relative medium blood viscosity of the adult will be 3.5-5 units, the plasma - 1.5-1.8. An increase of blood viscosity leads to an increase of the load on the cardiac muscle, and worsening of microcirculation in organs and tissues.

Erythrocytes sedimentation rate (ESR). Normally, men have 1-10 mm/hr, women have 2-15 mm / hr. Of great importance are the charges of the particles contained in the solution.

The qualitative and quantitative changes of protein in plasma are the determining factors on which the ESR depends. An increase in the number of highly fermented proteins (globulins) leads to an increase in ESR, and a decrease in their concentration and an increase in albumin content leads to its decrease.

ESR increases with a significant reduction in the number of erythrocytes (hematocrit), since it reduces the viscosity of blood. With an increase of hematocrit, the opposite reaction is observed. The size of ESR is also influenced by the ratio in plasma of cholesterol and lecithin, the content of bile pigments and bile acids, pH, the amount of hemoglobin, the properties of red blood cells. The

use of medicinal products can also lead to an increase in ESR (e.g., glucocorticoids, estrogens, aspirin)

APPLICATION №2

Control questions and answers on the topic: "Plasma proteins. Physical and chemical properties of blood and plasma."

1. List the main functions of plasma proteins.
   They hold the water in the blood stream, participate in the maintenance of blood pH, impact to blood viscosity, participate in the processes of immunity, blood clotting, provide transport to various substances.
2. Where are plasma proteins formed?
   They are formed in the liver; but globulins are also formed in the bone marrow, spleen, lymph nodes.
3. What are the main groups of biologically active substances in blood plasma?
   Hormones, enzymes, vitamins, prostaglandins, oligopeptides, metabolites (eg, CO2).
4. What properties should blood substitute solutions have? Give examples of solutions of blood substitutes.
   Osmotic pressure (isotonicity), number of ions, reaction (pH) and oncotic pressure should be the same as in blood plasma. Plasma, geelpone, polyoxidine, perfluorane, reforthane, gelatinol.
5. What solution is called physiological? How will the condition of the tissue and the work of the internal organs change when a large amount of physiological solution is used as a blood substitute? Why?
   0.9% solution of sodium chloride. Swelling of tissues is developing due to increased blood pressure and decreased oncotic pressure of blood plasma (including increased filtration pressure in capillaries); the activity of internal organs is broken due to the violation of the ratio of ions in the blood.
6. List the physical and chemical constants of blood.

Proportion, viscosity, pH, osmotic pressure, oncotic pressure, ESR.

7. What is the viscosity of whole blood and plasma ?
   The viscosity of whole blood is 3,5-5 units relative to distilled water, the viscosity of which is taken per unit, the plasma viscosity is 1.5-1.8 units.
8. What factors affect blood viscosity?
   Corpuscular elements of blood (especially the number of erythrocytes, their shape and elasticity), qualitative and quantit ative composition of proteins, blood temperature, blood flow velocity, vascular diameter.
9. How does the viscosity of blood vary, depending on the diameter of blood vessels and on the rate of blood flow?
   In vessels with a diameter of less than 150 μm, blood viscosity decreases in proportion to the decrease of the radius of the vessel. With increasing blood flow blood viscosity decreases.
10. What is the ESR in men and women?
    Men – 1-10 mm/h, women – 2-15 mm/h.
11. What Is Osmotic Pressure? What is the osmotic pressure of blood plasma?
    The force that provides the movement of the solvent through a semi permeable membrane separating the solutions with different concentrations of substances. The total concentration of different particles of blood plasma (ions and molecules).
12. What is the physiological value of osmotic blood pressure of the body?
    Provides distribution of water in tissues and moving it between different water body spaces (blood, tissue fluid, intracellular fluid).
13. What is the hemolysis of erythrocytes? What types of hemolysis do you know?

Destruction of red blood cells and the release of their contents in the plasma of blood.There are osmotic, biological, mechanical and chemical types of hemolysis.

14. What is osmotic hemolysis?
    It is hemolysis caused by excess admission of water into the erythrocyte, which is located in hypotonic solution.
15. What is biological hemolysis?
    It is hemolysis, which occurs because of hemolysins of plants and animals (bee venom, vipers), bacterial toxins, natural and immune blood hemolysins.
16. What is mechanical hemolysis?
    It occurs due to the influence of mechanical factors (eg, blood circulation in lung machine, artificial kidneys, shaking of blood vials during transportation).
17. What is oncotic pressure?
    Oncotic pressure – is the part of osmotic pressure, which is created by concentration of plasma proteins. Equals 0.03-0.04 atm (25-30 mmHg).
18. What is the functional significance of oncotic plasma blood pressure? Explain the mechanism.
    It plays an important role in exchanging water between plasma and tissues. The molecules of proteins, due to their large size, do not leave the capillary in the tissue and, in accordance with the law of osmosis, keep water in the bloodstream.
19. List the factors that influence the amount of water filtration from the blood to the tissues.
    Hydrostatic and oncotic pressure of blood and tissue fluid.

Tasks for self-control:

1. Definition of the concept of colloidal plasma stability. Name the indicator that characterizes it.
2. What is an ESR, indicate the normal values for men and women and the factors that affect these indicators.
3. Explain changes in ESR during pregnancy and inflammatory processes.
4. Explain the mechanisms of "hungry edema".

1. A 16 year old boy after illness has diminished function of protein synthesis in liver as a result of vitamin K deficiency. It will cause disturbance of:

A. Blood coagulation *
B. Erythrocyte sedimentation rate
C. Anticoagulant generation
D. Erythro poietin secretion
E. Osmotic blood pressure

2. A 65-year-old smoker develops a squamous cell bronchogenic carcinoma, which metastasizes to the tracheobronchial and parasternal lymph nodes. Flow of fluid through the lymphatic vessels will be decreased if there is an increase in which of the following?

A. Capillary oncotic pressure *
B. Capillary pressure
C. Capillary permeability
D. Interstitial protein concentration
E. Central venous pressure

3. Glomerular filtration rate (GFR) increased by 20% due to prolonged starvation of the person. The most likely cause of filtration changes under this conditions is:

A. Decrease of oncotic pressure of blood plasma *
B. Increase of systemic blood pressure
C. Increase of penetration of the renal filter
D. Increase of filtration coefficient
E. Increase of renal plasma stream

4. After a surgery a 36-year-old woman was given an intravenous injection of concentrated albumin solution. This has induced intensified water movement in the following direction:
A. From the intercellular fluid to the capillaries *
B. From the intercellular fluid to the cells
C. From the cells to the intercellular fluid
D. From the capillaries to the intercellular fluid
E. No changes of water movement will be observed

5. Long-term starvation cure of a patient resulted in diminished ratio of albumin sand globulines in plasma. Which of the following will be the result of these changes?
A. Increase of ESR *
B. Decrease of ESR
C. Increase of hematocrit
D. Decrease of hematocrit
E. Hyper coagulation

6. A concentrated solution of sodium chloride was intravenously injected to an an animal. This caused decreased reabsorption of sodium ions in the renal tubules. It is the result of the following changes of hormonal secretion:
A. Aldosterone reduction *
B. Aldosterone increase
C. Vasopressin reduction
D. Vasopressin increase
E. Reduction of atrial natriuretic factor

7. Examination of a pregnant woman revealed twice as much concentration of fibrinogen in blood plasma. What is the most likely ESR of this woman ?
A. 40-50 mm/h *
B. 10-15 mm/h
C. 2-12 mm/h
D. 5-10 mm/h
E. 0-5 mm/h

METHODOLOGICAL DEVELOPMENT №3

Topic: Functions of erythrocytes. Hemoglobin and its compounds.
The number of hours: 2 hours
The object of learning:
To know: structure, functions of erythrocytes, mechanisms of regulation of erythropoiesis. Types, structure and functions of hemoglobin.
To be able to: evaluate the indicators of red blood, explain the role of erythrocytes in the adaptive reactions of the organism, know the method of counting red blood cells, determine the amount of hemoglobin by colorimetric method and to calculate the color index.

Theoretical questions for self-preparation

1. General characteristics of erythrocytes.
2. Functions of hemoglobin.
3. Erythropoiesis and its regulation.
4. The concept of anemia. Causes of anemia.
5. Color index.

Key words and terms: erythropoiesis, erythropoietins, erythroblast, normoblast, megaloblast, megalocyte, color index, vitamin B12, folic acid, anemia, hemoglobin, oxyhemoglobin, carbhemoglobin, methemoglobin, hemoglobintype A, F, oxygenhemoglobin capacity, curve dissociation of oxyhemoglobin, transferrin, ferritin, hemosiderin, hydrochloricacidhematin.

APPLICATION №1
Definition of main terms and conception:

General characteristics of erythrocytes.

Erythrocyte is a great example of a highly specialized cell. Its specialization is transportation of respiratory gases by the blood. All the morphological features of erythrocytes and its metabolic substances are subordinated to this function. Erythrocytes are flexible, biconcave, anucleated cells. The diameter of the erythrocyte is about 7,5μm. The mature erythrocyte doesn`t have nucleus, most organelles, in particular - mitochondria. Therefore, it receives the energy necessary to maintain its livelihood through anaerobic glycolysis. Glucose is also oxidized by pentose pathway, which results in the formation of 2,3-diphosphoglycerate. This substance changes the affinity of hemoglobin to oxygen. The normal range of erythrocytes in peripheral blood is about 4,0-5,0 × 10^{12}/liter in males and 3,7-4,7 × 10^{12}/liter in females.

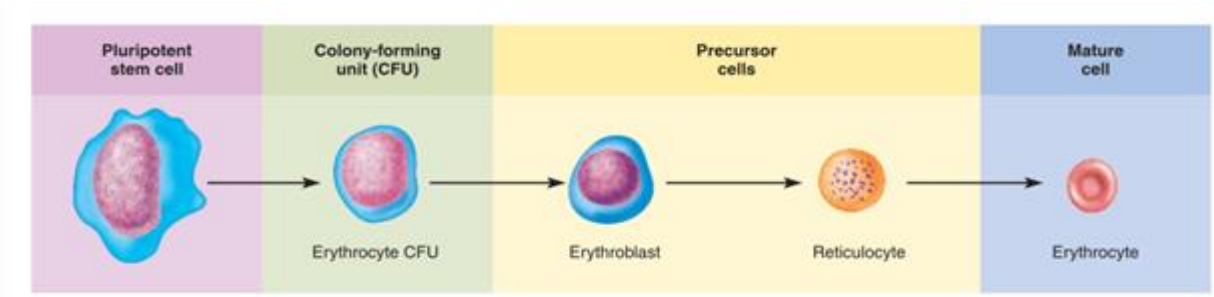
Hemoglobin functions.

Complex protein hemoglobin constitutes almost 90% of the dry mass of the erythrocyte. Its molecular weight is about 60,000 daltons. Each molecule of hemoglobin is formed by a protein part – globin and a nonprotein part, consisted from 4 subunits, each of which are represented by heme (iron-containing porphyrin derivates). The protein part consists of two alpha- and two beta-polypeptidechains. Hemoglobin with a such structure is called type A hemoglobin. Fetal blood contains mainly type F hemoglobin (F - means fetus). The protein part of type F-hemoglobin is represented by two alpha - and two gamma-polypeptide chains. The average range of hemoglobin in healthy men is about of 130-160 g/l and in healthy women – 120-150 g/l.

Oxygen capacity of hemoglobin– the maximum volume of oxygen, which 1 g of hemoglobin can bind. (1,34 ml of O2 per 1 g of hemoglobin). The compound of oxygen with hemoglobin is called oxyhemoglobin. The protein part of hemoglobin has the ability to bind carbon dioxide inside the working tissues, forming a carbhemoglobin. Carboxyhemoglobin is a compound of hemoglobin with carbon monoxide (CO) and it is formed in case of poisoning by CO. Methemoglobin is formed by the influence of strong oxidants (such as potassium permanganate, cyanides, etc.), which chemically transfer iron from two-valence state to trivalent.

Erythropoiesis and its regulation.

Erythropoiesis is the process of red blood cells formation in the red bone marrow. The polypotent steam cell is the precursor of erythrocytes and it turns into erythrocyte through a series of stages lasting 3-5 days.



Erythropoiesis is controlled by the renal hormone erythropoietin.
Vitamin B12 and folic acid (vitamin B9) take an active part in the dividing and maturing of the erythrocyte precursor cells. If there is a deficiency of these substances in the body, giant nuclear slow maturated cells – megaloblasts are formed instead of normal erythrocytes. Anemia, which occurs in this case, is called pernicious anemia (malignant). Erythropoiesis requires daily delivery of about 25 mg iron into the bone marrow. Almost all this amount of the iron is coming into the red bone marrow for reuse after the destroying of erythrocytes in the spleen and the reticuloendothelial system. Only about 1 mg of iron per day is absorbed in the small intestine, which replaces its loss with urine, feces, and menstrual blood.
The typical duration of the erythrocyte life is on average of 120 days. Particularly, intensive removal of aged red blood cells occurs when blood flows through the microcirculatory vessels of the spleen. Heme is converted into a pigment of biliverdine, and then - into a pigment bilirubin by macrophage enzymes. Bilirubin, as a part of bile, moves into the intestine, where microflora convert it into urobilinogen, which gives the characteristic brown color to the feces. A part of bilirubin is converted into urobilin (urochrome), which causes a yellow color of urine.

Anemia
Decrease in number of erythrocytes is called anemia and can be caused by a variety of causes. Normal range of reticulocytes in peripheral blood ranges from 0,5 to 1,5%. Reticulocytes are the precursor of mature erythrocytes, which have received their name due to the special cell structures constructed by clusters of ribosomes. An increase in the content of reticulocytes may be associated with an accelerated erythropoiesis after bleeding or, with pathological reasons (for example, bone marrow tumors).

APPLICATION №2

Calculation of the Color Index.
The color index (CP) reproduces the relative content of hemoglobin in erythrocytes. The normal range is 0.85 - 1.05.Its increase or decrease indicates a violation of the saturation of red blood cells by hemoglobin and has some diagnostic value. To calculate this indicator you need to know the number of red blood cells and the amount of hemoglobin. CP is calculated by the formula:
KP = (number of Hb (g / l) x 3) divided by the first three digits of the number of red blood cells.
For example, if the amount of hemoglobin is 150 g / l, red blood cells - 4500000, then KP = (150 x 3)/ 450 = 1.

Tasks for self-control:

1. Examination of a 43 y.o. anephric patient revealed anemia symptoms. What is the cause of these symptoms?

A. Reduced synthesis of erythropoietin *
B. Enhanced destruction of erythrocytes
C. Iron deficit
D. Vitamin B12 deficit
E. Folic acid deficit

2. A man weighs 80 kg, after long physical activity his circulating blood volume is reduced down to 5,4 l, hematocrit makes up 50%, whole blood protein is 80 g/l. These blood characteristics are determined first of all by:
   A. Water loss with sweat *
   B. Increased number of erythrocytes
   C. Increased protein concentration in plasm
   D. Increased circulating blood volume
   E. Increased dieresis

3. A 42-year-old patient was prescribed primaquine in order to prevent long-term effects of 4-day malaria. On the 3-rd day from the begining of treatment stomach and heart pains, dyspepsia, general cyanosis, hemoglobinuria appeared. What caused the side effects of the treatment?
   A. Genetic insufficiency of glucose 6-phosphate dehydrogenase *
   B. Cumulation of the drug
   C. Decreased activity of microsomal liver enzymes
   D. Delayed urinary excretion of the drug
   E. Drug potentiation by other medicines

4. A patient with incessant hiccups is instructed to breathe into and out of a bag in order to rebreathe exhaled CO2. In which of the following forms is the majority of CO2 transported in the blood?
   A. Bicarbonate *
   B. Dissolved CO2
   C. Carbonic acid
   D. Carbaminohemoglobin
   E. Carboxyhemoglobin

5. An 18-year-old male is presented with symptoms of vitamin B12 deficiency. Further diagnostic tests reveal that he has pernicious anemia. Which of the following is the cause of pernicious anemia?
   A. Malabsorption of vitamin B12 in gastrectomized patients due to removal of intrinsic-factor secreting tissue *
   B. Iron deficiency
   C. Cobalt deficiency
   D. Inadequate dietary intake of cyanocobalamin
   E. Autoimmune destruction of parietal cells in the gastric mucosa

6. An 18-year-old male with pernicious anemia lacks intrinsic factor, which is necessary for the absorption of cyanocobalamin. In which part of the GI tract is Vitamin B12 primarily absorbed?
   A. Ileum *
   B. Stomach
   C. Duodenum
   D. Jejunum
   E. Colon

7. A 23-year-old woman complains of abdominal cramps and bloating that are relieved by defecation. Subsequent clinical evaluation reveals an increased acid output, decreased serum calcium and iron concentrations, and microcytic anemia. Inflammation in which area of the GI tract best explains these symptoms?
   A. Duodenum *
   B. Stomach
   C. Jejunum
   D. Ileum
   E. Colon

8. A 47-year-old woman with hypermenorrhea develops an iron-deficiency anemia requiring iron supplements. Which of the following statements is correct regarding iron digestion and absorption?
   A. Iron is transported in the blood bound to transferine *
   B. About 100 mg of iron is absorbed per day
   C. Iron is absorbed rapidly from the small intestine
   D. In general, iron must be oxidized from the ferrous to the ferric state for efficient absorption
   E. Iron is transported into enterocytes by a ferropoetin transporter on the apical membrane

METHODOLOGICAL DEVELOPMENT №4

Topic: Blood groups and Rh factor.
The number of hours: 2 hours
The object of learning:
To know: the basic blood groups according to the AB0 system and Rh affiliation, blood transfusion rules, complications that can occur during blood transfusion, substitutes.
To be able to: determine the AB0 blood group system and Rh factor.

Theoretical questions for self-preparation

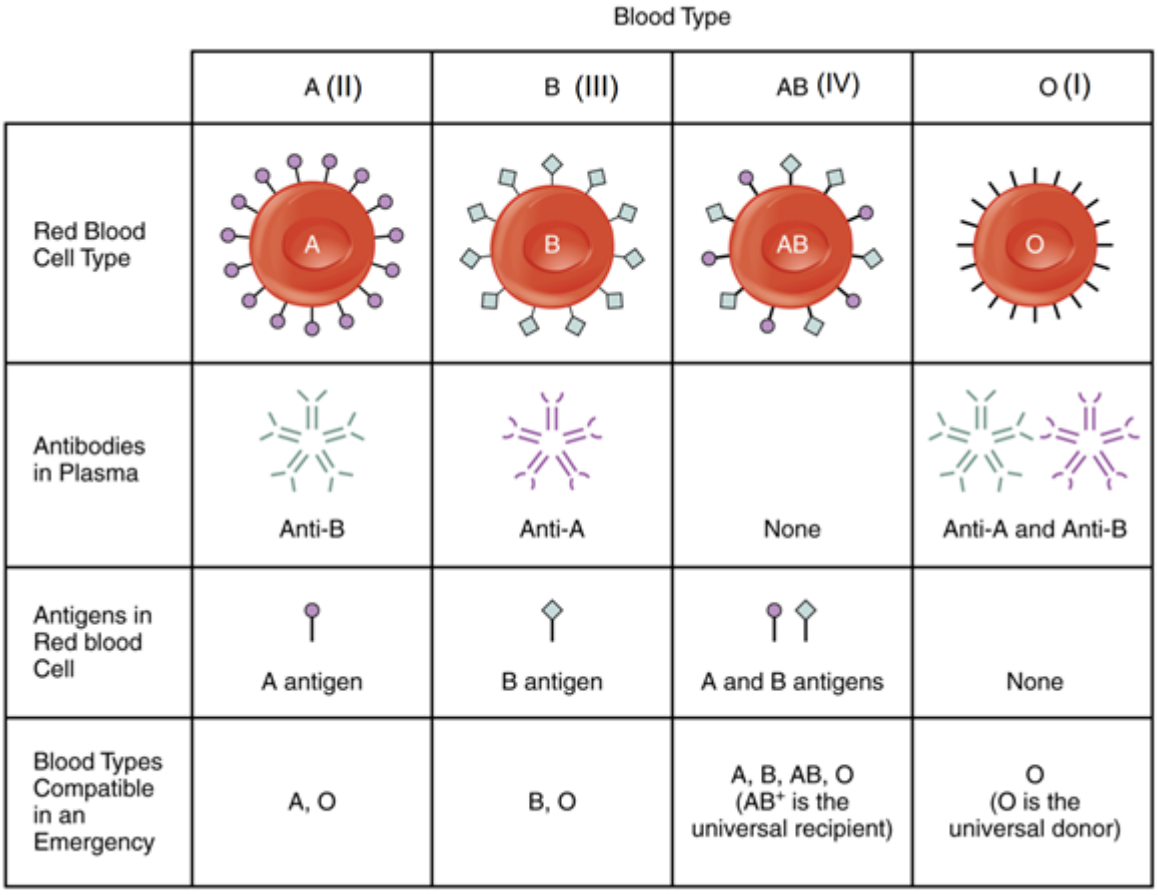
1. Blood groups according to the AB0.
2. Blood groups according to the Rh factor.
3. Methods of determination of blood groups of the AB0 system and Rh factor.
4. Basic rules of blood transfusion. The concept of hemotransfusion shock. Rh conflict and its prevention.

Key words and terms: agglutination, agglutinogens, agglutinins, donor, recipient, standard serum, Rh, Antirhesus serum, Antirhesus antibodies, Rh- conflict.

APPLICATION №1
Definition of main terms and conception:

Blood groups according to the ABO system.
Erythrocytes of each person contain an individual set of specific antigens. Depending on the presence of certain antigens in erythrocytes, blood is classified into groups according to different systems.
The main special feature of this system is that blood plasma of each person contains antibodies to agglutinogens A and B in different combinations. These antibodies are called agglutinins anti-A

and anti-B. The agglutinogens A and B are formed by transformation of the antigen H, which is contained in erythrocytes of group 0.
The system AB0 distinguishes 4 blood groups (Fig.5.10):
• Group I includes red blood cells with agglutinogen H and agglutinins anti-A and anti-B in plasma;
• Group II includes red blood cells with agglutinogen A and agglutinin anti-B in plasma;
• Group III includes red blood cells with agglutinogen B and agglutinin anti-A in plasma;
• Group IV includes red blood cells with agglutinogens A and B; agglutinins are absent in plasma.
In order to exclude the possibility of group conflicts in transfusions, only the same blood group must be transfused. In the case of incompatible blood transfusion into the recipient's body, the immune agglutination reactions of the donor erythrocytes with the agglutinins of the recipient occur.



Blood groups according to the Rh factor.
Depending on the presence of Rh-factor in erythrocytes, the blood is divided into Rh-positive and Rh-negative. Rh-antigen is a complex antigen that includes 3 components, denoted as antigens C, E, D. The most potent antigen, that determines the Rh activity of the blood, is the D-antigen. Erythrocytesof Rh-positive blood contain D-antigen. Accordingly, it is absent in the erythrocytes of Rh-negative blood. Normally, the blood does not contain anti bodies to the D-antigen. If Rh-positive blood enters to the body of the Rh-negative recipient, his immune system begins to produce anti-rhesus antibodies and becomes sensitized to the Rh-factor. Repeated transfusion of such blood to the previous sensitized recipient is very dangerous, because it causes transfusion complications, which are similar to the transfusion of incompatible blood according to AB0 system. A clinically important case is when a pregnant woman is carrying a child with inherited Rh-positive blood from the father. The child could be born with hemolytic disease of the newborn or fetal erythroblastosis. D-prevention is used nowadays in order to prevent this from happening, it is the injection of anti-D-serum to the mother's body.

APPLICATION №2

Determination of blood groups by standard serum.

It is necessary to have standard serums of I, II, III groups and the fourth group, glass plates and glass rods.

A drop of standard serum I, II and III groups is successively put (without mixing) on a glass. The glass rod transmits a small amount of blood to the drop of the serum of the first group, then the second, with a clean end of the sticks transfer the same amount of blood to the serum of the second group. Another glass rod transfers blood to the serum of the third group. Each time, stir blood in a drop of serum to obtain a uniform mixture.

Determination of the blood group is carried out within 5 minutes. In the presence of agglutination, the drop becomes transparent, and red blood cells are glued in the form of seeds. In its absence, the mixture is evenly colored in pink color.

Evaluation of the results of the isohem agglutination reaction:

1. The agglutination is absent when all the mixtures remained uniformly colored in pink, it indicates that the blood belongs to group 0 (1).
2. If agglutination occurs with serums of groups I and III containing respectively agglutinins alpha, beta and alpha, then the erythrocytes of the examined blood contain agglutinogen A, then the blood belongs to group A (II).
3. If agglutination occurred with sera of groups I and II containing agglutinins alpha, beta and beta, this indicates the presence of β-agglutinogen in erythrocytes - blood group B (III).
4. In the presence of agglutination with sera I, II and III, red blood cells contain A and B agglutinogens - the blood group belongs to AB0 (IV).

Determination of the Rh factor.

Put anti-rhesus serum, a drop of gelatin, a drop of blood at the bottom of the tube, using three pipettes. The test tube is placed in a water bath at a temperature of 480 C. After 5 minutes 3 ml of physiological solution are added to the test tube, mixing the contents of the test tube. When considering the tube in the light, determine the presence or absence of agglutination. With a positive result, agglutinates are clearly visible in the form of red grains or flakes on a colorless background of the fluid in the test tube. With a negative result in the test tube uniformly colored pink liquid is visible. If there was agglutination with serum anti-rhesus (D), then the blood is Rh-positive, if agglutination does not occur, the blood Rh-negative.

Tasks for self-control:

1. It was established that agglutination of the recipient's blood erythrocytes had been caused by the standard sera from the I and II groups. Serum from the III group as well as anti-Rh serum hadn't provoked any agglutination. Which blood group and rhesus is allowed to be transfused to this recipient?

A. B, α (III) Rh- *
B. A, β (II) Rh-
C. 0, α,β(I) Rh+
D. AB (IV), Rh+
E. AB (IV), Rh-

2. Testing blood groups according to the the system AB0, standart serum of the I and II groups caused erythrocytes agglutination of the examined blood and serum group of the III didn't. What agglutinogens are in this erythrocytes?

A. B *
B. A
C. A and B
D. C

E. D and C

3. A pregnant woman had her blood group identified. Reaction of erythrocyte agglutination with standard serums of 0α\β(I), Bα(III) groups didn't proceed with standard serum of Aβ(II) group. The blood group under examination is:
   A. Aβ(II) *
   B. 0α\β(I)
   C. Bα(III)
   D. AB (IV)

4. The blood group of a 30 year old man was specified before an operation. His blood is Rh-positive. Reaction of erythrocyte agglutination was absent with standard sera of 0α\β(I), Aβ(II), Bα(III) groups. The blood under examination is of the following group:
   A. 0α\β(I) *
   B. Aβ(II)
   C. Bα(III)
   D. AB (IV)

5. A pregnant woman underwent AB0 blood typing. Red blood cells were agglutinated with standard sera of the I and II blood groups, and were not agglutinated with the III group serum. What is the patient's blood group?
   A. B(III) *
   B. A(II)
   C. 0(I)
   D. AB(IV)

6. When defining blood group according to the AB0 system, using salt solutions of monoclonal antibodies, agglutination didn't occur with any of the solutions. What blood group is it?
   A. 0 (I) *
   B. A (II)
   C. B (III)
   D. AB (IV)

7. A boy has I (I0I0) blood group and his sister has IV(IAIB) blood group. What blood groups do their parents have?
   A. II (IAI0) and III (IBI0) *
   B. II (IAIA) and III (IBI0)
   C. I (I0I0) and IV (IAIB)
   D. III (IBI0) and IV (IAIB)
   E. I (I0I0) and III (IBI0)

8. Blood group of a 30 year old man was specified before an operation. His blood is Rh-positive. Reaction of erythrocyte agglutination was absent with standard sera of 0αβ (I), Aβ(II), Bα (III) groups. The blood under examination is of the following group:
   A. 0αβ (I) *
   B. Aβ (II)

C. Bα (III)
D. AB (IV)

9. When defining a blood type according to the AB0 system the agglutination of erythrocytes of the examined blood was caused by standard serums of the I and II blood groups and wasn't caused by the serum of the III blood group. What blood type is it?

A. Bα (III). *
B. Aβ (II).
C. AB0 (IV).
D. 0αβ (I).
E. It is impossible to define.

10. A woman with the blood type AB (IV) Rh-, who has a 3-year-old child with the blood type AB (IV) Rh+, was taken to a hospital with posttraumatic bleeding. It is necessary to transfuse blood. Which of the following blood types is it possible to transfuse to the woman?

A. AB(IV) Rh- *
B. 0(I) Rh-
C. A(II) Rh+
D. A(II) Rh-
E. AB(IV) Rh+

METHODOLOGICAL DEVELOPMENT №5

Topic: Leukocytes and their functions. Immunity, its types and basic mechanisms.
The number of hours: 2 hours
The object of learning:
To know: the main functions of leukocytes, the features of their structure, leucogram. Nonspecific and specific mechanisms of cellular and humoral immunity; primary and secondary immune response.
To be able to: characterise each type of leukocytes in the blood, describe the types of immunity.

Theoretical questions for self-preparation

1. General characteristics of leukocytes.
2. Leukogram, its age dependence and pathological changes.
3. Immunity.
4. Immunity types and their basic mechanisms.
5. Cooperation of immunocompetent cells in the immune response.

Key words and terms: leukopoiesis, leukocytosis, leukopenia, leukopoetins, granulocytes, agranulocytes, phagocytosis, immunity, immune system, leukocyte formula, immune system, cellular and humoral immunity, inflammation, phagocytosis, complement system, B-lymphocytes, T-lymphocytes.

APPLICATION №1
Definition of main terms and concepts:

General characteristics of leukocytes.

The number of white blood cells in adults is normally 4–10x10^9/l. The increase in the

number of leukocytes is called ***leukocytosis***, and the decrease – ***leukopenia***. The main function of leukocytes is a protective one. Unlike erythrocytes, leukocytes perform most of their functions in the connective tissue of the skin and internal organs, and to a lesser extent -- in the blood. Leukocytes enter the bloodstream from the places of their formation (bone marrow, thymus, lymphoid tissue), circulate in the blood for several hours and migrate to the tissue. The average lifetime of leukocytes is 3-5 days. White blood cells are able to move independently from bloodstream using their contractile proteins. Unlike erythrocytes, they have nucleus and other organelles. Depending on the presence of granules in the cytoplasm, the leukocytes are divided into two groups: ***granulocytes*** (containing granules) and ***agranulocytes*** (without granules). The main types of granulocytes are neutrophils, basophils and eosinophils. Agranulocytes are divided into lymphocytes and monocytes (table.5.3).

Neutrophils make up the majority of all leukocytes in the blood (in average 40-70%). In the young forms the nucleus is round; in rod-nucleus - elongated, and in segmented-nuclear - has 2-3 projections. After exiting the bone marrow, neutrophils are remaining in the blood for only 6-8 hours and migrate rapidly to the tissues. The main function of neutrophils is to phagocyte the foreign microorganisms and tissue debris. Sometime, they are called ***microphages*** for their ability to phagocytosis and relatively small size. The lysosome enzymes (proteases, peroxidases, DNA acids, lipase) are responsible for digestion of microorganisms, which were previously phagocyted. Neutrophils can produce energy, like erythrocytes, by anaerobic glycolysis, so they are able to perform their functions in tissues with low oxygen content (by edema, or inside of inflammation places). So, the pus, formed during inflammatory processes, consists mainly of neutrophils and their residues.

Eosinophils- have such name due to the tendency of their granules to acidic dyes. Their number makes on average 2-4% of all leukocytes. This quantity undergoes pronounced daily fluctuations. Their number is 20% less than the average daily during the second half of the day and in the morning, and 30% more – at the night. These deviations are inversely related to the level of glucocorticoid secretion by the adrenal cortex. Eosinophil diameter is about of 10-14 microns. Eosinophils perform a number of specific functions, related to the inactivation of factors, responsible for the development of allergic and autoimmune reactions, and they also have a toxic effect on helminthes and their larvae.

Basophils– are the cells with diameter about of 8-10 microns and they have a segmented nucleus. Their granules are prone to absorb the alkaline dyes. The amount of basophils in blood is in range 0.5-1% of the total number of leukocytes. Basophile granules contain such biologically active substances as heparin and histamine. Heparin is a substance, that prevents blood clotting (an anticoagulant), and histamine has powerful vasodilation effect.

Lymphocytes– make up 20-40% of all leukocytes. Their cytoplasm does not contain granules, and the nucleus has a round shape. Unlike granulocytes, these cells, after being released into the blood, retain the ability to proliferate and differentiate. There are two large fractions of lymphocytes: T-lymphocytes and B-lymphocytes. T-lymphocytes are formed in the thymus, and B-lymphocytes – in the bone marrow. After leaving the places of maturation, they migrate into the secondary lymphoid organs – lymphoid nodes, spleen, lymphoid tissue of the stomach and intestine, pharyngeal tonsils. When foreign bodies (antigens) enter the macroorganism, lymphocytes, that are sensitive to them, are intensively multiplying and provide the formation of so-called cellular and humoral immunity.

T-lymphocytes are responsible for the cellular immunity. Depending on the specialization in the implementation of the immune response, there are three subtypes of T-lymphocytes: T-helper cells, cytotoxic T-lymphocytes (T-killers), and T-suppressors (cells suppressing the cellular and humoral immunity interactions). T-lymphocytes make up 70-80% of all lymphocytes; the remaining part - 20-30% -are ***B-lymphocytes,*** responsible for the humoral immunity. After antigenic stimulation, they are multiplying and mature into plasmocytes, that are capable of producing a large number of antigen specific antibodies.

A special type of lymphocytes –***natural killers (NK cells)*** specialize in the destruction of cancer cells and play an important role in the innate immunity. They are somewhat larger, than normal lymphocytes, and contain granules with enzymes, that damage the membranes of their target cells. Their content in a healthy person is on average 100-200x10*^{6} cells/liter.

Monocytes– make up 2-10% of all leukocytes. They have the largest size comparing to all other leukocyte types – 16-20 microns in diameter. They are circulating in the blood after exiting the bone marrow for up to 3 days. Then monocytes migrate to the tissues, proliferate and turn into fixed, histiocytes, which can also be multiplied in the inflammation areas. They provide the presentation of antigens to other immunocompetent cells. Macrophages synthesize a number of biologically active substances – components of the complement system, interferon, as well as ***endogenous pyrogen***– a protein that enters the bloodstream, shifts the thermoregulatory center of the hypothalamus toward the higher fixed point and causes an increase in body temperature during inflammatory processes.

Leukogram, its age related and pathological changes.

The percentage ratio of different forms of leukocytes in peripheral blood is called leukocyte formula or leukogram.

Leukogram of the healthy adult

Leuko-cytes` type	Neutrophils			Eosino-phils	Baso-phils	Lympho-cytes	Mono-cytes
	juvenile	immature	segmented				
Percent	**0 – 1**	**1 – 5**	**45 – 70**	**1 – 5**	**0 – 1**	**20 – 40**	**2 – 10**

An increase in the number of juvenile and immature forms of neutrophils is called a ***shift to the left***. Such shift is often due to increased leukopoiesis in myeloid leukemia. However, it can also be detected after a considerable amount of blood loss and reflects reparation processes in the red bone marrow. ***A shift to the right*** means an increase in the percentage of segmented forms of neutrophils above the norm.

The leukocyte formula has pronounced age-specific features. Thus, a child is born with the same ratio of neutrophils to lymphocytes as that of adults. But following next days it begins to increase the percentage of lymphocytes and decrease the percentage of neutrophils. Their numbers become equal to 5-6 days of life. This equalization is called the ***first crossing of the leukocyte formula***. The number of lymphocytes increases after first crossing until 5 years of life and exceeds the relative content of neutrophils. But then at age of 5-6 years the ***second crossing of the leukocyte formula*** occurs, when the percentage of neutrophils and lymphocytes become equal again. After second crossing the leukocyte formula gradually acquires an appearance, typical for an adult.

The leukocyte formula also changes significantly in some pathological conditions. Thus, acute bacterial infections, as a rule, are accompanied by ***neutrophilic leukocytosis*** and a decrease in the number of eosinophils and lymphocytes. The appearance of ***monocytosis*** indicates a favorable course of the infectious process. Chronic infections are characterized by ***lymphocytosis***. ***Eosinophilia***is observed in autoimmune diseases and intestinal invasions by helminthes. An allergy, as a rule, is accompanied by an increase in the percentage of basophils.

.

Immunity. Its types and basic mechanisms.

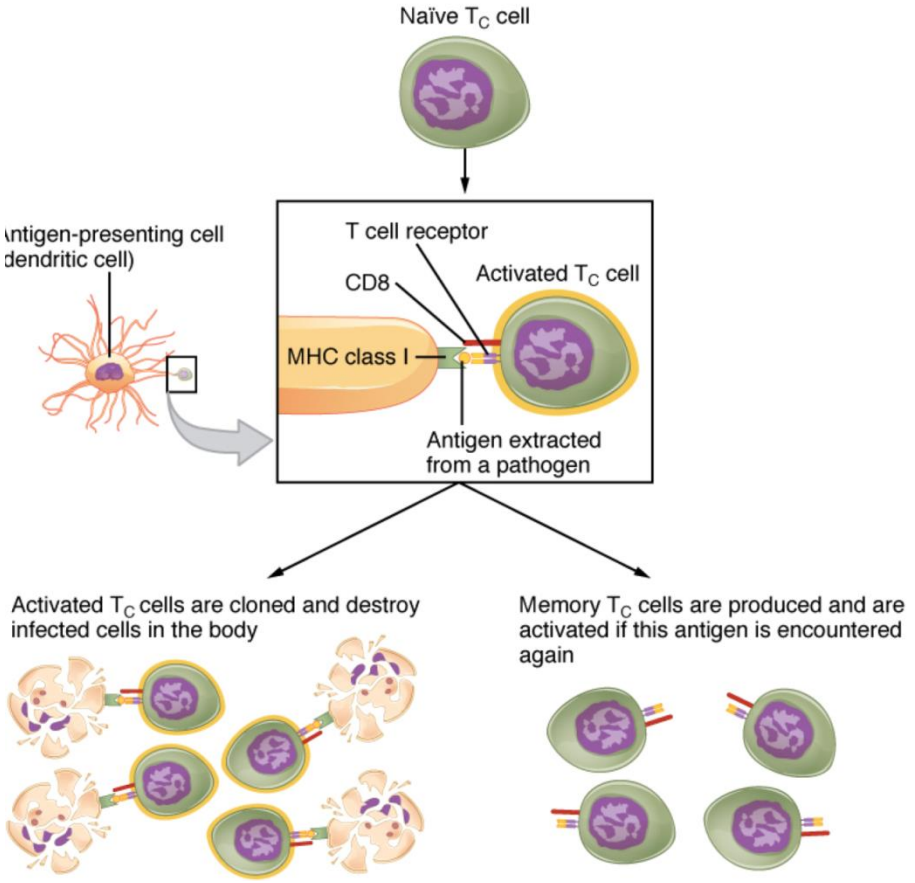
There is a special system in the body, that identifies and destroys genetically alien cells and macromolecules. This system is called ***immune system***. Its main components are bone marrow,

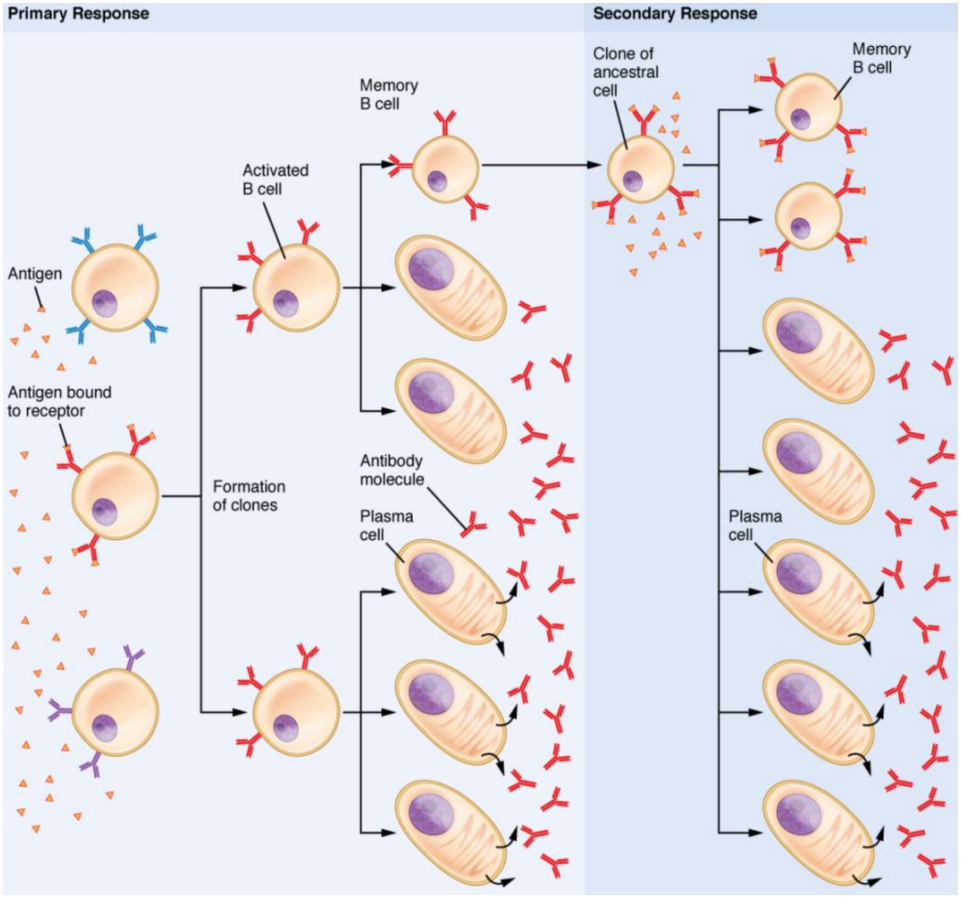
thymus, lymph nodes and lymphoid formations of the stomach and intestines, as well as lymphoid tissue of internal organs and leukocytes in blood and tissues. The immune system provides two types of protective mechanisms: ***non specific***– directed against all factors, regardless of their origin; and ***specific*** ones - directed specifically against a certain alien factor. Each of these types is realized in two ways: through ***cellular*** and ***humoral*** immunity. ***Non-specific cellular immunity*** includes the inflammatory response and phagocytosis, which are realized by micro- and macrophages, dendritic and NK-cells.

1. ***Non-specific humoral immunity***, which is presented by:
   • Lysozyme – protein, contained in saliva, lacrimal fluid, blood, airway mucus and other body fluids.
   • Complement system – consists of 11 plasma proteins, which are denoted by the letters C 1 ... 11. In physiological conditions, Sequential cascade activation of these proteins leads to the lysis of foreign cells membranes and death of infected cells.
   • Properdine system – consists of three components: peptide P, factor B - glycoprotein and proteolytic enzyme D. This system also affects foreign antigens.
   • Leukins and beta-lysine – substances, released by white blood cells;
   • Plakins – substances, secreted by platelets.
   •Interferon – a protein, secreted by B- and T-lymphocytes, macrophages and fibroblasts, which has antiviral activity.
2. ***Specific cellular immunity*** are realized by T-lymphocytes, macrophages and dendritic cells. T-lymphocytes make up 60-80% of all lymphocytes. Approximately 10% of this amount circulate in the blood for a very long time (up to 10 years), without dividing. These are the cells of the immune memory. Among effector T-lymphocytes the following classes are distinguished:
   • T-helper cells – stimulate differentiation of B-lymphocytes and proliferation of cytotoxic T-lymphocytes;
   • T-killers –provide cytotoxic effect to the antigens;
   • T-suppressors – suppress the immune response to a specific antigen, controlling its intensity.
3. ***Specific humoral immunity*** is provided by B-lymphocytes, which are formed in the red bone marrow. But their differentiation is carried out in the lymph nodes, the spleen, and the Payer`s plaques of the intestine. B-cells have receptors to antigens on their surface, which are represented by immunoglobulins M type. The small quantity of B-lymphocytes continues to circulate in the blood, providing the immune memory. Most of B-lymphocytes migrate into tissues and are converted to plasma cells, that secrete antibodies.

Cooperation of immunocompetent cells in the immune response.

The first exposure of the antigen to the body causes proliferation of immune memory lymphocytes and the formation of a small number of effector T-lymphocytes and antibodies after a certain latent period, that lasts from a few days to several weeks. This reaction of the immune system is called the ***primary immune response***. It unfolds, usually, within 3-4 weeks. In case of the next exposure of this antigen, a high concentration of antibodies to it is produced quickly without any latent period. Beside of this, it is occurred a significant increase in the number of effector T-lymphocytes, specifically sensitive to this antigen in the blood. Described events are called the ***secondary immune response***, which is maintaining for a long time: months and even years.


Naïve T_C cell
ntigen-presenting cell
dendritic cell)
T cell receptor
CD8
Activated T_C cell
MHC class I
Antigen extracted
from a pathogen
Activated T_C cells are cloned and destroy infected cells in the body
Memory T_C cells are produced and are activated if this antigen is encountered again


Primary Response
Secondary Response
Memory B cell
Activated B cell
Clone of ancestral cell
Memory B cell
Antigen
Antigen bound to receptor
Formation of clones
Antibody molecule
Plasma cell
Plasma cell

According to the ***clonal selection theory***, in the human body there are cells of immune memory, that have receptors to any potentially possible antigen, which can enter the internal environment. When encountered with such antigen, it is absorbed by antigen-presenting cells and is broken down inside the lysosomes. Then antigenic determinants are transported to the surface of the cell and give impulse to the powerful protective immune reactions described above. If during the period of embryonic development, when the immune system is formed, the fetus is contacted with a certain antigen, then it forms ***immunological tolerance*** to this antigen in adulthood.

Tasks for self-control:

1. Blood analysis of a patient showed signs of HIV infection (human immunodeficiency virus). Which cells does HIV-virus primarily affect?
   A. Cells that contain receptor T4 (T-helpers) *
   B. Cells that contain receptor IgM (B-lymphocytes)
   C. Specialized nervous cells (neurons)
   D. Mast cells
   E. Proliferating cells (stem hematoplastic cells)

2. A 5 year old child is ill with measles. Blood analysis revealed increase of total number of leukocytes up to 13 · 109/l. Leukogram: basophils - 0, eosinophils - 1, myelocytes - 0, juvenile neutrophils - 0, band neutrophils - 2, segmented neutrophils - 41, lymphocytes - 28, monocytes - 28. Name this phenomenon:
   A. Lymphocytosis
   B. Agranulocytosis
   C. Monocytosis *
   D. Eosinopenia
   E. Neutropenia

3. At the laboratory experiment the leukocyte culture was mixed with staphylococci. Neutrophile leukocytes engulfed and digested bacterial cells. These processes are termed:
   A. Pinocytosis
   B. Phagocytosis *
   C. Diffusion
   D. Facilitated diffusion
   E. Osmosis

4. Donor skin transplantation was performed to a patient with extensive burns. On the 8-th day the graft became swollen and changed colour; on the 11-th day graft rejection started.What cells take part in this process?
   A. T-lymphocytes *
   B. Erythrocytes
   C. Basophils
   D. Eosinophils
   E. B-lymphocytes

5. Which of the changes in a common blood analysis could be found after running?
   A. Anemia.
   B. Leukopenia.
   C. Leukocytosis. *
   D. Increase of SRE.

E. Increase of the Color Index.

6. The result of a blood test showed an insignificant increase of the number of leukocytes (leukocytosis) without any change of other indexes. What activities of a patient can be the reason for leukocytosis?

A. That he slept deeply.
B. Did not have breakfast.
C. Had breakfast. *
D. Smoked.
E. Drank 200 ml ofwater.

7. Donor skin transplantation was performed to a patient with extensive burns. On the 8-th day the graft became swollen and changed colour; on the 11-th day graft rejection started.What cells take part in this process?

A. T-lymphocytes
B. Erythrocytes
C. Basophils
D. Eosinophils
E. B-lymphocytes

8. Origin and maturation of B cells takes place at:

A. Bone marrow *
B. Thymus
C. Liver
D. Spleen
E. Blood

9. Another name for innate immunity:

A. Is immunity
B. Is explicit immunity
C. Is specific immunity.
D. Is non-specific immunity. *
E. Immune adaptation

10. The two types of lymphocytes are:

A. Platelets and erythrocytes.
B. Platelets and the T-cells.
C. T-cells and erythrocytes.
D. B-cells and the T-cells.*
E. Basophils and macrophages

11. The physical barriers that form part of the immune system are:

A. The skin, body temperature and the mucosal membranes.
B. The skin and the mucosal membranes.
C. The bones and the mucosal membranes.
D. All of the above
E. None of these

METHODOLOGICAL DEVELOPMENT №6

Topic: Functions of platelets. Coagulation and anticoagulation system.
The number of hours: 2 hours
The object of learning:
To know:a description of the mechanisms of the hemostasis (primary, coagulation hemostasis), anticoagulation system of blood and pathological conditions, accompanied by insufficiency and excessive activity of coagulation hemostasis.
To be able to: interpret the methods of clinical evaluation of the blood coagulation system.

Theoretical questions for self-preparation

1. Blood platelets and their functions.
2. General characteristics of the hemostasis mechanisms.
3. Mechanisms of primary hemostasis.
4. Mechanisms of coagulation hemostasis.
5. Anticoagulation system of blood.
6. Typical abnormal conditions accompanied by insufficiency and excessive activity of coagulation hemostasis.
7. Methods of clinical assessment of the blood coagulation system.

Key words and terms: hemostasis, blood coagulation, cell and plasma blood-clotting factors, adhesion, aggregation, plasminogen, plasmin, fibrinolysis, thrombocytopenia, hemophilia.

APPLICATION №1
Definition of main terms and conception:

Practical skills:

Work 1. Determination of bleeding time by Duke.

Wipe the ring finger with 96% ethyl alcohol and use a sterile needle-scarifier to make a deep (3 mm) incision and mark the time. Then, every 30 seconds, touch the surface of a drop of blood with filter paper until there are no traces of blood on the paper. The duration of bleeding is marked from the onset of the first drop to the discontinuation of blood. Normally, bleeding time is 1-3 minutes.

Work 2. Determination of the time of blood clotting by Mas-Margo.

On a watch glass covered with paraffin, put a drop of vaseline oil. In a pipette from the hemometer of Sali, pre-moistened with vaseline oil (oil is collected in an eyedropper and blown up again), gain 20 mm3 of blood and quickly blush in a drop of oil on the glass. This time is marked on the watch as the beginning of the study. Every 2 min blood is sucked back into the pipette again as long as it is impossible to collect blood in the pipette. The time of blood clotting by this method is equal to 8-10 minutes.

APPLICATION №2
Definition of main terms and conception:

Control questions and answers on the topic: "Hemostasis"

1. Why is the circulating blood liquid?
   Stabilization of the liquid state of blood contributes to the following factors: the integrity and features of the structure of the walls of the blood vessels; blood coagulation system; spatial separation of plasma and cellular factors of blood clotting.
2. Participation of thrombocytes in the vascular component of hemostasis.
   To make adhesion, aggregation, secrete vasoconstrictive substances (serotonin, adrenaline), and others.

Clotting plasma factors.

Factor number	Name	Type of molecule	Source	Pathway(s)
I	Fibrinogen	Plasma protein	Liver	Common; converted into fibrin
II	Prothrombin	Plasma protein	Liver*	Common; converted into thrombin
III	Tissue thromboplastin or tissue factor	Lipoprotein mixture	Damaged cells and platelets	Extrinsic
IV	Calcium ions	Inorganic ions in plasma	Diet, platelets, bone matrix	Entire process
V	Proaccelerin	Plasma protein	Liver, platelets	Extrinsic and intrinsic
VI	Not used	Not used	Not used	Not used
VII	Proconvertin	Plasma protein	Liver *	Extrinsic
VIII	Antihemolytic factor A	Plasma protein factor	Platelets and endothelial cells	Intrinsic; deficiency results in hemophilia A
IX	Antihemolytic factor B (plasma thromboplastin component)	Plasma protein	Liver*	Intrinsic; deficiency results in hemophilia B
X	Stuart–Prower factor (thrombokinase)	Protein	Liver*	Extrinsic and intrinsic
XI	Antihemolytic factor C (plasma thromboplastin antecedent)	Plasma protein	Liver	Intrinsic; deficiency results in hemophilia C
XII	Hageman factor	Plasma protein	Liver	Intrinsic; initiates clotting in vitro also activates plasmin
XIII	Fibrin-stabilizing factor	Plasma protein	Liver, platelets	Stabilizes fibrin; slows fibrinolysis

3. What is the difference between the time of bleeding and the time of blood clotting?
   Clotting time is the time from the time of taking blood to the appearence of filaments of fibrin, the time of bleeding is the time from the moment of puncturing the skin and the start of bleeding to the formation of blood clots.
4. Why does blood clotting increase with pain irritations?
   The pain reactions activate the sympathetic NS, increase the concentration of adrenaline that activates coagulants.
5. What is common and different in the effect of heparin and sodium citrate on the system of blood clotting?
   Both substances prevent the blood from clotting. The difference - heparin binds a number of factors of blood clotting, and citric acid sodium binds calcium ions.
6. How will the increase of tone of the sympathetic NS influence the hemostasis?
   By hypercoagulation.

Tasks for self-control:

1. A patient with liver disease revealed the decreasing of protrombin level in the blood. It can first of all, result in the impairment of:
   A. The second phase of the coagulator hemostasis
   B. Anticoagulative properties of the blood
   C. Vascular-thrombocytic hemostatic
   D. Fibrinolysis
   E. The first phase of the coagulatory hemostasis

2. A patient who has thrombosis of blood vessels has a lowered activity of the anticoagulant blood system. Which factor concentration is likely to be lowered?
    A. X-factor
    B. Heparin
    C. Fibrinogen
    D. Prothrombin
    E. Prothrombinase

3. Hemophilia is:
    A. Absence of blood clotting
    B. Acceleration of blood clotting
    C. Erythrocyte destruction
    D. Deceleration of blood clotting
    E. Increase of bleeding time

4. After applying a tourniquet an examined person has got punctuated hemorrhages. The dysfunction of what blood cells is it connected with?
    A. Thrombocytes. *
    B. Eosinophils.
    C. Monocytes.
    D. Lymphocytes.
    E. Neutrophils.

5. A 49-year-old man is being observed at a clinic. He is suffering from a substantial increase of the time of blood coagulation, gastroenteric bleeding, and subcutaneous hemorrhages. Such symptoms can be explained by the lack of a certain vitamin. Which vitamin is it?
    A. E.
    B. B1.
    C. PP.
    D. H.
    E. K. *

6. Prior to having his first colonoscopy, a 50-year-old male undergoes a bleeding time test to rule out any clotting disorders. Bleeding time is determined by nicking the skin superficially with a scalpel blade and measuring the time required for hemostasis. It will be markedly abnormal (prolonged) in a person who has which of the following?
    A. Thrombocytopenia *
    B. Anemia
    C. Vitamin K deficiency
    D. Leukopenia
    E. Hemophilia

7. A 67-year-old woman with a history of venous thromboembolism is placed on warfarin (Coumadin) prophylactically. The blood concentration of Coumadin becomes too high and bleeding occurs. The bleeding can best be treated by the administration of which of the following?
    A. Vitamin K *

B. Fibrinogen
C. Thrombin
D. Platelets
E. Protein C

8. A 57-year-old woman is undergoing a femoral popliteal bypass for her peripheral vascular disease. The vascular surgeon wishes to induce a localized arteriolar constriction to help control hemostasis. An increase in the local concentration of which of the following agents will cause systemic vasoconstriction?
   A. Angiotensin II *
   B. Nitric oxide
   C. Atrial natriuretic peptide
   D. A b2-adrenergic agonist
   E. Adenosine

9. A 16 year old boy after an illness has diminished function of protein synthesis in liver as a result of vitamin K deficiency. It will cause a disturbance of:
   A. Blood coagulation *
   B. Erythrocyte sedimentation rate
   C. Anticoagulant generation
   D. Erythropoietin secretion
   E. Osmotic blood pressure

METHODOLOGICAL DEVELOPMENT №7

Topic: Physicochemical and physiological mechanisms of maintenance of acid-base balance.
The number of hours: 2 hours
The object of learning:
To know: the concept of pH, buffer systems and mechanisms for maintaining acid-base homeostasis.
To be able to: evaluate the indicators of the acid-base balance, clarify the role of buffer systems in the adaptive reactions of the organism.

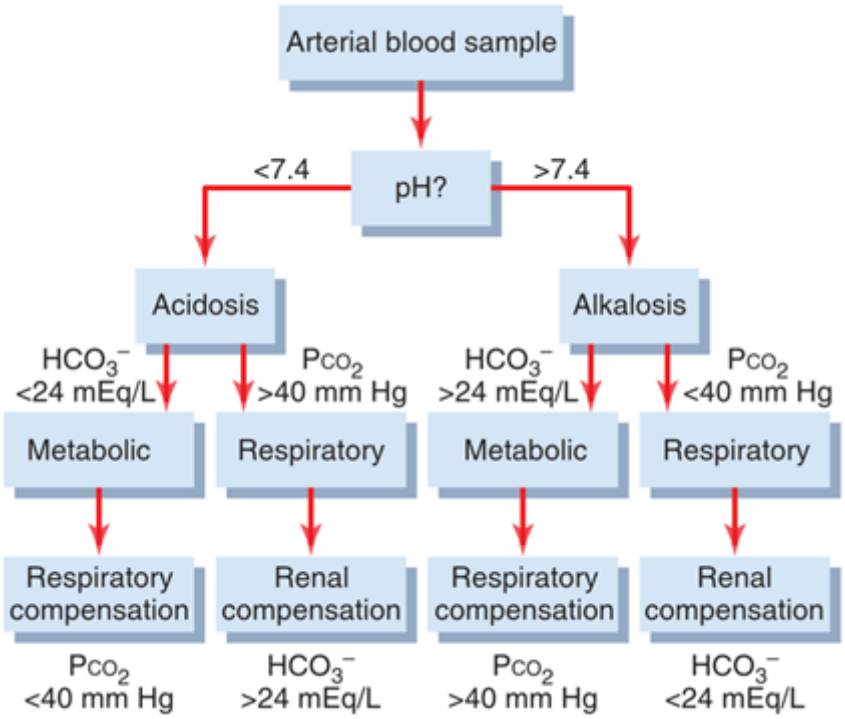
Theoretical questions for self-preparation

1. Concept about pH and buffer properties of solutions.
2. The pH of blood and its significance for homeostasis.
3. Blood buffer systems and their physiological characteristics.
4. Participation of the respiratory system in the regulation of acid base balance.
5. The involvement of the kidneys in the regulation of acid base balance.
6. The role of the gastrointestinal tract and the liver in the displacement of acid base balance.
7. Clinical and physiological characteristics of typical acid base disorders.

Key words and terms: blood pH, base excess (BE), respiratory acidosis, respiratory alkalosis, metabolic acidosis, metabolic alkalosis.

APPLICATION №1
Definition of main terms and concepts:

Practical skills: Determine the acid-base disturbances using the following algorithm:



Active liquid reaction– is the acidity or alkalinity of the internal environment (eg, arterial blood pH, etc.) in the body under given conditions. According to pH we can determine whether the concentration of hydrogen ions in the blood is normal or it is altered in some way.

Acid-base balance (pH balance, acid-base balance) – is the homeostatic property of the internal environment, characterized by the relative constancy of the hydrogen and hydroxyl ions ratio and determined by the optimal character of metabolic processes and physiological functions.

pH – negative logarithm of the concentration of hydrogenions. Plasma pH arterial blood in a healthy person varies between 7,35-7,45. The blood has weakly alkaline reaction, despite the constant flow the acid products of metabolism in blood. This relative stability is provided by buffer systems and physiological mechanisms.

The buffer system - a solution that binds excess hydrogen ions or hydroxyl ions without significant deviation of pH. It consists of a weak acid and its conjugate base.
In the body there are 4 buffer systems:

The bicarbonate buffer system consists of the carbonic acid H_2CO_3, which acts as a proton donor, and its conjugated base HCO_3-, which acts as an acceptor of hydrogen:
$H_2CO_3 = H^+ + HCO_3^-$.
This system is connected with the system of external breathing, kidneys, blood, tissues.

The phosphate buffer system consists of an ion of $H_2PO_4^-$(a donor of hydrogen ion) and anion of HPO_4^{2-}(an acceptor of hydrogen ion).
$H_2PO_4^- = H^+ + HPO_4^{2-}$.
The system is connected with blood and kidneys.

The protein buffer system is represented by the acid-base groups in the protein molecule. The carboxyl group gives the proteins the acidic properties, the amino group – the basic ones. The system is connected with blood and tissues.

The buffer function of hemoglobin is due to its involvement in the transport of oxygen and carbondioxide. When saturated with Nb oxygen, it becomes a stronger acid ($HHbO_2$). In tissues, giving oxygen, Hb becomes very weak organic acid (HHb) and becomes an acceptor of hydrogen ions. Also reduced hemoglobin at the expense of aminogroups binds carbondioxide and forms carbhemoglobin.

Buffer bases (BB buffer basis) – the concentration of anions of all weak acids, hydrocarbons and anionic groups of proteins (norm of 48 mmol / l).

Base excess (BE – base excess) is the deviation of the concentration of buffer bases from the normal level (from -4 mmol / l to + 4 mmol / l).

APPLICATION №2

Control questions and answers on the topic: "Physicochemical and physiological mechanisms of maintenance of acid-base balance."

1. What is the significance of the constancy of blood pH for life of the whole organism?
   Provision of optimal conditions for the activity of the enzyme systems of the body.
2. Name the basic systems of the organism, necessary to maintain the pH constant.
   Systems of excretion of organs (lungs, kidneys, sweat glands) and the blood system (buffer systems).
3. What are the buffer systems of blood? List the buffer blood systems, specify their constituent parts.
   A set of substances that prevent the shift of blood pH. The buffer system of hemoglobin (KHbO2 and HHb), the carbonate system (Na HCO3 and H2CO3), phosphate (NaH2PO4) and (Na2 HPO4), the buffer system of plasma proteins of blood.
4. Explain the mechanism of the buffer action of plasma proteins in the blood.
   Proteins are ampholites due to the presence of end (NH2 and COOH) groups and some of the side groups of the peptide chain, some of which are acidic, others are the main properties, which can bind both hydrogen and hydroxyl ions .
5. Explain the mechanism of the buffer action of hemoglobin and write down the appropriate chemical reaction. In which cells of the body does this reaction take place? What part of the buffer capacity is done due to hemoglobin?
   Reduced hemoglobin binds hydrogen ions and is a weaker acid than the carbonic acid.
   $KHbO2 + H2CO3 = HHb + HCO3 + O2$.
6. What is an uncompensated acidosis and alkalosis?
   Conditions in which the buffering capacity of the blood is exhausted and the pH is shifted to acid (acidosis) or alkaline (alkalose) side.
7. What is a compensated acidosis and alkalosis?
   Conditions in which there is no shift of blood pH, but its buffer capacity changes.
8. What is an alkaline reserve? How do you determine its size?
   The amount of alkaline salts of weak acids that the blood contains. It is determined by the amount of CO2 that can be linked to 100 ml of blood at a pressure of carbon dioxide 40 mm Hg.
9. What is the biological essence of greater stability of blood to acidification than to alkalization? Under what conditions is it most important?
   Most metabolic products are acid, so acidosis should be more potent, especially with increasing activity of organs, tissues or the body as a whole. When a large number of acid metabolites accumulates.

Tasks for self-control:

1. For a man undergoing surgery, it was necessary to aspirate the contents of the upper gastro-intestinal tract. After surgery, the following values were obtained from an arterial

blood sample: pH 7.55, PCO2 52 mm Hg and HCO3- 40 mmol/l. What is the underlying disorder?

A. Metabolicacidosis
B. Respiratoryalkalosis
C. Metabolicalkalosis *
D. Respiratoryacidosis
E. It is normal condition

2. A person was admitted to hospital in a coma. Analysis of the arterial blood gave the following values: PCO2 16 mm Hg, HCO3- 5 mmol/l and pH 7.1. What is the underlying acid-base disorder?

A. Metabolicacidosis *
B. Respiratoryalkalosis
C. Metabolicalkalosis
D. Respiratoryacidosis
E. mixed acidosis

3. A climber reaches a high altitude of 5000 meters (16,400 ft) in the Andes mountains above the sea level. What will happen to his arterial PCO2 and pH?

A. Bothwillbelowerthannormal.
B. The pH will rise and PCO2 will fall. *
C. Both will be higher than normal due to physical exertion.
D. The pH will fall and PCO2 will rise
E. None of these

4. A medical student is presented to the emergency room with a 2-day history of severe vomiting and orthostatic hypotension. Which of the following metabolic abnormalities are most likely in this patient?

A. Hypokalemia, hypochloremia, and metabolic alkalosis
B. Hypokalemia, hypochloremia, and metabolic acidosis *
C. Hyperkalemia, hyperchloremia, and metabolic alkalosis
D. Normal serum electrolytes and metabolic acidosis
E. Normal serum electrolytes and metabolic alkalosis

5. Metabolic acidosis is caused by which of the following?

A. Hypoaldosteronism
B. Hypoventilation
C. Hypovolemia
D. Hypokalemia *
E. Hypocalcemia

6. A 37-year-old maleis presented with dehydration and hypokalemic metabolic acidosis. This acid-base and electrolyte disorder can occur with excess fluid loss from which of the following organs?

A. Colon *
B. Stomach
C. Ileum

D. Pancreas
E. Liver

7. A patient's arterial blood gas reveals a decrease in PaCo2. Hyperventilation normally occurs during which of the following?

A. Pregnancy *
B. Exercise
C. Sleep
D. Morphineadministration
E. Metabolicalkalosis

8. A 35-year-old male smoker complains about burning epigastric pain that is most demonstrated on an empty stomach. Further investigations established high level of gastrin and HCl connected with the diagnosis of Zollinger-Ellison syndrome. Normally, basal acid output is increased by which of the following?

A. Acidification of the antrum
B. Administration of an H2-receptor antagonist
C. Alkalinization of the antrum *
D. Vagotomy
E. Acidification of the duodenum

9. The daily production of hydrogen ions connected with CO2 is primarily buffered by which of the following?

A. Extracellular bicarbonate
B. Red blood cell bicarbonate
C. Plasma proteins
D. Red blood cell hemoglobin *
E. Plasma phosphate

METHODOLOGICAL DEVELOPMENT №8

Topic: Morpho-functional characteristics of the respiratory system.
The number of hours: 2 hours
The object of learning:
To know: the main stages of respiration and their physiological characteristics, the structural components of the respiratory system, their role in breathing, non-respiratory functions of the lungs.
To be able to: explain the stages of breathing, describe the structural components of the respiratory system.

Theoretical questions for self-preparation

1. The major stages of breathing and their physiological characteristics.
2. Structural components of respiratory system and their role in breathing.
3. Physiological features of the upper and lower respiratory tract.
4. Non-respiratory pulmonary functions.

Key words and terms: lung ventilation, respiratory tract, alveoli, bone structures and skeletal muscles, upper and lower respiratory tract, respiratory zones, negative pleural pressure, dead anatomical space, respiratory unit (primary lobula), surfactant, blood shunting.

APPLICATION №1

Definition of main terms and conception:

Surfactants are biological active substances of lipid nature which reduce the surface tension of a liquid layer covering the alveoli surface.

Anatomical dead space – all divisions of the respiratory tract, including up to 16 generations of bronchi, that do not take part in gas exchange because they do not contain alveoli.

Alveoli are spherical sacs that terminate branching of terminal bronchioles. They are braided with a net of capillaries and form an exchange surface for the bilateral diffusion of respiratory gases.

The physiological dead space is the sum of the anatomical dead space and the volume of the alveoli without gas exchange.

APPLICATION №2

Control questions and answers on the topic: "Morpho-functional characteristics of the respiratory system."

1. What is respiration?
   A set of processes that ensures the flow of oxygen into the body, its transportation to the cells, oxidazation of organic substances (release energy) and release of carbon dioxide.
2. What set of organs forms the respiratory system?
   They are: lungs with air pathways, the chest skeleton with muscles, blood, cardiovascular system and organelles of cells that realize tissue respiration.
3. List the 5 stages of the respiratory process in humans.
   1) ventilation of the lungs; 2) gas exchange between the lungs and the blood; 3) transportation of gases with blood; 4) gas exchange between blood and tissues; 5) tissue respiration.
4. What set of organs provides ventilation of the lungs?
   The combination of the chest skeleton with muscles, lungs with airway paths.
5. Name the main function of the lungs. What does breathing mean?
   Providing gas exchange between the blood of the organism and the environment. The release of energy necessary for the life of the organism.
6. List the non-gas exchange functions of the lungs.
   1) the excretion of water and volatile toxic products of metabolism; 2) synthesis of biologically active substances (heparin, histamine); 3) an environmental barrier; 4) thermoregulation; 5) blood depot; 6) air reservoir for sound formation.
7. What is the dead space? List the constituent elements, specify the main functions.
   Divisions of the respiratory tract without direct gas exchange between air and blood; nasopharynx, larynx, trachea, bronchi up to the 16^{th} generation (to the gas exchange surface of the alveoli). Its functions: I) transport air to the gas exchange zone; 2) air purification; 3) heating of air; 4) humidifying the air entering the lungs.
8. What is the role of the chest in the processes of breathing?
   1) Is a hermetically sealed cavity, which protects the lungs from mechanical influences and drying; 2) provides ventilation of the lungs, the flow of fresh air into the lungs and the expulsion of exhaled air from the lungs.
9. What is the pleural cavity and the significance of negative pressure in it?

It is a space between visceral and parietal pleura, coated with a thick layer of serous fluid. Negative pressure in the pleural space is below the atmospheric; - 8 mm Hg at inhalation and - 5 mmHg at exhalation.

10. What is the importance of the negative pressure in the pleural space? What is the role of serous fluid lining the pleura?
    The reason is the elastic traction of the lungs that occurs when they stretch out. Condition of tightness of the pleural space. The liquid enables the gliding of the pleura leaves against each other.
11. What is the role of surfactant lining the inner surface of the alveoli?
    Reduces the surface tension of the film covering the inner surface of alveoli, so that the lungs do not collapse while exhaling; reduce elastic traction of the lungs, facilitate breathing, have bacteriostatic activity.

Tasks for self-control:

1. An X-ray examination discovered a lung emphysema in a patient. What is the reason of development of shortness of breath in this case?
   A. Decreased lungs elasticity *
   B. Increased lungs elasticity
   C. Inhibition of respiratory center
   D. Excitation of respiratory center
   E. Decreasing of alveoli receptors sensitivity

2. A 27-year-old man develops an adult respiratory distress syndrome (ARDS) after nearly drowning. Conventional mechanical ventilation with 100% O2 together with inhaled nitric oxide do not provide sufficient oxygenation. Portion of surfactant was instilled via fiberoptic bronchoscope. The improvements in respiratory function occurred because surfactant increased which of the following?
   A. Bronchiolar smooth muscle tone
   B. The pressure gradient needed to inflate the alveoli
   C. Alveolar surface tension
   D. Lung compliance *
   E. The work of breathing

3. A subject training for a triathlon reaches a workload during running that exceeds his anaerobic threshold. As a result, which of the following is increased?
   A. Alveolar ventilation *
   B. PaCO2
   C. Arterial pH
   D. [HCO3–]
   E. Firing of the central chemoreceptors

4. A patient with emphysema is referred for his annual pulmonary function testing to assess the progression of his disease. Because of emphysematic alveolar septal destructions, there is a decrease in which of the following?
   A. Lung compliance
   B. Diffusing capacity *
   C. Airway resistance

D. Alveolar dead space
E. Total lung capacity

5. A 58-year-old factory worker, who has worked in the insulation industry for over 30 years, develops progressive shortness of breath. He went to the doctor with hemoptysis. A chest x-ray revealed alveolitis because of asbestos inhalation. Which process is able to remove small particles from the alveoli?
   A. Osmosis
   B. Diffusion
   C. Expectoration
   D. Ciliary transport
   E. Phagocytosis *

6. Which of the following processes decreases the pulmonary vascular resistance?
   A. The lungs are inflated to total lung capacity
   B. Sympathetic stimulation to the pulmonary vessels is increased
   C. Alveolar oxygen tension is decreased
   D. Plasma hydrogen ion concentration is decreased
   E. Cardiac output is increased *

7. A healthy 32-year-old woman undergoes pulmonary exercise stress testing prior to starting a training routine to prepare for her first marathon. Normally, during moderate aerobic exercise, which of the following occurs?
   A. Alveolar ventilation increases *
   B. PaO2 increases
   C. PaCO2 decreases
   D. Arterial pH decreases
   E. Blood lactate level increases

8. A 68-year-old patient with shortness of breath is referred for pulmonary function testing, including lung volumes, flow-volume curves, and lung compliance. Which one of the following statements characterizes the pulmonary compliance best of all?
   A. It is equivalent to $\Delta P/\Delta V$
   B. It is inversely related to the elastic recoil properties of the lung *
   C. It decreases with advancing age
   D. It increases when there is a deficiency of surfactant
   E. It increases in patients with pulmonary edema

9. A hospitalized patient was found in a semicomatose state. Arterial blood gases reveal hypercapnia. Which of the following is the most likely cause of the high arterial PCO2?
   A. Decreased metabolic activity
   B. Decreased alveolar dead space
   C. Profound hypoxia *
   D. Alveolar capillary block
   E. Increased alveolar ventilation

10. A patient complains of paroxysmal episodes of shortness of breath. When no abnormalities are detected with conventional pulmonary function screening, the pulmonologist orders a

methacholine challenge test. Which of the following will increase as a result of stimulating cholinergic receptors of the bronchial smooth muscles?

A. Lung compliance
B. Airway diameter
C. Elastic work of breathing
D. Resistive work of breathing *
E. Anatomic dead space

METHODOLOGICAL DEVELOPMENT №9

Topic: Pulmonary ventilation and its mechanisms**.**
The number of hours: 2 hours
The object of learning:
To know: the process of ventilation of the lungs, the role of the main respiratory and accessory muscles in the processes of inhalation and exhalalation , the biomechanics of the respiratory act, factors influencing the ventilation of the lungs, the oxygen value of respiration in normal and pathological state.
To be able to: perform a functional assessment of lung ventilation using spirometry by measuring the parameters of external respiration. Compare the obtained results with physiological constants.

Theoretical questions for self-preparation

1. Biomechanics of respiratory cycle.
2. The factors affecting pulmonary ventilation.
3. Oxygen value of breathing in normal and pathological state.
4. The functional assessment of pulmonary ventilation by method of spirography.
5. Gas exchange mechanisms between alveolar and atmospheric air.

Key words and terms: pulmonary ventilation, inspiration, expiration, pneumothorax atelectasis, surfactants, protective respiratory reflexes, restrictive/obstructive disorders, friction/elastic work, tissue/resistive work, respiratory distress of newborns.

APPLICATION №1
Definition ofmain terms and concepts:

Spirography - is a method of graphic recording of changes in lung volume during respiration.
Hysteresis of the lungs – the delay in the decline of alveoli under exhalation.
Apnea – no breath or exhalation;
Pneumothorax – is a broken hermeticity of interpleural space;
Atelectasis – is a pulmonary collapse;
Pressure gradient – the difference between the levels of pressure of gases on both sides of the biological membrane;
Compliance (dilation) of the lungs is a change in volume under the influence of transmural pressure changes;
Elasti c work –is directed against the forces of elastic traction of the lungs during inhalation;
The tissue resistive work – is directed against the forces of viscosity (internal friction) of the lungs and structures of the chest;
Frictional work – is directed against the air flow resistance forces in bronchi;

1. **<u>Tidal volume (TV= 500 ml)</u>**

Tidal volume is the amount of air inhaled or exhaled normally at rest.

2. **Inspiratory reserve volume (IRV = 2500 ml)**

IRV is the maximum air volume, which can be inhaled by a person additionally after normal inspiration.

3. **Expiratory reserve volume (ERV = 1000 ml)**

ERV is the maximum air volume, which can be exhaled by a person additionally after calm expiration.

4. **Vital capacity (VC)**

Is the greatest volume of air exhaled after maximal inhalation.
Vital capacity consists of the following volumes: Tidal volume (500 ml) + Inspiratory reserve volume (2500 ml) + Expiratory reserve volume (1000 ml) = 4000 ml.

5. **Forced vital capacity (FVC)**

Forced vital capacity (FVC) is the volume of air that can be forcibly blown out after full inspiration, measured in liters.

6. **Residual volume (RV = 1000 ml)**

Is the air volume, which remains in the lungs after maximum deep expiration.

7. **Functional residual capacity (FRC = 2000 ml)**

Is the air volume, which remains in the lungs after calm expiration.
Expiratory reserve volume (1000 ml) + Residual volume (1000 ml) = 2000 ml.

8. **Total lung capacity (TLS)**

Is the air volume contained in the lungs after completing a maximum possible inspiration.
Vital capacity (4000 ml) + Residual volume (1000 ml) = 5000 ml.

APPLICATION №2

Control questions and answers on the topic: "Pulmonary ventilation and its mechanisms."

1. What is the elastic traction of the lungs? Name its parameters during exhalation and inhalation.
   The force with which the stretched lungs are trying to reduce their volume. It depends on the change of the intrapleural pressure which is 8 mm Hg at inhalation and 4 mm Hg at exhalation.
2. Name the components that make up the elastic traction of the lungs.
   Stretched elastic fibers, smooth muscle cells, bronchi and bronchioles, surface tension of a surfactant film covering the inner surface of the alveoli.
3. Why are the lungs not folding, despite the presence of elastic traction that tries to compress them?
   This is prevented by atmospheric pressure acting on the lungs only through airways and compresses the lungs to the inner surface of the chest. The forces of adhesion between the visceral and parietal leaves of the pleura play an insignificant role.
4. What is pneumothorax?
   A pneumothorax is an abnormal collection of air in the pleural space between the lung and the chest wall.
5. What is the role of negative pressure in the chest cavity in the processes of inhalation and exhalation?
   It provides: 1) reduction of the volume (compression) of the chest during exhalation; 2) dome-like arrangement of the diaphragm (top dome), which makes it possible to move the diaphragm down while inhaling; 3) maintain bronchi and bronchioles in a stretched condition, reducing their resistance to airflow.
6. Name the processes that occur under inhalation sequentially. Are they passive or active (with energy consumption)?

Contraction of muscles of inspiration, increased in chest volume, expansion of lungs and decrease of pressure in them, arrival of airflow to the lungs.They are active.

7. How much energy does the body spend on the work of the respiratory muscles in a state of rest and with intense physical work (forced breathing). What is the main reason for this increase?
   At rest 2 - 3%, with intensive work up to 20%. The need for a sharp increase in the activity of the respiratory muscles is due to the sharp increase in the elastic resistance of the external respiration organs.
8. List the components of the non-elastic resistance of the organs of external respiration.
   They are: aerodynamic resistance of airways, resistance of tissues, inertia resistance.
9. What muscles carry out the act of breathing during calm and forced breathing?
   At calm breathing diaphragm, external intercostal and interstitial muscles. At forced respiration additional muscles of the shoulder, neck, back, abdominal muscles, pectoral muscles are involved.
10. What basic forces need to be overcome for inhalation? Which of the passive forces contributes to the expansion of the chest during inhalation?
    They are the forces of elastic traction of lungs and abdominal wall. The strength of the chest elasticity.
11. What is the origin of the strength of the chest elasticity, which facilitates inspiration, and enables chest expansion of up to 60% of the volume of vital capacity of the lungs?
    After the relaxation of the respiratory muscles, the chest decreases in volume (compresses) due to the elastic pull of the lungs, at the same time the strength of elasticity of the thorax increases, which tries to expand it (the equilibrium state of the chest is achieved at a volume of 60% , equal to the vital capacity of the lungs).
12. Name the primary and secondary forces that provide the expansion of the lungs, along with the expansion of the chest during inhalation.
    The primary is the one-way atmospheric pressure acting on the lungs through the airways and presses them to the inner surface of the chest. The secondary force is the grip between visceral and parenteral pleura leaves.
13. List the sequence of processes that result in exhalation. Are they passive or active?
    They are: relaxation of the respiratory muscles, reduction of the volume of the chest and volume of lungs, increase of pressure in the lungs and expulsion of air from the lungs into the atmosphere. They are passive.
14. Due to which forces does the volume of the chest decrease during a calm exhalation?
    Due to the elastic traction of the lungs, the elastic forces of the abdominal wall and the weight of the chest.
15. What is the mechanism of transferring of the force of elastic traction of the lungs to the chest, which compresses it and promotes exhalation?
    Creation of a gradient of atmospheric pressure on the thorax , it is larger outside than inside (acting through the airways) on the force of elastic traction of the lungs.
16. Contraction of which muscles provides active exhalation during forced breathing? Why does the contraction of internal intercostal muscles lead to the lowering of the chest?
    The abdominal and internal intercostal muscles. Because the momentum of force lowering the ribs downwards is greater than the momentum of force that raises them upwards.
17. What types of breathing are there, what is the difference between them, what factors determine the type of breathing, which is the main type of breathing for men and women?

They are: thoracic and abdominal. With the thoracic type of breathing, the expansion of the chest cavity occurs mainly due to the contraction of the chest muscles, with the abdominal mainly due to the diaphragm. The factors are: gender and type of work. Men have a predominantly abdominal respiration type, and women - thoracic.

18. What pulmonary volumes do you know? What lung capacities do you know?
    They are: tidal volume, reserve volume of inhalation, reserve volume of exhalation, residual volume. Pulmonary capacity - is a combination of two or more pulmonary volumes: total lung capacity, vital lung capacity, functional residual capacity.
19. What is lung ventilation? What indicator characterizes its intensity?
    It is the gas exchange between atmospheric and pulmonary air. Minute volume.
20. Name the basic methods of artificial respiration.
    Rhythmic propulsion of air into the lungs through the respiratory tract, artificial rhythmic expansion or compression of the chest, rhythmic stimulation of the respiratory muscles.
21. What is the composition of the atmospheric air?
    Oxygen comprises 20.93%, carbon dioxide 0.03%, nitrogen 79.04%.
22. Starting from which week of intrauterous development has the fetus periodic breathing movements? What is their significance? What factors enhance them?
    From 11 weeks. Contributes to the development of lungs and blood circulation in the fetus due to the occurrence of negative pressure in the chest (suction action). Hypoxia, hypercapnia, acidosis.
23. What is the frequency of periodic respiratory movements of the fetus, do the lungs unfold, or does the amniotic fluid enter the respiratory tract and lungs?
    It is 40-70 per minute, the lungs are partially unfolded, liquid enters the respiratory tract and the lungs.
24. What is the frequency of respiration in the newborn? Compare with adult norm.
    It is 30-40 per min. (12 to 16 per minute for adults).
25. How does the percentage of carbon dioxide and oxygen in the alveolar air vary with age? What are these indicators in a newborn child and in adults?
    The content of carbon dioxide gradually rises from 2, 8% to 5.5% (adult norm). The oxygen content is gradually reduced from 17.8% to 14.0% (adult norm).
26. Determine the main difference of the hemoglobin of the fetus from adult hemoglobin? What functional value does this have?
    Greater affinity to oxygen; It helps the fetus to develop normally under conditions of hypoxia.
27. What is the percentage ratio of fetal hemoglobin, hemoglobin of an adult and hemoglobin of a newborn ? In what period of postnatal development is the fetal hemoglobin substituted by adult hemoglobin in greater percentage?
    For the fetus: 60-80% HbF, for an adult 40-20% HbA. During the newborn period up to the 5-6 months of life.
28. What is the organ of external breathing for a fetus? Does the fetus have respiratory movements?
    It is the placenta. It does.

Tasks for self-control:

1. A 68-year-old woman with pulmonary fibrosis is complaining of increased dyspnea during daily activities. She is referred for pulmonary function testing to assess the progression of

her disease. Which of the following laboratory values can be found at her diagnosis?
A. Decreased diffusing capacity of the lung *
B. Increased residual volume
C. Decreased forced expiratory volume exhaled in 1 second (FEV1)/forced vital capacity (FVC)
D. Increased lung compliance
E. Increased airway resistance corrected for lung volume

2. A 78-year-old woman visits her physician's office with a chief complaint of fatigue and shortness of breath. The doctor indicates that he wants her to go to the hospital to get some pulmonary function tests. A spirometer can be used to directly measure which of the following in this case?
A. FRC
B. Peak flow rate
C. Residual volume
D. Total lung capacity
E. Vital capacity *

3. A 76-year-old patient with emphysema came for his annual pulmonary function testing to assess the progression of his disease. As a result of alveolar septal destruction because of emphysema, there is a decrease in which of the following?
A. Airway resistance
B. Alveolar dead space
C. Diffusing capacity *
D. Lung compliance
E. Total lung capacity

4. A 48-year-old coal miner complains of shortness of breath and a strong cough. He has smoked one to two packs of cigarettes per day since he was 16 years old. Pulmonary function studies are ordered, including an esophageal balloon to measure intrapleural pressure. Normally, intrapleural pressure is negative throughout tidal inspiration and expiration because of which of the following?
A. The lungs have the tendency to recoil outward throughout a tidal breath.
B. The chest wall has the tendency to recoil inward throughout a tidal breath.
C. The lungs and chest wall recoil away from each other throughout a tidal breath. *
D. The lungs and chest wall recoil in the same direction throughout a tidal breath.
E. A small volume of air leaves the pleural space during a tidal breath.

5. A 6′3″ tall, 140-lb, 20-year-old man was watching television when he felt pain in his shoulder blades, shortness of breath, and fatigue. His father noticed how pale he was and took him to the emergency department. Physical examination revealed decreased tactile fremitus, hyperresonance, and diminished breath sounds. A chest x- ray revealed a 55% pneumothorax of the right lung, which was attributed to rupture of a bleb on the surface of the lung. What changes in lung function occur as a result of pneumothorax?
A. The chest wall on the affected side recoils inward.
B. The intrapleural pressure in the affected area equals to atmospheric pressure. *

C. The trachea deviates away from the affected lung.
D. There is hyperinflation of the affected lung.
E. The ratio on the affected side increases above normal.

6. A 62-year-old man with congestive heart failure (CHF) develops increasing shortness of breath in recumbent position. A chest x-ray reveals cardiomegaly, horizontal lines perpendicular to the lateral lung surface indicative of increased opacity in the pulmonary septa, and lung consolidation. Pulmonary edema in CHF is promoted by which of the following?
A. Decreased pulmonary capillary permeability
B. Decreased pulmonary interstitial oncotic pressure
C. Increased pulmonary capillary hydrostatic pressure *
D. Increased pulmonary capillary oncotic pressure
E. Increased pulmonary interstitial hydrostatic pressure

7. A 28-year-old woman on oral contraceptives develops tachypnea and reports dyspnea. A ventilation/perfusion scan is ordered to check for pulmonary thromboembolia. Which of the following explains best of all the fact, that when she makes normal inspiration, more air gets to the alveoli of the base of the lungs than to the alveoli of the apex?
A. The alveoli at the base of the lung have more surfactant.
B. The alveoli at the base of the lung are more compliant. *
C. The alveoli at the base of the lung have a lower ratio of surfactants
D. There is a more negative intrapleural pressure at the base of the lung.
E. There is more blood flow to the base of the lung.

8. A 43-year-old woman with a history of asthma gets to the emergency department with an acute asthma attack after her bronchodilator inhaler ran out the day before. At which of the following is the airway resistance greater?
A. At low lung volumes compared with high lung volumes *
B. At lower values for Reynolds number
C. During inspiration compared with expiration
D. In the total cross-section of the small airways compared with the total cross-section of the central airways
E. With laminar flow than with turbulent flow

9. Lung ventilation of a person is increased as a result of physical activity. Which of the following indices of the external respiration is much higher than in a state of rest?
   A. Respiratory volume *
   B. Vital capacity of lungs
   C. Inspiratory reserve volume
   D. Expiratory reserve volume
   E. Total lung capacity

10. A man made a quiet expiration. Name the air volume that his lungs contain:
   A. Functional residual capacity *
   B. Residual volume
   C. Expiratory reserve volume

D. Respiratory volume
E. Vital lung capacity

11. A child asked you to blow a balloon as much as possible in a one exhalation.What air volume will you use?
A. Vital volume of the lungs *
B. Inspiration volume
C. Functional residual volume
D. Total volume of the lungs
E. Backup volume of the inspiration

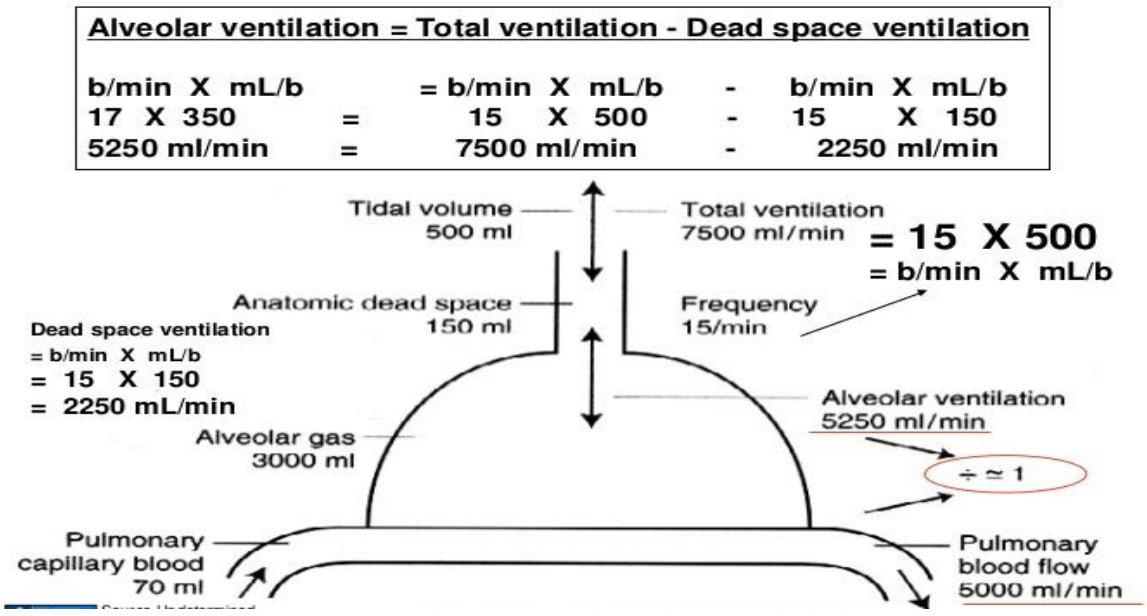
METHODOLOGICAL DEVELOPMENT №10

Topic: Exchange of respiratory gases in lungs and tissues**.**
The number of hours: 2 hours
The object of learning:
To know: the laws of diffusion of gases from one space to another, the morphology and peculiarities of the pulmonary and vascular membranes, through which blood gases are diffused, the exchange of respiratory gases between different environments, the mechanisms of ventilation and blood supply of alveoli.
To be able to: Explain the mechanisms of diffusion of gases between alveolar and atmospheric air, between blood and alveoli, between blood and tissues, ways of transport of gases.

Theoretical questions for self-preparation

1. Respiratory gas exchange between alveolar air and venous blood in the pulmonary capillaries.
2. The factors affecting pulmonary gas exchange between alveolar air and venous blood in the pulmonary capillaries.
3. The relationship of ventilation to alveoli blood supply.
4. Gas exchange between tissues and blood in capillaries of systemic circulation.

Key words and terms: diffusion ability of the lungs, diffusion, perfusion, ventilation, alveolar ventilation, minute volume of breath, gas pressure, partial pressure of gases.



Functional pulmonary tests
(can be obtained by spirography)

Respiration rate (RR) is in range of 12-14 per min at a resting state.
Minute respiratory volume (MRV) – is the air volume, inhaled into lungs in 1 min. during calm breathing, it is near 6-8 l per min; It equals to the Tidal Volume (TV 500 ml) x Respiration Rate (RR).
Anatomic dead space (ADS) – 150 ml - all divisions of the respiratory tract, including up to 16 generations of bronchi, that do not take part in gas exchange because they do not contain alveoli.

Alveolar ventilation (AV) – the total volume of air, entering the alveoli per 1 min.

AV= (Tidal Volume (500 ml) - Anatomic Dead Space (150ml)) x Respiratory Rate

Coefficient of lung ventilation (CLV) = Tidal volume (500 ml) – Anatomic dead space (150 ml) divided by the Functional residual volume (Expiratory reserve volume + Residual volume)

APPLICATION №1
Definition of main terms and concepts:

Spirography is a graphic record of inspired and expired air volumes during breathing.
The gas pressure gradient is the difference between the levels of gas pressure on both sides of the biological membranes.
Gas tension is the partial pressure of gas molecules dissolved in liquid.
Partial pressure is part of the total pressure of a gas mixture, which is proportional to the portion of the content of a particular gas.
Perfusion – blood flow through the microcirculation system.
Shunt – blood flow from the artery to the vein bypassing the capillaries, that are not involved in the process of gas exchange.
The Holden effect is the ability of reconstituted hemoglobin (deoxyhemoglobin) of the venous blood to actively bind carbondioxide.
Gas exchange is a process of equalizing the inequality of partial gas pressures between two environments.
Blood gases are gases dissolved in the blood plasma (O_2, CO_2, N_2), which determine the value of their tension. The term "blood gases" also includes the concentration ratio of water ions (H, pH).

APPLICATION №2

Control questions and answers on the topic: "Diffusion exchange of respiratory gases in lungs and tissues."

1. What is the minute respiratory volume, with which device can it be measured? Indicate the number of respiratory movements per minute in a state of rest. What does the term "hyperventilation" mean?
   The volume of air passing through the lungs in one minute, which can be measured with a spirograph. It is 12-18 per min. An arbitrary increase in breathing that does not meet the metabolic needs of the body.
2. What is the minute ventilation at resting state? What does the term "hyperpnea" mean?
   It is 6-7 liters. Involuntary increased of respiration due to real needs of the body.
3. What is the maximum ventilation of lungs, what average value does it have for a trained and untrained person?
   Maximum volume of air passing through the lungs at maximum forced respiration (maximum frequency and depth of breath). It is 70-100 liters and 120-150 l, respectively.

4. What is the composition of exhaled air?
   Oxygen 16.0%, carbon dioxide 4.5%, nitrogen 79.5%.
5. What is the composition of alveolar air?
   Oxygen 14.0%, carbon dioxide 5.5%, nitrogen 80.5%.
6. Why is the composition of alveolar air in resting state constant?
   In resting state one inhales a small amount of air and fresh air does not get to the alveoli by convection, their ventilation is carried out by diffusion continuously during the phase of inhalation and exhalation.
7. Name the driving force that provides the transition of CO2 from the venous blood of the lungs into the alveolar air. Calculate its value.
   The difference between the tension of CO2 in venous blood (46 mm Hg) and its partial pressure in the alveolar air (40 mm Hg), that is pCO2 46-40 = 6 mm Hg.
8. What is the driving force that provides O2 transition from alveolar air to venous blood (oxygenation of blood); calculate its value.
   The difference between the partial pressure of O2 in the alveolar air (100 mm Hg) and its tension in the venous blood (40 mm Hg), that is, pO2 100 - 40 = 60 mm Hg.
9. List the factors contributing to gas exchange between alveolar air and blood.
   1) Large surface of alveoli and pulmonary capillaries; 2) the high rate of diffusion of gases through a thin pulmonary membrane; 3) the intensity of blood circulation and ventilation of the lungs; 4) correlation between the intensity of blood circulation in the lungs and their ventilation.
10. What is the relation between the minute volume of alveolar ventilation and the minute volume of blood in the small circle of blood circulation? Indicate the amount of O2 consumed by a person in 1 minute.
    It is approximately 0.8.It is about 300 ml.
11. Explain the mechanism of correlation between the intensity of blood circulation in the lungs and their ventilation.
    When blood flows with a lack of oxygen in the small circle (in areas of the lungs that are poorly ventilated), the vessels in the walls of the corresponding alveoli are narrowed to provide a reduction in blood flow through this area of the lungs. In the alveoli, well-ventilated vessels are dilated, and the blood flow is properly full.
12. What is the name of the barrier through which the gas exchange between the blood and the lungs occurs? Name its structural elements. Specify its thickness.
    It is the pulmonary membrane formed of a layer of endothelial cells, two main membranes, layer of alveolar epithelium and a layer of surfactant. It is about 12 microns.
13. What is the partial pressure of gas? What indicators do you need to know for its calculation?
    Part of the pressure of a gas mixture, which is accounted for this gas. The total pressure of the gas mixture and the percentage of the gas in this mixture.
14. Calculate the partial pressure of oxygen in the alveolar air.
    (760x21)/100 = 159.6 mm Hg
    because
    760mm is 100% and 21%- is x (in the atmospheric air)
    In the alveolar air:
    (760 mm Hg - 47 mm Hg) / 100% x 14%
    x = 104 mm Hg
    47 mm Hg is the partial pressure of water vapor in the alveolar air.

15. What is the partial pressure of oxygen in the alveolar air and its tension in the arterial and venous blood and in the cells?
    In alveolar air and arterial blood - 100 mm Hg. In venous blood - 40 mm Hg, in the cells is about 1-10 mm Hg
16. What is the partial pressure of CO2 in the alveolar air and its tension in the arterial and venous blood and in the interstitial fluid?
    In the alveolar air and in arterial blood is 40 mm Hg, in venous blood is 46 mm Hg, in interstitial space is 70-80 mm Hg.

Tasks for self-control:

1. A 12-year-old boy has a severe asthmatic attack with wheezing. He experiences rapid breathing and becomes cyanotic. His arterial Po2 is 60 mm Hg and his Pco2 is 30 mm Hg. Which of the following statements about this patient is most likely to be true?

A. Forced expiratory volume1/forced vital capacity (FEV1/FVC) is increased
B. Ventilation/perfusion (V/Q) ratio is increased in the affected areas of his lungs
C. His arterial Pco2 is higher than normal because of inadequate gas exchange
D. His arterial Pco2 is lower than normal because hypoxemia is causing him to hyperventilate *
E. His residual volume (RV) is decreased

2. To treat this patient, the physician should administer:

A. an α1-adrenergic antagonist
B. a β1-adrenergic antagonist
C. a β2-adrenergic agonist *
D. a muscarinicagonist
E. a nicotinicagonis

3. A young woman had bronchospasm when she entered a chemical plant with a strong smell of paint and varnishes. This reflex was caused by irritation of the following receptors:

A. Irritant *
B. Juxtaglomerular
C. Pleura receptors
D. Central chemoreceptors
E. Peripheral chemoreceptors

4. A patient with Guillian-Barre syndrome develops paralysis of the respiratory muscles that increases PaCO2 from 40 to 60 mmHg and increases the concentration of hydrogen ions in the arterial blood from 40 mEq/L (pH 7.4) to 50 mEq/L (pH 7.3). As a result, which of the following would happen?

A. The central chemoreceptors would be stimulated *
B. The plasma [HCO3–] would decrease
C. The pH of the urine would increase
D. The amount of ammonium excreted in the urine would decrease
E. The peripheral chemoreceptors would be inhibited

5. A 26-year-old man training for a marathon reaches a workload that exceeds his anaerobic threshold. If he continues running at or above this workload, which of the following will increase?

A. Alveolar ventilation *
B. Arterial pH

C. PaCO2
D. Plasma [HCO-3]
E. Firing of the central chemoreceptors

6. A 14-year-old adolescent girl was presented with a lump in the neck. Fine needle aspiration biopsy reveals acinic cell carcinoma of the parotid gland. During the parotidectomy, there was a compressive injury of the glossopharyngeal nerve. As a result, which of the following respiratory reflexes will be impaired?

A. Aortic baroreceptor reflex
B. Carotid body chemoreceptor reflex *
C. Hering-Breuer inflation reflex
D. Irritant airway reflex
E. Juxta pulmonary capillary (J) receptor reflex

7. A 36-year-old man visits his doctor because his wife was complaining about his snoring, but recently she noticed that his breathing stops for a couple of minutes during sleeping. He undergoes polysomnography and ventilatory response testing to ascertain the extent and cause of his sleep apnea. The activity of the central chemoreceptors is stimulated by which of the following?

A. A decrease in the metabolic rate of the surrounding brain tissue
B. A decrease in the PO2 of blood flowing through the brain
C. An increase in the PCO2 of blood flowing through the brain *
D. An increase in the pH of the CSF
E. Hypoxemia, hypercapnia, and metabolic acidosis

8. A 58-year-old woman experiences an acute period of asthma, which causes her breathing to become obstructed and faster. As a result, which of the following change in airflow is expected?

A. Flow in the trachea and upper airways will become more laminar.
B. The pressure gradient required for airflow will increase. *
C. The resistance to airflow will decrease.
D. The resistance to airflow will increase linearly with the decrease in airway radius.
E. Reynolds number will decrease.

METHODOLOGICAL DEVELOPMENT №11

Topic: Respiratory gas transport in the blood.
The number of hours: 2 hours
The object of learning:
To know: the transport of oxygen by blood, the oxygen capacity of hemoglobin, the oxygen capacity of arterial blood, the dissociation curve of oxyhemoglobin and the factors that influence it, the effect of Bohr, the forms of carbondioxide transported by blood.
To be able to: calculate oxygen capacity of the blood, explain the methods of carbondioxide transport.

Theoretical questions for self-preparation

1. Oxygen transport by blood.
2. Oxyhemoglobin dissociation curve and factors affecting it.
3. Carbon dioxide transport by blood.
4. Exchange of gases between venous blood and alveolar air.
5. Exchange of gases between tissues and blood.

Key words and terms: hypoxia, hypoxemia, hypercapnia, hypocapnia, hyperbaric oxygenation, arterio-venous difference, oxyhemoglobin, oxygen capacity of hemoglobin, oxygen capacity of arterial blood, oxygen utilization, half-saturation, Bohr effect, Halden effect, carbhemoglobin.

Practical skills:

Task 1. **Draw the scheme of oxyhemoglobin dissociation curve and list the factors influencing the oxygenation of arterial blood.**

Task2**. Draw the scheme of transportation of carbon dioxide gas in the capillaries of the large and small circles of blood circulation.**

APPLICATION №1
Definition of main terms and concepts:

Oxygemaglobin is an unstable compound of hemoglobin with oxygen.
Oxygen capacity of hemoglobin is the ability of 1 gram of hemoglobin (partial pressure of oxygen 100 mm Hg and temperature 37 C) to bind 1,34 ml of O2 under normal conditions.
Oxygen capacity of arterial blood is the quantity of oxygen transported by arterial blood (when the content of hemoglobin in the blood is 150g per liter, it can binds about 200 ml of oxygen). (Oxygen capacity of hemoglobin 1,34 ml x hemoglobin level in blood).
Hyberbaric oxygenation is a method of oxygen saturation while the patient is put in a high pressure chamber and is breathing air with high oxygen content.
Carbhemoglobin is the compound of hemoglobin with CO 2.
Carbonicanhydrase is an erythrocyte enzyme that catalyzes the reaction of hydration of carbondioxide.

APPLICATION №2

Control questions and answers on the topic: "Respiratory gas transport in the blood".

1. In what states are gases transported by blood? What determines the amount of dissolved O2 and CO2 in arterial and venous blood?
   In the state of physical dissolution and in the form of chemical compounds.It is depends on the partial pressure of O2 and CO2 in the blood, that is, in the alveoli of the lungs and in the tissues, respectively.
2. What compound does hemoglobin form with carbonmonoxide? What is its feature?
   Carboxyhemoglobin. This is a stable compound that dissociates slowly, and it is in 150-300 times more stable than the compound of hemoglobin with O2.
3. What compound does hemoglobin form with CO2? What is its feature?
   Carbhemoglobin. It dissociates easily at lower content of CO2.
4. How is CO2 transported by blood?
   Carbon dioxide is transported by blood in three forms: approximately 7% as carbon dioxide dissolved in the plasma, approximately 70% in the form of $HCO3^-$ dissolved in plasma and in red blood cells, and approximately 23% bound to hemoglobin.
5. What are the stages of transformation of CO2.
   1) Hydration of CO2 in erythrocytes, i.e. formation of carbonic acid; 2) dissociation of carbonic acid to ions (H + and HCO3-) in red blood cells; 3) formation of bicarbonates in red blood cells and plasma.
6. Where is the size of the red blood cells bigger ? In venous or arterial blood? How can you explain it?

In venous blood. This is due to the flow of water into the red blood cells due to the accumulation of ions in side the red blood cells and increased osmotic pressure in them.

7. What enzyme catalyzes the hydration and dehydration of CO2 and where? What is necessary for this reaction?
   It is carbonic anhydrase in erythrocytes. Zinc is needed.
8. Which cations bind to the anions of HCO3 in red blood cells and plasma? Name these compounds.
   Cation of K + in erythrocytes and cation of Na + in plasma. Bicarbonates.
9. What is Holden effect?
   Holden effect is the ability of deoxyhemoglobin to increase CO2 binding compared to oxyhemoglobin.
10. What factors influence the saturation of hemoglobin with oxygen in the lungs?
    They are: increased tension of O2, decreased tension of CO2, increased values of pH, decreased values of temperature in the blood.
11. What factors influence the dissociation of oxyhemoglobin in the blood of tissues? What is the biological content of the high dissociation rate of oxyhemoglobin at low voltage of O2?
    The decreased tension of O2, increased tension of CO2, decreased pH, increase of temperature in the blood.
12. What is the biological essence of small dependence of saturation of hemoglobin with oxygen in the case of reduction of the partial pressure of oxygen from 100 to 60 mm Hg in the blood?
    The saturation of hemoglobin with oxygen in the lungs will be sufficient for the body even at significant (up to 60 mm Hg) fall of partial pressure O2 in the alveolar air.
13. What method can determine the saturation of hemoglobin with oxygen? What is the oxygen capacity of blood?
    By oxygenometry, it is 96-98%. The maximum amount of oxygen (in ml), which binds to 100 ml of blood.
14. How much oxygen (in% and ml / l) is contained in arterial and venous blood? Calculate the arteriovenous oxygen difference.
    It is 19-20 vol.% (190-200 ml / l) in arterial blood, in venous 14,5-15,5 vol.% (145-155 ml / l). The difference is 4.5 vol%(about 45 ml / L).
15. How much dissolved and chemically bound oxygen is contained in arterial blood with a total oxygen content of 20% (200 ml / l)?
    The physically dissolved oxygen content is 0.3 vol% (3 ml / l), chemically bound is 19.7% (197 ml / l).
16. What is the coefficient of oxygen utilization?
    It is the percentage of oxygen absorbed by tissues from arterial blood. The percentage of oxygen in the arterial blood is 30-40% at resting state, and up to 50-60% during work. How much oxygen does a person consume during 1 min. in resting state, at fast walking and during forced muscular work?
    At resting state 250-300 ml per minute, at fast walking 2,5 liters per minute, during forced muscular work up to 4 liters per minute.
17. What is external breathing? What are the four stages of this process?
    It is the process of gas exchange between the blood of the body and the environment. It includes ventilation of the lungs and gas exchange between the lungs and the blood, transportation of blood gases, gas exchange between the blood and tissues

Tasks for self-control:

1. After hyperventilation a sportsman has a short stop of breathing. What changes in blood are the reasons for it?

A. Decrease of pH.
B. Decrease of the tension of CO2. *
C. Increase of the tensionof CO2.
D. Decrease of the tension of O2.
E. Increase of the tension of CO2 and O2.

2. A group of mountain climbers went through a blood analysis at the height of 3000 m. It revealed a decrease of HCO3 to 15 micromole/l (the normal is 22-26 micromole/l). What is the mechanism of HCO3 decrease?

A. Intensification of acidogenesis
B. Hyperventilation *
C. Hypoventilation
D. Decrease of ammoniogenesis
E. Decrease of bicarbonate reabsorption in the kidneys

3. The patient suffer of increased of carbon dioxide content in blood. How will be changed the breathing of the patient?

A. The depth and frequency will increase. *
B. The depth will decrease.
C. The depth will increase.
D. The frequency will decrease.
E. The frequency will increase.

4. The most powerful respiratory stimulus for breathing for a healthy person is _____.

A. A low tension of oxygen in tissues
B. An increased tension of carbondioxide *
C. Decrease of pH (acidosis)
D. Increased of pH (alkalosis)
E. All mentioned above

5. A hospitalized patient was found in semi comatose state. Arterial blood gases reveal hypercapnia. Which of the following is the most likely cause of the high arterial PCO2?

A. A decreased metabolic activity
B. A decreased alveolar deadspace
C. Profound hypoxia *****
D. Alveolar capillary block
E. Increased alveolar ventilation

6. A patient with incessant hiccups is instructed to breathe into and out of a bag in order to rebreathe exhaled CO2. In the blood, the majority of CO2 is transported as which of the following?

A. Dissolved CO2
B. Carbonic acid
C. Carbaminohemoglobin*
D. Carboxyhemoglobin

E. Bicarbonate

7. An increase in the P50 of the oxyhemoglobin curve would result in the decrease of ….
A. Metabolism
B. pH *
C. Temperature
D. PCO2
E. 2,3-BPG (diphosphoglycerol)

8. A pregnant woman came to the hospital for blood analysis. Which of the following values would normally be smaller in the fetus than in the mother?
A. Hemoglobin concentration
B. Affinity of hemoglobin for oxygen
C. Erythrocyte binding of 2,3-BPG (diphosphoglycerol)*
D. Cardiac output/kg body weight
E. Cardiac glycogen content

9. What factors will increase the process of hemoglobin saturation?
A. The increased CO2tension of the arterial blood
B. An increased level of hemoglobin
C. An increased temperature
D. An increased O2 tension of the arterial blood *
E. The decreased pH level of arterial blood

10. Which of the following processes can explain best of all why oxygen tension of blood is adequate for the needs of the tissues of acclimatized persons at high altitudes?
A. Arterial PO2 returns to normal
B. The increased hemoglobin concentration *
C. The blood flow to the lungs increases, improving the V/Q ratio
D. An increased Nitric oxide release from endothelial cells
E. A compensatory decrease in the of mitochondria's number

11. Which of the following increases the affinity of hemoglobin to oxygen?
A. Metabolic acidosis*
B. Exercises
C. Hypoxemia
D. Anemia
E. Carbon monoxide poisoning

12. A 67-year-old male with chronic bronchitis is brought to the Emergency Department with disturbed breathing and cyanosis. Which of the following can cause cyanosis in this case?
A. An increased affinity of hemoglobin to oxygen
B. A decrease of red blood cells percentage (hematocrit)
C. An increased concentration of carbon monoxide in the venous blood
D. A decreased concentration of iron in the red blood cells
E. An increased concentration of deoxygenated hemoglobin *

METHODOLOGICAL DEVELOPMENT №12

Topic: Regulation of respiration**.**

The number of hours: 2 hours

The object of learning:

To know: the basic principles of breathing regulation, the structure and activity of the respiratory center.

To be able to: determine the maximum duration of respiratory retention at different tests (Shtange, Gench, etc.) and analyze the mechanisms of respiratory regulation.

Theoretical questions for self-preparation

1. The brainstem respiratory center and its participation in the regulation of respiration.
2. Mechanoreceptor respiratory reflexes.
3. Chemoreceptor respiratory reflexes.
4. Influence of non-specific factors on respiration.
5. The features of breathing regulation under water (great depth).
6. The functional system of maintaining the constancy of gas composition of arterial blood.

Keywords and terms: hypoxia, hypoxemia, hyperventilation, hypoventilation, apnea, asphyxia, hypercapnia, hypocapnia, pre-Botzinger complex, dorsal respiratory group, ventral respiratory group, apneustic center, pneumotoxic center, Hering-Breuer reflex, carotid bodies, aortic bodies.

Practical works:

Task 1. Shtange test with maximum breathing delay during inspiration.

After a deep inspiration (but not maximal possible deep), hold the breathing as long as possible, closing your nose. Record the time of start and the duration of it. Record the result. The next test can be done in 5 minutes. (Normal value is 55-60 seconds)

After a quiet exhale record the time of the beginning of breathing delay. Don't breathe as long as possible. Determine the duration of the delay. Record the result. The next test can be done in 5 minutes. (Normal value is 35-40 s.)

Task 2. A test with maximum breathing delay after a deep inspiration, which is done after hyperventilation.

Within a few seconds, breath in the mode of hyperventilation (deeply and with high frequency), then take a deep inhale and delay your breathing, record the duration of this period.

APPLICATION №1

Definition of main terms and concepts:

Hyperventilation is a state in which the volume of pulmonary ventilation exceeds its normal values.

Alveolar hyperventilation is an increase in the volume of atmospheric air or a mixture of gases reaching the alveoli of the lungs; characterized by a decrease in the partial pressure of C02 in the arterial blood, namely hypocapnia;

Hypercapnia is a concept that characterizes the level of partial pressure of CO2 in arterial blood plasma, which is higher than 45 mm Hg.

Hypocapnia is a concept that characterizes the level of partial pressure of CO2 in arterial blood plasma, which is less than 35 mm Hg.

Hypoxemia is a decrease in the partial pressure of O2 in the arterial and mixed venous blood plasma, below 80 and 40 mmHg, respectively.

Hypoxia is a lack of oxygen of a tissue.

APPLICATION №2

Control questions on the topic: " Regulation of respiration"

1. Where are the respiratory center neuronal groups located (name part of the brainstem)? Where is the main part of the respiratory center located?

In the pons and the medulla oblongata.

2. Which neurons of the spinal cord receive impulses from the respiratory center?
The motor neurons of the respiratory muscles, located in the anterior horns of the spinal cord.
3. What happens with breathing after the spinal cord is cut directly under the medulla oblongata or after a damage of the medulla oblongata?
Breathing will stop in both cases.
4. How does breathing change after the spinal cord is cut between the cervical and thoracic segments or between the pons and the medulla oblongata?
Breathing will continue only by contraction of the diaphragm; the rhythm of breathing will be disturbed, the frequency of respiration will be reduced due to a longer exhalation.
5. List the factors that provide and support the automatism of respiratory center.
The spontaneous activity of the neurons of the respiratory center, humoral impacts on the center, afferent impulses from chemo- and mechanoreceptors, interaction of excitatory and inhibitory neurons of the respiratory center.
6. What factors cause excitation of the inspiratory neurons?
Increase in partial pressure of CO_2, decrease in pH (due to excitation of peripheral (arterial) and central chemoreceptors), decrease in partial pressure of O_2 (only through excitation of arterial chemoreceptors), descending effects of the neurons of the pons.
7. What impulses can cause inhibition of inspiratory neurons? What are the underlying principles of structural-functional connections in the implementation of inhibitory influences?
Afferent impulses from pulmonary stretch receptors based on negative feedback, as well as from inspiratory neurons according to the principle of reciprocal feedback, descending effects of the neurons of the pons according to the principle of positive feedback.
8. What processes cause excitation and inhibition of the excitatory neurons? What regulatory principle is required to provide these processes?
By stimulating impulses from central chemoreceptors and stretching pulmonary receptors, inhibitory impulses from the inspiratory neurons according to the principle of reciprocal feedback.
9. What is the role of hypothalamus in regulation of respiration? Give examples.
It provides increased respiration for various types of activity and body conditions. In the case when it is necessary to increase metabolic activity (for example, in the case of a general protective response, during physical work, at emotional excitement, at an increase in body temperature).
10. What is the role of the cerebra in the regulation of respiration?
Adaptation of breathing to changed conditions of external environment, through voluntary breathing control.
11. What is the Hering-Breuer reflex, what is its significance in self-regulation of breathing?
They are reflexes arising from mechanoreceptors of the lungs because of their stretching during inspiration through afferent fibers of the vagus nerves; they contribute to rhythmic changes of inhalation and exhalation.
12. What are the main peripheral and central chemoreceptor zones, what is their role in the regulation of respiration?
They are: aortic arch, carotid sinus, medulla oblongata.
They promote changes in pH and partial pressure of respiratory gases to the needs of the body.
13. How the decrease of pH, partial pressure of O_2 and increase of CO_2 partial pressure influence the central and peripheral (arterial) chemoreceptors of blood?
The decreased pH and increased CO_2 partial pressure excite both receptors; decreased O_2 partial pressure stimulates arterial receptors.
14. Where are the irritant receptors located, what are their functional features?
In the epithelium and subepithelial layer of all respiratory tract; they have properties of mechanoreceptors.
15. What type of irritants are the irritant receptors of the respiratory tract and lungs sensitive to? What reactions arise during this?
Parts of dust, a vapor of caustic substances (ether, ammonia), pathological processes in the respiratory tract and lungs.

The reactions can be: cough, scratching in the throat, sore throat, shortness of breath.
16. Describe briefly Frederick's experiment, that proves the role of the blood gas composition in the regulation of the respiratory center.
The experiment is performed on two dogs with "cross-flow" blood circulation: each dog's head is supplied with blood from the trunk of another one ("intersection" of the carotid arteries and jugular veins, respectively).
17. How and why will the dogs' respiratory center activity change with a squeezed trachea in Frederick's experiment?
It is inhibited by the blood supply to its head that is rich in carbondioxide and poor in oxygen from a dog with an uncompressed trachea.
18. What proves Frederick`s experiment with a cross-flow of blood connected with breathing regulation?
The humoral regulation of respiration, by changes of gas composition of blood (pCO2, pO2, pH) and its influence on the respiratory center.
19. Describe Holden's experiment, that proves the main stimulatory effect of carbon dioxide on breathing?
In a confined space (the content of O2 falls, and CO2 is increasing) the respiration increase causes hyperpnea; in case of excessive absorption of CO2 hyperpnea does not develop.
20. What happens with breathing after intense hyperventilation of the lungs? Why?
Short-term respiratory stoppage (apnea) in connection with a sharp decrease in the partial pressure of CO_2.
21. What happens with oxygen saturation of hemoglobin after hyperventilation of the lungs? Why?
It will not change, because hemoglobin of a healthy person is richly saturated by oxygen during quiet breathing.
22. What happens to breathing after any voluntary delay in it? Why?
Hyperpnea occurs, that is a more frequent and deeper breathing as a result of the accumulation of CO_2 in the blood.
23. Why a voluntary respiratory delay cannot be prolonged? How can it be prolonged?
CO2 that is accumulated in the blood excites the inspiratory neurons of the respiratory centers, which results in an irresistable desire for inhalation.
Previous hyperventilation or regular training.
24. What is the principle of negative feedback in the regulation of respiration when the partial pressure of CO2 in the blood is changing? What does it lead to?
Hypercapnia causes increased activity of the respiratory center, increased ventilation of the lungs and, consequently, a decrease in the CO_2 content in the blood.
Hypocapnia causes opposite effects. As a result, the pressure of CO_2 in the blood is maintained at a constant level.
25. What irritates the chemoreceptors of the carotid sinus: the decrease of the total amount of oxygen, or the decrease of its partial pressure?
Only a decrease in the partial pressure of O_2 (that is, the amount of oxygen dissolved physically in the blood).
26. How do arterial baroreceptors affect breathing reacting to changes of blood pressure?
Increased activity of baroreceptors by increased blood pressure is accompanied by decreased ventilation of lungs, with a decrease of blood pressure the ventilation lungs increases.
27. At what height the mountain disease occurs? What are the manifestations of this disease?
Usually at a height of 3-4 km above sea level and higher. They are: weakness, headache, cyanosis, due to decrease in depth of breathing, heart rate, and blood pressure.
28. List the adaptive changes observed by lack of oxygen in the blood during acclimatization?
1) Increase in the number of erythrocytes in the blood; 2) increase of hemoglobin content in erythrocytes; 3) acceleration of hemoglobin dissociation in tissue capillaries.
29. What changes are observed during acclimatization to lack of oxygen in the body (except changes in the blood)?

1) increase in ventilation of the lungs; 2) increase in the density of blood capillaries; 3) increase in the stability of cells, especially nervous cells to hypoxia.
30. What can lead to aeroembolism (caisson disease)? What danger does it have?
A rapid transition from the conditions of high pressure (in a baroque chamber, under water) to normal. The bubbles of gas (nitrogen) appears in blood that can cause gas embolism (blockage of small vessels).
31. What is the purpose of using hyperbaric oxygenation? What is the mechanism of this phenomenon?
To increase the transport of oxygen to the tissues. In blood, the amount of dissolved oxygen sharply increases, enough to provide the needs of the organism, even without the participation of hemoglobin.
32. What stimulus ensures the development of respiratory motion in the fetus? Why?
It is lack of oxygen. In the body of fetus, the lack of oxygen excites the respiratory center, similarly to adults.
33. List the factors that stimulate the first breath in the newborn.
Accumulation of carbon dioxide in the blood and reduction of oxygen content due to clamping of the umbilical cord, which leads to the excitation of the respiratory center, as well as the flow of afferent impulses in the CNS from the viscero-, proprio- and vestibular receptors.

Changes of breathing after intersection at different levels of the central nervous system.

1. At the level of the first cervical segment of the spinal cord – stopping of breathing;
2. Above the fifth cervical segment of the spinal cord – stopping of breathing;
3. Below the fifth cervical segment of the spinal cord – the respiration becomes superficial and less frequent;
4. Below the sixth thoracic segment of the spinal cord – breathing does not change;
5. Between the medulla oblongata and the Varolii bridge – less frequent and deep breathing;
6. Above the Varolii bridge – the breathing will not change significantly.
7. At the level of the first thoracic – due to diaphragm breathing – superficial and less frequent.

Tasks for self-control:

1. After inhalation of dust a man had a cough. By the excitation of what receptors is it caused:
   A. Irritant *
   B. Juxtaglomerular
   C. Chemoreceptors of lungs
   D. Thermoreceptors of lungs
   E. Nociceptors

2. The toxin produced by Clostridium botulinum blocked the entrance of calcium ions into the nerve endings of the axons of the motorneurons. What is dangerous for life because of this toxin:
   A. Vomiting
   B. Cardiac arrest
   C. Disorder of the vascular tone
   D. Respiratory arrest *
   E. Diarrhea

3. X-ray examination of a patient revealed lung emphysema. What is the reason of short (brief) breath development in this case:
   A. Decreased lung elasticity *
   B. Increased lung elasticity
   C. Inhibition of the respiratory center
   D. Excitation of the respiratory center
   E. Decreasing of alveoli receptor sensitivity

4. A group of mountain climbers went through a blood analysis at the height of 3000 m. It revealed decrease of HCO3 to 15 mmols/l (normal value = 22-26 mmol/l). What is the mechanism of HCO3 decrease?

A. Intensification of acidosis
B. Hyperventilation *
C. Hypoventilation
D. Decrease in ammoniogenesis
E. Decrease in bicarbonate reabsorption in kidneys

5. A child has inhaled a button accidentally. Where is it likely to be?

A. In the trachea
B. In the left main bronchus
C. In the right main bronchus *
D. In the larynx
E. In the esophagus

METHODOLOGICAL DEVELOPMENT №13

Topic: General characteristics of the functions of the cardiovascular system. The electrical activity of the heart and its physiological significance.
Number of hours: 2 hours.
The object of learning :
To know: the structure and functions of the circulatory system (pulmonary circulation and systemic circulation): physiological properties of the myocardium, pacemaker activity of atypical cardiomyocytes.
Be able to: schematically depict pulmonary circulation and systemic circulation, the structure of the heart, the valvular apparatus, to reproduce the experiment of Stanius.

Theoretical questions for self-preparation:

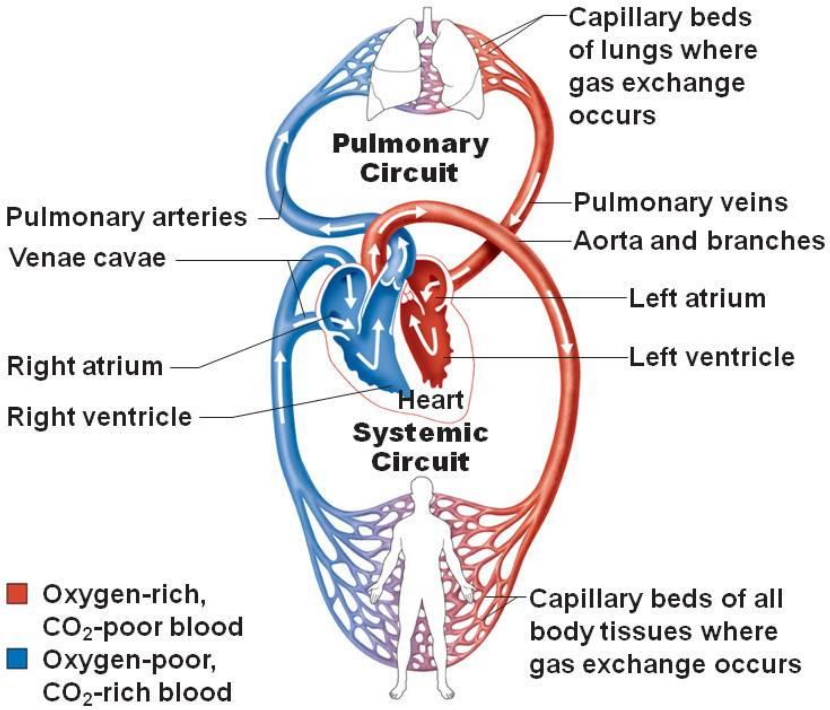
1. The morphological organization of the cardiovascular system.
2. The functions of the heart.
3. Electrical activity of the heart and its physiological importance.
4. Pacemaker activity of atypical cardiomyocytes.
5. Action potential of contractile cardiomyocytes and its ionic mechanisms.
6. The refractory period of the myocardium and it's physiological explanation.
7. The excitation-contraction coupling in the myocardium.
8. The conductive system of the heart and its role in the coordination of the pumping function.

Keywords and terms: large (systemic) circle of blood circulation, small (pulmonary) circle of blood circulation, tricuspid valve, mitral valve, pulmonary semilunar valve, aortic semilunar valve, papillary muscles, upper and lower vena cava.

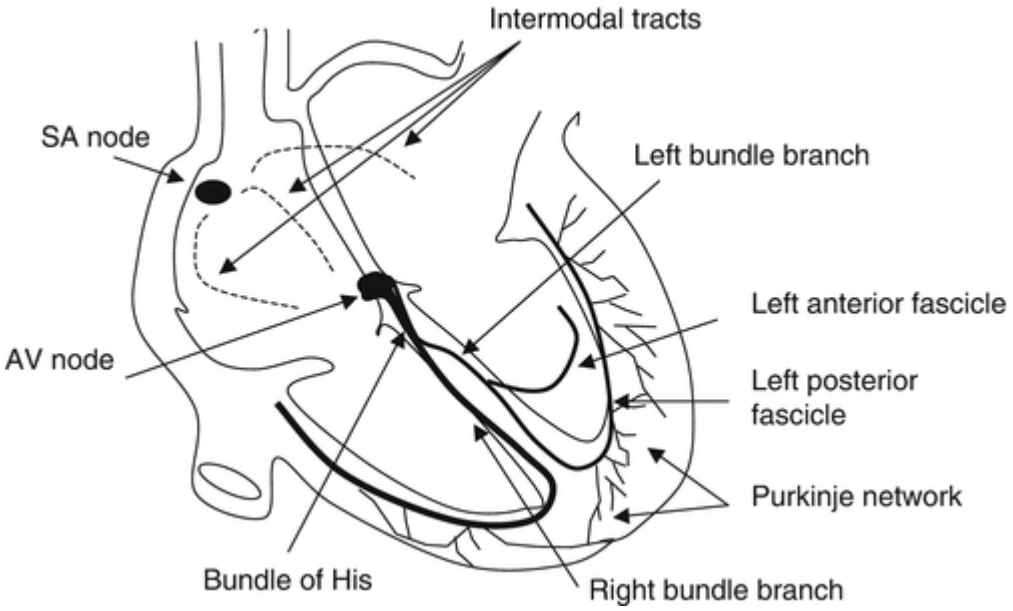
APPLICATION №1
Definition of basic terms and concepts:

Transport of substances in the cardiovascular system **-** consists of substances entering the body, substances transported within the body and substances excreted from the body.

Small (pulmonary) circle - provides the right half of the heart with venous blood from tissues and directs it to the lungs for oxygenation and release from carbon dioxide.
Large (systemic) circle - provides the left half of the heart with oxygenated blood from the lungs and pushes it to all organs and tissues.
The functions of the heart*:* a) to generate the pressure gradient between aorta and right atrium in the systemic circuit (up to 130 mm Hg) and the pressure gradient between the pulmonary artery and the left atrium (up to 25 mm Hg) in the pulmonary circuit.
b) to direct the movement of blood in two sequentially connected hemodynamic circuits: systemic and pulmonary.
c) to regulate blood supply to the body.
The all-or-none law - is the principle that the strength by which a nerve fibre or cardiac muscle responds to a stimulus is independent of the strength of the stimulus. If that stimulus exceeds the threshold potential, the nerve fibre or cardiac muscle will give a complete response; otherwise, there is no response.
Automatism of heart - is the ability of the myocardium to spontaneously generate excitation.
Spontaneous diastolic depolarization - lack of resting phase in the structure of the action potential of the atypical cardiomyocyte.
The conductive system of the heart - is a set of nodes, that provide generation and conduction of excitation to the contractile myocardium. It is formed by atypical cardiomyocytes.
The gradient of automatism - means that the most common rhythm is generated in the sinoatrial node, somewhat less - in the atrioventricular node, the most rare - in the atypical cardiomyocytes of the bundle of His. Normally, all components of the conductive system are excited from the sinus node and do not have their own rhythms.
Electromechanical excitation-contraction coupling not only triggers the process of contraction, but also maintains it for the whole action potential. In its implementation, the leading role belongs to Ca + 2 ions and to their transport mechanisms.
Na + -Ca + 2 exchanger - is a special active transport system that removes calcium ion from the cell in exchange for three ions of sodium entering the cell through a sodium-potassium pump (Na + -K + ATPase)
Practice: 1. Schematic image of circles of blood circulation.



2. **Schematic image of conductive system of the heart.**



APPLICATION №2

Control questions with answers on the topic: General characteristics of the functions of the cardiovascular system. The electrical activity of the heart and its physiological significance.

1. Functional value of the atrium and ventricles.

An atrium is a reservoir that collects blood during systole of the ventricles, and provides additional ventricular filling at the end of their diastole. The ventricles are functioning as a pump forcing blood into the artery.

2. What phase of a AP of a contractile myocardium's cell has the greatest duration?

Phase of repolarization (its slow part - "plateau"). Long refractory period.

3. What is the physiological significance of such a long refractory period of the contractile myocardium cells? What is it's duration in resting state?

It prevents the emergence of tetanic contraction, maintains the pumping function of the heart. 0.27 s (at heart rate 75 beats / min).

4. What is called extrasystole? In what phase of myocardium contraction or relaxation can it appear? Why?

Extraordinary contraction of the heart. In the phase of relaxation, because in the phase of contraction, the cardiac muscle is not excitable.

5. What is fundamentally different from conduction of excitation in the cardiac muscle from conduction of excitation in the skeletal muscle? What is the speed of excitation spread in the contractile myocardium of the atria and ventricles?

The propagation of excitation in the cardiac muscle has a diffuse nature. The speed is lower than in the skeletal system - about 1 m / s.

6. What structural and functional feature of the myocardium provides the possibility of diffuse propagation of excitation along it?

The presence of nexus - intercellular contacts with low resistance (functional syncytium).

7. What is the significance for heart activity of diffuse excitation in the myocardium?

It provides the possibility of excitation and contraction of all cardiomyocytes in systole in accordance with the law "all or none."

8. List the main differences between the process of heart's and skeletal muscle's contraction?

Heart muscle is not contracted tetanically, works according to the law "all or none", the period of contraction of cardiac muscle is longer.

9. What tissue forms the conductive system of the heart? What properties do the cells have that provide automatism of the heart?

Atypical muscle tissue. The ability to spontaneous generation of excitation due to the presence of slow spontaneous depolarization of its cells in the diastole.

10. What is the main difference between true and potential (latent) pacemakers? In what conditions is the activity of potential heart pacemakers realized?

True heart pacemaker generates impulses with greater frequency than potential pacemaker. Latent pacemakers realize their own automatic activity only in the absence of excitation coming from the true pacemaker.

11. Describe the sequence of excitation in the heart.

Excitation occurs in the SA node, spreads through the conductive system and the myocardium of atrium, the atrioventricular node, the bundle of His, its branches, Purkinje fibers to the contractile myocardium of ventricles.

12. What is the speed of excitation of the atrio-ventricular node? What does this mean for contractile heart function?

The speed is very low - 0,02 - 0,05 m / s, which provides the necessary sequence of atria and ventricles contraction.

13. What is the speed of excitation spreading through the bundle of His and Purkinje fibers? What significance does this have for the contractile function of the heart?

The speed is about 1.5 - 4 m / s. This provides synchronic excitation and contraction of cells of the contractile myocardium of the ventricles. It increases the efficiency of the pumping function of the heart.

14. What is the average human HR if the pacemaker is sinus node, the atrio-ventricular node and Hiss bundle ?

60 - 70 bpm; 40-50 bpm.; 20-30 bpm.

15. What featuresof the conductive system of the heart provide the sequence of atria and ventricles' contraction?

Localization of the pacemaker in the sinus node; delayed conduction of excitation in the atrio-ventricular node.

16. What are the main features of the membrane potential of pacemaker cells of the heart (compared with the membrane potential of the contractile cells of myocardium)?

Low membrane potential (20-30 mV lower than in working cardiomyocytes), the presence of slow spontaneous diastolic depolarization.

17. List the main features of AP of pacemaker cells (compared with the AP of the cells of the contractile myocardium).

The amplitude of the AP is small (60-70 mV), phases 1 and 2 of the repolarization are absent.

18. How to explain the heart muscles'greater sensitivity to the lack of oxygen in comparison to the skeletal muscles? What is its clinical importance?

Energy supply of the heart muscle, in contrast to the skeletal system, is carried out mainly due to the aerobic oxidation of fatty acids and carbohydrates; anaerobic glycolysis has a lesser role. The cardiac muscle is more sensitive to damage of blood supply.

Tasks for self-control:

1. Due to an emotional excitement of a 30-year-old person the heart rate ran up to 112 Bpm. What part of the conducting system of the heart caused it?

A. Synoatrial node *
B. Purkinje's fibers
C. His bundle branches
D. Intraventricular node
E. His bundle

2. The speed of conduction through the atrioventricular node of a healthy adult is 0,02-0,05 m/sec. The atrioventricular delay enables:

A. Sequence of atrial and ventricular contractions *
B. Simultaneity of both atria contractions
C. Simultaneity of both ventricles contractions
D. Sufficient force of atrial contractions
E. Sufficient force of ventricular contractions

3. The heart rate of a patient permanently equals 40 beats per minute. What is the pacemaker?

A. Atrioventricular node *
B. Sinoatrial node
C. His bundle
D. His bundle branches
E. Purkinje's fibers

4. Examination of an isolated cardiomyocyte revealed that it doesn't generate excitation impulses automatically. This cardiomyocyte was obtained from:

A. Ventricles *
B. Sinoatrial node
C. Atrioventricular node
D. His bundle
E. Purkinje's fibers

5. An isolated cell of a human heart automatically generates excitation impulses with the frequency of 60 times per minute. What structure does this cell belong to?

A. Sinoatrial node *
B. Atrium
C. Ventricle
D. Atrioventricular node
E. His bundle

6. The vagus branches innervated the heart during an experimental excitation. It resulted in an interruption of the conduction of excitation fromatria to the ventricles. It was caused by electrophysical changes in the following structures:

A. Atrioventricular node *
B. His bundle
C. Sinoatrial node

D. Ventricles
E. Atria

7. A patient complaining of an irregular heart beat is referred for a cardiac electrophysiological (EP) examination. Propagation of the action potential through the heart is slowest in which of the following?
A. Purkinje fibers
B. SA node
C. Atrial muscle
D. AV node *
E. Ventricular muscle

8. A physician is examining a 58-year-old man who had been diagnosed with insufficiency of the valve system. In this case, the blood from the left ventricle returns to the left atrium. Which valve is damaged?
A. Valve of the pulmonary artery
B. Mitral valve *
C. Tricuspid valve
D. Aortal valve
E. Oval window

METHODOLOGICAL DEVELOPMENT № 14

Topic: Physiological bases of electrocardiography.
Number of hours: 2 hours.
The object of learning:
To know: Electrophysiological bases of ECG, basic elements of ECG and their origin, electrocardiographic leads and their axes in the frontal and horizontal plane, the concept of electric cardiac vector and its projection on the axis of electrocardiographic leads.
***Be able to*:** recognize the parameters of a normal electrocardiogram and to know the physiological characteristics, to interpret the use of ECG in the diagnosis of heart diseases.

Theoretical questions for self-preparation:

1. Basic elements of ECG and their origin.
2. Electrocardiographic leads and their axes in the frontal and horizontal plane.
3. The concept of an integral electric vector of the heart and its projection on the axis of electrocardiographic leads.
4. Basic parameters of a normal electrocardiogram.
5. Role of ECG in the diagnosis of heart diseases.

Key words and terms: augmented leads from the extremities, Wilson's chest leads, lead axis, zero electrical potential, integral electric heart vector, dipole vector, isoelectric line, ventricular complex, electric systole, myocardial infarction.

Practical work:

Work 1. Registration and analysis of ECG in humans.

To record electrocardiogram from the extremities, the electrodes are placed on the left and right wrists and on the left foot in accordance with the markings indicated on the instrument panel. The ground electrode is located on the right leg. The right hand – red color, the left hand - yellow, the left foot - green, the right leg - black. When recording an electrocardiogram in standard leads from the extremities, the electrodes are as follows: I lead - the left hand (+) and the right hand (-); II lead - left foot (+) and right hand (-); III lead - left foot (+) and left hand (-).

When recording an ECG in augmented unipolar leads, the active and positive (+) electrode is located on one of the extremities (aVR is the right arm; aVL is the left arm; aVF is the left foot), and the negative (-) used a combined electrode from the other two limbs.

When recording chest leads, the active and positive (+) electrode is located at definite points on the surface of the chest, and the negative (-) is a combined electrode, which is formed by connecting the three extremities. Represented by letter "V". V1 – 4th intercostal space on the right side of the sternum; V2 – 4th intercostal space along the left side of the sternum; V3 - between V2 and V4; V4 – 5th intercostal space on the left mid-clavicular line, V5- the left anterior axiliary line; V6 - the left middle axillary line. Record multiple cardiac cycles in each of the leads and start ECG analysis. In an ECG analysis, attention is drawn to the severity (amplitude) of the P, Q, R, S, T waves in mV and their duration (in seconds), the duration of the intervals and ECG segments (in sec). The obtained results are compared with the physiological norm of these indicators.

APPLICATION №1

Definition of basic terms and concepts:

The electric heart vector is the geometric sum of elementary electric dipole vectors that simultaneously arise when the heart is excited and have a different size and direction.

Electrocardiography - graphic recording of changes in the difference of electrical potentials that occur on the surface of the body due to the activity of the heart.

The total electric vector is the geometric sum of many elementary dipole vectors that occur simultaneously when the myocardium is excited.

The lead axis is a hypothetical line that unites the electrodes by which the ECG is registered in this axis, and passes through the hypothetical point of the zero potential.

The isoelectric line is a zero ECG line in the diastole period when the heart is not excited.

The wave (P, Q, R, S, T) is the deviation of the ECG curve from the isoelectric line.

Interval - the segment of the ECG curve from the beginning of one of the wave to the beginning of the second (P -Q, R-R)

The segment is an area of the ECG, located on the isoelectric line (P-Q, S-T).

Electric systole - QRST complex.

APPLICATION №2

Control questions and answers on the topic: "Physiological bases of electrocardiography."

1. What system of leads is used in the clinic for complete ECG examination?

Standard two-pole leads from the limbs by Einthoven (1,2,3), augmented unipolar leads from the limbs by Goldberger (aVR, aVL, aVF), and single-pole chest leads by Wilson (V1-V6).

2. What ECG leads are called bipolar and why, and which are unipolar? Which of the electrodes, (+) or (-) is active in single-pole leads?

The standard ones from the extremities are bipolar, since both electrodes are active, that is, they record the potential changes from two specific points of the electric field of the heart. Augmented leads from the extremities and the chest are unipolar, since one electrode (+) is active, and the second (-) is indifferent or zero.

3. What is the lead axis? In what units and how do they determine its direction?

The lead axis is a conditional line connecting two electrodes of this ECG lead. The direction of the lead axis is determined by the magnitude of the angle formed by the positive half-axis of the given lead and the positive half-axis of the I standard lead, conventionally accepted at 0.

4. Specify the direction of the axes of the standard leads (1,2,3).

1 standard release 0; Second standard lead: +60; Third standard lead +120.

5. Specify the direction of the axes of unipolar augmented leads from the extremities (aVL, aVR, aVF).

AVF – $+ 90^0$; aVR – 150^0; aVL – 30^0.

6. In what plane are the potentials of the heart's electric field mainly recorded using standard and augmented unilateral leads from the extremities and chest leads?

With the help of leads from the extremities - in the frontal plane, with the help of chest leads - in the horizontal.

7. What elements are distinguished by ECG? Give a definition of each of them.

Waves - deviation of ECG curve from isoelectric line; segments - parts of the isoline between the waves, intervals - consist of segments and associated ECG waves.

8. What does the value and direction of the ECG wave depend on?

On the magnitude and direction of the moment vector of the electric force and its projection on the ECG lead axis.

9. In which cases on an ECG a positive wave is registered, and in which - negative?

Positive - if the projection of the momentary vector of the electric force of the heart is directed to a positive (+) electrode; negative - if the projection of the momentary vector of the heart is directed to a negative (-) electrode.

10. What segments are distinguished on the ECG curve, what do they mean?

Segments P-Q and S-T. The lack of potential difference between electrodes at the moment.

11. Specify the intervals that are distinguished on the ECG curve and their elements.

The interval P-Q includes a wave P and a segment P-Q; The Q-T interval includes a complex of QRST waves, the S-T segment.

12. What does the PQ interval represent on the ECG? What is its normal duration?

Spreading of excitation in the atria, atrioventricular node, His bundle, its brunches and Purkinje fibers. 0,12-0,2 s.

13. Describe the sequence of heartbeat conduction spread and the corresponding sequence of the ECG elements?

The spreading of excitation by the conductive system through the atria (wave P), the atrioventricular node and the conductive system of the ventricles (segment P-Q) through the contractile ventricular myocardium (QRST).

14. What does the P wave reflect on the ECG? What is its amplitude and duration?

The process of propagation of excitation by the conductive system through the right and left atrium. Amplitude of the P wave does not exceed 2.5 mm (0.25 mV), duration - 0,1 s

15. What does the PQ segment represent on the ECG? What is its duration?

The time of excitation through the atrioventricular node and the conductive system of the ventricles, 0,1 s.The delay is due to the low rate of excitement in this node.

16. Why isn't the atrial repolarization wave usually registered by ECG?

The atrial repolarization wave coincides with the QRS complex and is "lost" in it.

17. What do the Q, R, S waves reflect on the ECG? What is the duration of the QRS complex?

Q is the initial vector of depolarization of ventricles (interventricular septum); R - myocardial excitation of the right and left ventricles; S - depolarization of the basis of the ventricles. 0.06-0.09s.

18. What does the ST segment display on the ECG? Specify the normal ratio of the P, T and R waves in standard leads.

The period of total spread of excitation through the contractile myocardium of both ventricles, as a result, the potential difference between the various parts is absent or very small. 1: 3: 9.

19. What is the normal range of deviation of the ST segment from the isoline (in mm)? What process does the T-wave of ECG reflect?

It does not exceed 0,5 mm (0,05 mV). The process of repolarization of the contractile myocardium of the ventricles.

20. Explain why the direction of the R and T waves coincides normally on the ECG, though these waves reflect different processes: R is depolarization, and T is the ventricular myocardial repolarization.

These processes in the myocardium are oppositely directed (depolarization - from the endocardium to the epicardium, repolarization - from the epicardium to the endocardium), while the direction of the resulting vectors of depolarization and repolarization of the ventricles of the heart coincide (from the epicardium to the endocardium).

21. What elements of ECG are electric systole and electric ventricular diastole?

Electric systole - a set of ECG elements from the beginning of the Q wave to the end of the T wave (coincides in time with the mechanical systole of the ventricles). Electrical diastole - a set of elements from the end of the T wave to the beginning of the Q wave (coincides in time with the mechanical ventricular diastole).

22. How is the regularity of the heart rate (heart rhythm) evaluated on an ECG? What rhythm is normal?

By comparing the duration of several successive R-R intervals. The rhythm is normal if the difference does not exceed 10% of the average length of this interval.

23. How can the heart rate be counted by the ECG? What is the heart rate in the resting state?

At normal heart rate - by the formula: HR = 60: (R-R) , where (R-R) is the average interval duration in seconds. Normally 60-80 beats per minute.

24. What is the sinus rhythm of the heart? What ECG signs characterize it?

Rhythm of cardiac contractions, the "pacemaker" of which is the sinus node, its features are: 1) in all standard leads each QRS complex preceded by a positive wave P; 2) in the same lead of ECG there is a constant, identical form of all the R waves.

25. Which ECG signs evaluate the conduction of the atria myocardium, atrioventricular node and myocardium of the ventricles of the heart?

Conduction of the atrium myocardium - according to the duration of the P wave; atrioventricular node - according to the length of the P-Q segment; for ventricles - according to the duration of the QRS complex.

26. What is the normal position of the heart axis in standard ECG leads?

$R_{II} > R_I > R_{III}$; in in the III lead R and S waves are approximately equal.

27. What are the ECG signs of the horizontal position of the heart axis in standard leads?

High R wave in lead I, and $R_I > R_{II} > R_{III}$ deep S wave in lead III.

28. What are the ECG signs of the vertical position of the heart in standard leads?

High R wave in lead III, with $R_{III} > R_{II} > R_I$, R=S in lead I.

29. Indicate the main feature of the ECG with complete blockage of excitation in the atrioventricular node. Explain the mechanism.

Complete inconsistency of excitation of the atria and ventricles, since their pacemakers of rhythm are different: the sinus and atrioventricular nodes, respectively.

Tasks for self-control:

1. An ECG study showed that the T-waves were positive in the standard extremity leads, their amplitude and duration were normal. The right conclusion would be that the following process runs normally in the heart ventricles:
   A. Repolarization *
   B. Depolarization
   C. Excitement

D. Contraction
E. Relaxation

2. The ECG of a patient with hyperfunction of the thyroid gland showed an accelerated heart rate. It is indicated by depression of the following ECG part:
A. R-R interval *
B. P-Q segment
C. P-Q interval
D. P-T interval
E. QRS complex

3. The ECG of a patient shows prolongation of theT-wave. This is caused by deceleration in the ventricles of:
A. Repolarization *
B. Depolarization and repolarization
C. Depolarization
D. Contraction
E. Relaxation

4. A patient has delayed conduction of excitation through the atrioventricular node. What changes of the ECG will be observed?
A. Prolongation of P-Q interval *
B. Prolongation of Q-S interval
C. Negative T wave
D. S-T-segment displacement
E. Prolongation of Q-T interval

5. A 32-year-old female complains of intermittent chest discomfort that occurs most frequently when she drinks lots of coffee to stay up to meet deadlines at work. She is referred to cardiology for an stress test exercise to rule out cardiac ischemia as the cause for her angina. The test will be considered positive if which of the following occurs?
A. ST segment depression occurs *
B. Mean arterial blood pressure increases
C. Tachycardia develops
D. A diastolic murmur is heard
E. The QRS complex widens

6. A patient with an inferior myocardial infarction develops a stable bradycardia of 50/min. The cardiologist orders an ECG to evaluate whether there is a sinus node dysfunction or an atrioventricular conduction disturbance. The diagnosis of a first-degree heart block is made in which of the following cases?
A. The PR interval of the ECG is increased *
B. The P wave of the ECG is never followed by a QRS complex
C. The P wave of the ECG is sometimes followed by a QRS complex
D. The T wave of the ECG is inverted
E. The ST segment of the ECG is elevated

METHODOLOGICAL DEVELOPMENT № 15

Topic: The pumping function of the heart.
Number of hours: 2 hours.
The object of learning:
To know:the phases and periods of the heart cycle; modern methods for evaluating the phase structure of the cardiac cycle, the pressure-volume curve during the cardiac cycle, the basic physiological parameters of the heart function, heart sounds and their diagnostic value.
Be able to*:* detect heart sounds, pulse, interpret their diagnostic value, characterize the functional significance of autonomic cardiac reflexes.

Theoretical questions for self-preparation:

1. Phase structure of the heart cycle.
2. The pressure-volume curve during the heart cycle.
3. Basic physiological parameters of the heart's pumping function.
4. Heart sounds and their physiological mechanisms. Diagnostic value of phonocardiography.
5. Features of the the myocardium metabolism.

Keywords and terms: systolic volume, systole, diastole, cardiac cycle, venous pulse, ejection fraction, minute volume of blood, cardiac output, auscultation, phonocardiography, valve insufficiency, regurgitation, valve stenosis, systolic, diastolic murmurs.

Task 1. Palpatory method of pulse detection.

Determining the pulse of superficial arteries, you give a description of: a) its frequency (oscillations for 1 min); b) speed (speed of pulse wave lift); c) tension (force with which you need to compress the artery so that the pulse is gone); d) amplitude of the pulse wave (the height of the vibration of the vessel wall); e) rhythm (the same intervals between pulse fluctuations of the vessel wall).You need a stopwatch or a smartphone with a stopwatch function.

Procedure: Find the pulse of the radial artery by the left fingers. The pulse must be determined using the 2nd, 3rd and 4th fingers. The patient is standing or facing the examiner.The count of the pulse begins with the start of the stopwatch. The count lasts for a certain period of time (10-15 s.). The measurment is repeated three times. In sports practice, the pulse is counted for ten-seconds and multiplied by six. The pulse rate is counted twice: in a state of rest and after dosed physical activity (20 sit-ups for 30 seconds.). Record the results in resting state and after physical load. The results are recorded in the table.

Characteristics of the frequency of arterial pulse in humans.

Indicators	**Characteristic of the indicator**
Availability	+/-
Frequency in 1 min.	60, 72, ... 86 ...
Rhythm	Rhythmic, arhythmic
Tension	Normal, tense, soft
Amplitude height	High, low, thready

Task 2. Determination of the duration of the heart cycle by pulse.

Knowing the number of pulse beats in 1 minute, 60 seconds are divided on the HR in order to obtain the average duration of the heart cycle in seconds.

Task 3. Auscultation of heart tones.

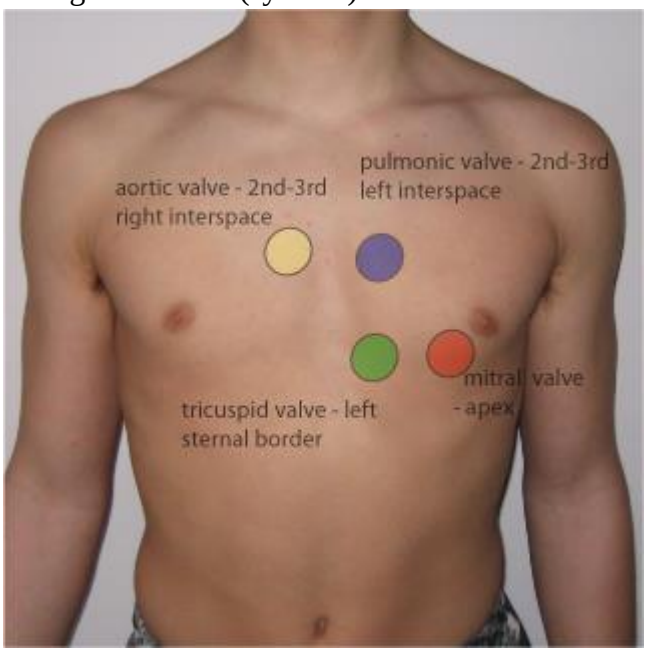
The heart is listened with a stethophonendoscope in the following sequence:

a) find the point of the cardiac impulse and there is the point of listening the mitral valve;

b) in the place of attachment of the 4th and the 5th ribs to the sternum one can listen to the tricuspidal valve of the heart;

c) in the 2nd intercostal space on the right - the aortic valve can be listened, and to the left - the valve of the pulmonary artery.

It is necessary to clearly distinguish the 1st (systolic) heart tone from the 2nd (diastolic).



APPLICATION №1

Definition of basic terms and concepts:

The heart cycle is a continuous alternation of contraction and relaxation of the heart.

The period of tension **-** lasts from the beginning of excitation of the ventricles until the opening of the semilunar valves. It consists of a phase of asynchronous and isometric contraction.

The period of isovolumetric contraction- is a period in which the volume of blood remains constant but intra-ventricular pressure rapidly increases from 0 to about 80 mm Hg.

The period of ejection of blood begins when blood pressure in the ventricles exceeds the diastolic blood pressure in the aorta and pulmonary artery, ceases when pressure in the arteries is equal to the pressure in the ventricles. Consists of a phase of rapid and slow ejection.

The proto-diastolic period - the first period of diastole, in which the reverse flow of blood from the arteries to the ventricles closes the semilunar valves.

The period of isovolumetric relaxation is the period in which both valves are closed, the volume of blood in the ventricle does not change, and the pressure continues to decrease from 80 to the level of 6-7 mm Hg.

The filling period - blood enters the relaxed ventricles due to a pressure gradient between the atria and the ventricles. It consists of a phase of fast and slow filling.

The systolic volume of the heart is the volume of blood pushed out by the ventricles at each contraction (in men, about 65 - 80 ml, in women - 50-60 ml).

The end-diastolic volume (EDV) is the volume of blood that is contained in the ventricle before the systole (130-140 ml).
Residual diastolic volume is a reserve of EDV (30 - 40 ml).
The end-systolic volume (ESV) is the volume of blood in the ventricle at the end of the systole (60-70 ml).
Residual systolic volume is the volume of blood that can be reduced by ESV (30-40 ml).
Residual volume (RV) is the volume of blood remaining in the ventricle after a maximum contraction (40 ml).
Minute blood volume (MBV) is the volume of blood pushed out by the ventricles during 1 min (for women 4 - 4.5 l / min, for men - 4.5 - 5 l / min).It is the same as cardiac output (CO).
Systolic index (SI) is the ratio of MBV to the surface area of the body (in m^2). It is 2.5 - 3 l/m^2 min. at resting state.
The index of blood supply to the body (IBS) is the ratio of MBV (in ml) to body weight (in kg). It is 55 - 60 ml / kg min. at resting state.

APPLICATION №2

Control questions and answers on the topic:"The pumping function of the heart**".**

1. Name the heart valves and other structures similar to them in function, specify their localization and function.

Two AV valves - between the atria and ventricles; two semilunar - between ventricles and arterial trunks (aorta and pulmonary trunk); sphincter - at the point of veins entering the atrium.They provide one-way blood flow.

2. What are the tendons of atrioventricular valves attached to, what is their functional significance?

To the top of the papillary ventricular muscles. During muscle contraction, the tendon strands are stretched and hold the AV valves, preventing them from being turned into the atrial cavity during the systole of the ventricles.

3. Which three phases does the heart cycle consist of? What is the duration of each phase and the full heart cycle at the heart rate of 75 beats / min? What is the duration of atrial and ventricular diastole?

The atrial systole (0,1 s),the ventricular systole (0,33 s), the total pause of heart (0,37 s), the total cycle duration - 0,8 s. The atrial diastole - 0,7 s, the ventricular diastole - 0,47 s.

4. Does the blood flow from the atria to v. cavae and pulmonary veins during the systole? Why?

It does not, because the atrial systole begins with the contraction of the main veins sphincters, which prevents the reverse flow of blood from them into the atrium.

5. What are the two periods of ventricles systole and what is their duration? In what position are the heart valves and the sphincters of the main veins at the end of the atrial systole?

The period of tension (0,08 s) and the period of ejection (0,25 s). The semilunar valves are closed, the sphincters are contracted, the AV valves are open.

6. What two phases does the period of ventricular tension consists of? What is their duration?

The phase of asynchronous contraction (0,05 s) and the phase of isometric contraction (0,03 s).

7. What is the phase of asynchronous contraction of ventricles? Explain the position of the heart's valves and the sphincters of the main veins after the completion of this phase.

It is the beginning of ventricular contraction, before all the cells of the contractile myocardium are excited. The semilunar and the AV valves are closed, the sphincters are relaxed.

8. What is the phase of isometric ventricular contraction? How does pressure in the ventricles change during this phase? In what condition are the valves of the heart and sphincters of the main veins during this phase?

It is a contraction phase, in which the size of the ventricles does not change, but the tension of the myocardium and pressure in the ventricles are sharply increased. The AV and semilunar valves are closed, the sphincters are relaxed.

9. What kind of force provides the opening of the semilunar valves during systole of ventricles? Indicate what values does the pressure reach in the right and left ventricles until the start of the period of blood ejection in a resting state.

The pressure gradient: in ventricles it should be slightly higher than diastolic pressure in the aorta and pulmonary artery. It is 60-80 mm Hg and 10-12 mm Hg, respectively.

10. In what position are the heart valves and sphincters of the main veins during the period of ejection of blood from the ventricles? What are the maximum values of pressure in this period in the right and left ventricles of healthy people at resting state?

The AV valves are closed, the semilunar ones are open, the sphincter is relaxed. And the pressure is 25-30 and 120-125 mm Hg, respectively.

11. What two phases does the period of ventricles ejection consist of? What is their duration? How does the blood pressure in the ventricles change during each of these phases?

The phase of rapid (0.12 s) and the phase of slow (0.13 s) ejection. During the phase of rapid ejection, the pressure rises to the maximum systolic, during the phase of slow ejection, the pressure is somewhat reduced, but remains slightly higher than in the aorta or pulmonary trunk, respectively.

12. What periods is the diastole of ventricles divided into? To what minimum value does the pressure of both ventricles decrease during the diastole?

The proto-diastolic period, the period of isometric relaxation and period of filling. Down to 0 mm Hg

13. What is the proto-diastolic period? What is the reason of closure of semilunar valves ?

The interval from the beginning of ventricular relaxation to the moment of semilunar valves' closure. The reverse blood flow to the ventricles due to reduced pressure in them.

14. What is the period of isometric relaxation of the ventricles? How does the myocardial tension and pressure in the ventricles change? In what condition are the semilunar and AV valves, the sphincters of the main veins during this phase?

The relaxation phase, in which the size of the ventricles does not change, but the tension of the myocardium and the pressure in the ventricles are reduced. The AV and semilunar valves are closed. The sphincters are relaxed.

15. Name the phases of the filling period and their duration. In what condition are the semilunar and AV valves, the sphincters of the main veins during the entire filling period?

The fast filling phase (0.15 s),the slow filling phase (0.20 s).The semilunar valves are closed, the AV are open, the sphincters are relaxed.

16. What phase of the heart cycle coincides with the end of the ventricles diastole?

The systole of atria. Additional blood of 8-15% is pumped into the ventricles.

17. What are the end-diastolic and end-systolic volumes of the heart?

The volume of blood in the ventricles of the heart at the end of their diastole (130-140 ml) and at the end of the systole (60-70 ml), respectively.

18. What are the end-diastolic and end-systolic volumes of blood? What is their value (in ml) in a state of rest?

The blood volume in the ventricles at the end of their diastole (about 130 ml) and at the end of systole (60-70 ml), respectively.

19. What is the ejection fraction of blood? What property of the heart muscle characterizes this indicator and what is its value in a resting state?

The ratio of systolic blood volume to its end-diastolic volume. Heart muscle contractility (inotropic condition).It is 50-70%.

20. What is the systolic (stroke) blood volume? What is its magnitude in rest?

The amount of blood that the heart ejects into the aorta (or pulmonary artery) per systole. It is 60-70 ml.

21. What is the residual blood volume? What is its normal value (in ml) ?

The volume of blood remaining in the ventricles after maximum systolic ejection. It is about 40 ml.

22. What is the minute volume of blood (cardiac output)? What is the heart index? Specify the values of these indicators of the pumping function of the heart in a resting state.

The amount of blood ejected by the heart to the aorta for 1 min (CO). 4-5 l. The ratio of CO to the area of the body surface. It is 2.5-3 l / m^2 x min.

Tasks for self-control:

1. The minute blood volume of a 30-year-old woman at rest is 5 l/m. What blood volume is pumped through the pulmonary vessels per minute?

A. 5 l *
B. 3,75 l
C. 2,5 l
D. 2,0 l
E. 1,5 l

2. During examination of the person it was revealed that the minute blood volume of heart is 3500mL, systolic volume is 50 mL. What is the frequency of cardiac contraction?

A. 70 bpm *
B. 60 bpm
C. 50 bpm
D. 80 bpm
E. 90 bpm

3. Before a heart surgical operation it was necessary to measure the pressure in the heart chambers. In one of them the pressure varied from 0 mm Hg up to 120 mm Hg within one cardiac cycle. What heart chamber is it?

A. Left ventricle *
B. Right ventricle
C. Right atrium
D. Left atrium

4. It was established that the cardiac output of a patient is equal to 3500 ml,the systolic output was 50 ml. What is the patient's heart rate per minute?

A. 70 *
B. 60
C. 50
D. 80
E. 90

5. A 42-year-old woman with mitral prolapse is admitted to the hospital for evaluation of her cardiac function. Which of the following values is the best index of the preload of her heart?

A. Left ventricular end-diastolic volume *
B. Blood volume
C. Central venous pressure
D. Pulmonary capillary wedge pressure
E. Left ventricular end-diastolic pressure

6. The wife of a 58-year-old-man calls 9-1-1 because her husband complains of chest pain radiating down his left arm. He is transported to the Emergency Department, where the electrocardiogram and cardiac enzymes revealed a recent myocardial infarction. The man is sent for a cardiac catheterization, including coronary angiography and hemodynamic recordings throughout the whole cardiac cycle. No valvular defects were present. Where were the smallest pressure differences in the heart chambers?

A. Left ventricle and aorta *
B. Pulmonary artery and left atrium
C. Right ventricle and right atrium
D. Left ventricle and left atrium
E. Aorta and capillaries

METHODOLOGICAL DEVELOPMENT № 16

Topic: Regulation of the function of the heart.
Number of hours: 2 hours.
The object of learning:
To know: mechanisms of myogenic, humoral and nervous regulation of the heart
Be able to: explain the mechanisms of regulation of the heart rate (HR), the rate of atrial-ventricular conduction of excitation, excitability and myocardial contractility.

Theoretical questions for self-preparation:

1. Control of the heart pumping function. Myogenetic regulation of the heart.
   2. Nervous intracardiac regulation of the heart.
   3. The influence of the autonomic nervous system on the heart work. Autonomic cardiac reflexes.
   4. Main subcortical centers of regulation of the heart. Influence of the cerebral cortex on the heart work.
   5. The role of hormones in the regulation of heart activity.
   6. Dependence of the heart's work on the ionic composition of blood.
   7. Metabolism in the myocardium.

Key words and terms: intra- and extracardial regulation, chronotropic, inotropic, batmotropic, dromotropic effects, heart rate, Ashner's effect, Bowditch effect.

Practical work:

Work 1. Research of reflex influences on the activity of the human heart (Danini-Aschner's reflex).

A person's heart rate decreases when his eyeballs are slightly pressed . The reflex loop consists of afferent fibers of the oculomotor nerve,the neurons of the medulla oblongata, parasympathetic fibers of the vagus nerves, which through their impulses cause an inhibitory effect to the heart. The heart rate of the patient is determined by the pulse. After this, the patient closes his eyes. The examiner presses on the eyeballs during 20 s (pressing should not be painful) with the first and second fingers. Simultaneously while the eyeballs of the patient are being pressed on, the heart rate is measured. Usually, under these conditions, the pulse becomes rarer on average by 10-12 strokes.

APPLICATION №1

Definition of basic terms and concepts:

Myogenic regulatory mechanisms of the heart - are related to physiological properties of the heart muscle.

Humoral mechanisms - are realized through influence of hormones on the heart.

Nervous mechanisms - are carried out by intra-and extracardiac reflexes.

Franck-Starling Law - the force of ventricular contractions depends on the length of the muscle fibers before contraction. Another name is the heterometric myogenic autoregulation of the heart.

Anrep's effect - with increasing diastolic pressure in the aorta or pulmonary artery, the strength of the contraction of the myocardium increases. Another name is homeometric myogenic autoregulation.

Bowditch effect- with an increase of heart rate, the strength of heart contraction increases and vice versa. Another name is chronoinotropic dependence.

Effects on the heart

Effect	*Characteristic*	*Parasympathetic*	*Sympathetic*
Chronotropic	The effect on the frequency heart rate	Negative	Positive
Inotropic	The effect on the strength of heart contractions	Negative	Positive
Batmotropic	Effect on cardiac muscle excitability	Negative	Positive
Dromotropic	Effect on cardiac muscle conduction	Negative	Positive

APPLICATION №2

Control questions and answers on the topic:" Regulation of pumping function of the heart".

1. List the four main factors that affect the size of the minute blood volume.

The heart rate, the magnitude of venous return of blood, resistance to ejection of blood from the ventricles (arterial pressure), myocardial contractility.

2. List the mechanisms of regulation of cardiac activity. Name the varieties of the myogenic regulatory mechanism.

Nervous, humoral and myogenic (heterometric and homeometric).

3. What is the heterometric regulation of cardiac activity? Give an example.

Heart rate regulation related to the change of the initial length of the fibers.

4. State the Frank-Starling law.

The greater the filling of ventricles cavity with blood and the stretching of myocardial fibers during diastole the greater will be the strength of heart contractions during systole.

5. Why does the stretching of heart muscle during diastole lead to the increase of its contraction?

During stretching the future contact area of actin with myosin increases, as well as the release of an additional amount of calcium from the sarcoplasmic reticulum, accompanied by increased contraction.

6. What is the physiological significance of the Frank-Starling law for blood circulation?

Adaptation of cardiac activity to the increased amount of blood flow: an increased blood flow to the heart increases the strength of its contraction and vice versa.

7. What indicators characterize the filling of the ventricles of the heart with blood at the end of diastole and what does it depended on?

The end-diastolic pressure or end-diastolic volume of ventricles. It depends on the magnitude of the venous return of blood to the heart.

8. What is the homeometric regulation of cardiac activity? Give an example.

Heart rate regulation, which is implemented without changing the initial length of the myocardium fibers . E.g. "Bowditch effect ", rhythmoionotropic effect.

9. What is the rhythmoionotropic dependence of the heart regulation? Give an example

Increased strength of heart contractions at increased frequency.An increase of the concentration of calcium ions in the nearfibrillary space at an increased frequency of cardiomyocyte excitation.

10. What is the indicator of blood ejection resistance from the left ventricle during systole? What changes are observed in the heart activity during a sudden increase of this indicator?

The pressure in the aorta. The period of isometric contraction increases, the stretching of the ventricular myocardium increases during diastole, the strength of heart contraction increases.

11. What is the inotropic state of the heart? What are the indicators used to evaluate this condition? Give examples.

Contractility of the heart muscle under conditions when the parameters of venous return and blood pressure do not change.The indices of contractility.The ejection fraction (SV / EDV), the maximum rate of pressure change in the left ventricle with systole.

12. What are the regulatory influences that improve or worsen the inotropic state of the myocardium? How do these influences change the systolic volume and ejection fraction with the same venous return and pressure in the aorta?

Positive inotropic effects (systolic volume and ejection fraction are increased), negative inotropic effects (systolic volume and ejection fraction are reduced).

13. What neurons form the intra-cardiac nervous system? List the structures that are innervated by them.

The afferent intracardiac neurons,whose dendrites form receptors for stretching of the myocardium and coronary vessels,the efferent neurons whose axons innervate structures of the conducting system,the contractile myocardium and smooth muscles of the coronary vessels; interneurons that form synapses with afferent and efferent neurons.

14. List the places of the greatest accumulation of intra-cardiac neurons. What extracardiac nerve fibers do they synaptically connect with?

The atrial wall, the atrial septum, the upper part of ventricles,the hollow and pulmonary veins. With preganglionic fibers of vagus nerves.

15. What are the intracardiac reflexes? What is their significance for blood circulation?

Reflexes, whose reflex arches are located in the heart.They prevent significant changes in blood flow to the arterial system.

16. What factors determine the direction of the myocardium response (increase or inhibition of its activity) in the implementation of intra-cardiac reflexes?

The level of end-diastolic volume, change of venous return, systemic blood pressure.

17. Whydo intracardiac efferent neurons form a common final route for extra- and intracardiac nerve effects? What does this mean?

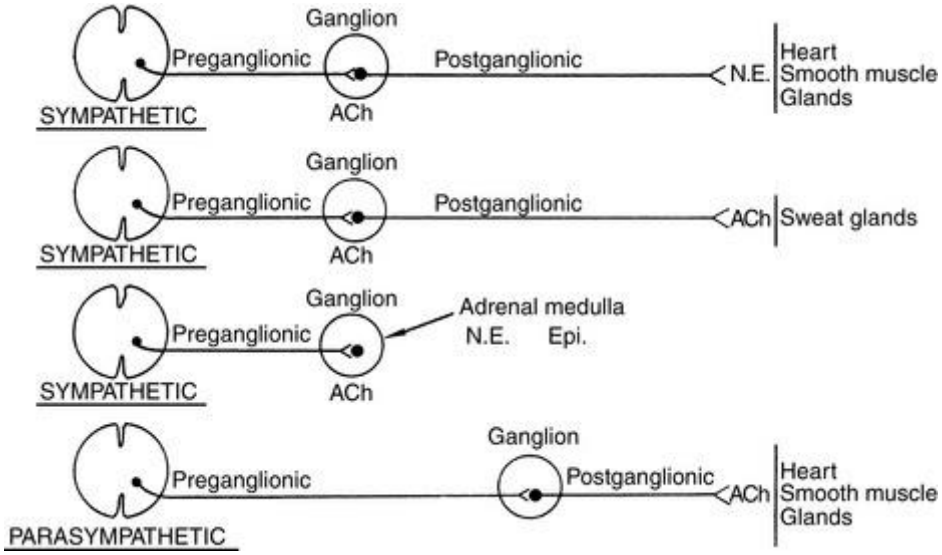
These neurons are synaptically connected with afferent intracardiac neurons, and with preganglionic fibers of vagus nerves. The direction of the change in the heart activity depends on the result of the interaction of impulses that have extra-and intracardiac origin.

18. List the mediators, their respective receptors and the structures on which these receptors are located, for pre-and postganglionic parasympathetic nerve fibers that innervate the heart.

Preganglionic fibers - acetylcholine, H-cholinoreceptors of intracardiac cholinergic neurons; postganglionic fibers - acetylcholine, M-cholinoreceptors of the myocardium.

19. List the mediators, their respective receptors and the structures on which these receptors are located, for the pre- and postganglionic sympathetic nerve fibers that innervate the heart.

Preganglionic fibers - acetylcholine, H-cholinoreceptors of adrenergic neurons of sympathetic ganglia; Postganglionic fibers - norepinephrine and adrenaline, beta-adrenergic receptors of cardiomyocytes.



20. Which segments of the spinal cord are the preganglionic sympathetic neurons located in that innervate the heart? Where are these fibers interrupted?

In the lateral horns of the five upper segments of the thoracic spinal cord. In all cervical and five upper chest sympathetic nodes.

21. From what nerve ganglia does the most of the sympathetic fibers exit that innervate the heart? By merging of which nodes is it formed?

From the stellate ganglion, formed by the merging of the lower cervix and the three upper thoracic ganglia of the sympathetic chain.

22. What effect has the vagus nerve on heart rate? What is the name of this effect?

It decreases the heart rate and is called negative chronotropic effect.

23. What is the mechanism of the inhibitory effect of the vagus nerve on heart rate?

Acetylcholine, released from the parasympathetic nerves endings, causes the slowing of spontaneous diastolic depolarization and hyperpolarization of the pacemaker cells, which leads to a decrease in the frequency of pulse generation in it.

24. What is the mechanism of hyperpolarization of the heart pacemaker cells at an increase of parasympathetic effects?

Increasing the permeability of the membrane for potassium ions, which leads to increased outcome from the cell according to its concentration gradient.

25. What effect does the vagus nerve make on the strength of cardiac contractions?

Reduces the strength of heart contractions (negative inotropic).

26. How does stimulation of the vagus nerve affect the excitability and conduction of the heart? What are these effects? How is it revealed by an electrocardiogram?

It reduces, negative batmotropic and dromotropic effects.An increase of P-Q segment; increase of atrioventricular delay.

27. What do you call the "slipping of the heart" from the vagus nerve influence?

Resumption of heart contractions, which was stopped in response to stimulation of the vagus nerve, despite prolonged nerve stimulation.

28. How will the heart rate of a dog change after a cut of both vagus nerves?

It increases by 2-3 times, proving the presence of inhibitory tonic influence of the vagus nerves on heart activity.

29. How does the heart rate change under the influence of atropine, what is the reason for these changes?

It increases because atropine blocks myocardial M-cholinoreceptors, eliminates the inhibitory tonic effect of the vagus nerve on the heart activity.

30. What is the origin of the tone of vagus nerves centers that innervate the heart?

The tone is supported by an afferent impulse (from the baroreceptors of the vascular reflexogenic zones, the heart, from the proprioceptors of the skeletal muscles) and the action of a number of humoral factors (adrenaline, CO2, H +, etc.) directly to the vagus nerves centers, as well as the spontaneous activity of the center neurons.

31. What is a respiratory arhythmia? What is its mechanism? How does atropine block afferent vagus nerves fibers? Why?

It changes the heart rate in accordance with the phases of the respiratory cycle as a result of changes in the tone of the vagus nerves centers. It disappears as a result of the exclusion of the effects of the vagus nerves.

32. What effect does the sympathetic nerve have on the heart rate, how is this effect called?

It increases the heart rate (positive chronotropic effect).

33. What is the mechanism of increased heart rate during increased sympathetic effects?

Catecholamines, released from synaptic endings, accelerate diastolic depolarization of the pacemaker cells in the heart, which leads to an increase in the pulse frequency.

34. What effect does the sympathetic nerve have on the strength of heart contractions?

It increases heart contraction (positive inotropic effect).

35. What effect does the sympathetic nerve have on the excitability and conduction of the heart? What are these effects? How is it revealed by an electrocardiogram?

It increases; they are positive batmotropic and dromotropic effects.By a decrease of the PQ segment, i.e. the reduction of atrioventricular delay.

36. How will the heart rate change when cut off of sympathetic nerves? What does this fact indicate?

The heart rate will not change. It shows the absence of tonic influence of sympathetic nerves on the heart.

37. Why does the effect of the vagus nerve on the heart immediately disappear after stopping its stimulation, and the effect of the sympathetic nerve persists for some time?

Acetylcholin released from the vagus nerve endings is rapidly destroyed by cholinesterase, and the sympathetic mediator is destroyed much slower and therefore acts longer.

38. What are the main reflexogenic zones that are especially important in the regulation of cardiac activity?

The aortic arch, the carotid sinus, blood vessels of the pulmonary circle, coronary vessels, hollow veins.

39. How and why does the heart changes its work with increased pressure in the aorta and in the carotid sinus?

The strength and heart rate decrease as a result of increased impulses from the baroreceptors of reflexogenic zones and increase of the inhibitory influences of the vagus nerves centers.

40. How will the work of the heart change with increased pressure in the right atria or in the hollow veins? What is the name of this reflex? What is its physiological significance?

The frequency and strength of heart contractions increases. It is the Bainbridge reflex.It provides the ability to quickly "unload" the right ventricle from increased blood flow.

41. Explain why pressing on the area of the carotid sinus can cause slowing of the heart activity?

The excitation of baroreceptors in the carotid sinus increases, afferent impulses from them stimulates the vagus nerve centers, increasing the inhibitory effect of these centers on heart activity.

42. Why does the heart change its work with decreased pressure in the aorta and in the area of carotid sinuses?

The frequency and strength of cardiac contractions are increased in connection with the decrease in the tone of the vagus nerves centers as a result of the reduction of impulses from the baroreceptors.

43. How and why does the work of the heart change with increased pressure in the pulmonary artery?

The heart rate decreases due to a reflex increase in the tonus of vagus nerves.

44. What reaction of the heart is called "Goltz reflex" (vagovagal reflex)?

The reflex of cardiac arrest by severe stimulation of the abdominal cavity receptors.

45. How to prove experimentally that the stimulation of receptors of the abdominal wall stop the heart?

With the destruction of the spinal cord or any other chain of this reflex, stimulation of the bowel receptors does not cause cardiac arrest.

46. What is the oculocardiac reflex of Danini-Aschner?

Slowing of heart rate by 10-20 beats per min when the eyeballs are being pressed.

47. How and why does the heart activity change with abrupt irritation of the mucous membrane of the nose (for example, when inhaling ammonia vapors)?

The heart rate sharply decreases up to the heart stop, due to the increased tone of the vagus nerves centers.

48. Explain the mechanism of heartbeat enhancement of athletes in pre-start condition. What is the significance of this fact?

The reduction of conditional-reflex tone of the vagus nerve centers and arousal of the sympathetic nervous system in response to emotional stress before the start. Ensuring the readiness of the cardiovascular system to perform significant loads.

49. What hormone is especially important in the regulation of cardiac activity under physical and emotional stress? What mechanism is the basis of its influence?

Adrenaline.The activation of the intracellular enzyme - adenylate cyclase, which stimulates the processes of myocardium energy supply and increases the permeability of the cell membrane for calcium ions.

50. What effect does an an increased and decreased calcium concentration in the intercellular fluid on the heart rate have? What is the mechanism of this effect?

Its increase intensifies cardiac contractions (up to a heart stop in the systole); a decrease reduces cardiac contractions. Calcium ions provide the interaction of actin and myosin and, accordingly, the number of formed actin-myosin bridges.

51. How does a significant increase of potassium ions in the intercellular fluid affect the myocardium, what can it lead to? What is the mechanism of this effect?

It reduces excitability, conductivity and contractility of the myocardium, as well as inhibits the activity of the pacemaker cells, which can lead to a heart stop in diastole. The basis of these changes is the reduction of the resting potential, decrease of steepness, amplitude and duration of AP, inhibition of slow diastolic depolarization.

52. How and why does the decrease in the concentration of potassium ions in extracellular fluid affect the myocardium, what can it lead to?

The myocardial excitability and slow diastolic depolarization increases, leading to the appearance of heterotopic centers of excitation, accompanied by violations of cardiac rhythm.

53. What experimental evidence proves the presence of the cardiac regulation centers in the hypothalamus? How do these centers function in the natural environment?

With point irritation some parts of the hypothalamus can cause isolated heart reactions, for example, changes in the rhythm or only the strength of the left ventricular contractions.They interact with other cardiac activity regulatory centers, adapting its work to the needs of the body.

Tasks for self-control:

1. The high level of Lactate Dehydrogenase (LDH) enzymes concentration showed the increase of LDH-1 and LDH-2 in a patient's blood plasma. Point out the most probable diagnosis:

A. Myocardial infarction *
B. Skeletal muscle dystrophy
C. Diabetes mellitus
D. Viral hepatitis
E. Acute pancreatitis

2. In response to a change in body position from horizontal to vertical the blood circulatory system develops reflectory pressor reaction. Which of the following is its compulsory component?

A. Systemic constriction of the venous vessels *
B. Systemic dilatation of the arterial resistive vessels
C. Decrease in the circulating blood volume
D. Increase in the heart rate
E. Weakening of the pumping ability of heart

3. Injection of a big dose of histamine to an experimental animal caused abrupt drop of arterial pressure as a result of:

A. Dilatation of resistance vessels *
B. Constriction of resistance vessels
C. Increase of heart rate
D. Decrease of heart rate
E. Decrease of heart rate and force

4. Systemic arterial pressure of an adult dropped from 120/70 to 90/50 mm Hg that led to reflectory vasoconstriction. The vasoconstriction will be greatest in the following organ:

A. Bowels *
B. Heart
C. Brain
D. Kidneys
E. Adrenals

5. A 72-year-old female is presented to the Emergency Department with generalized weakness. An ECG reveals peaked T waves. Which of the following electrolyte disturbances should be corrected to return the ECG to normal?

A. Hyperkalemia *
B. Hypokalemia
C. Hypercalcemia
D. Hypocalcemia
E. Hypermagnesemia

METHODOLOGICAL DEVELOPMENT № 17

Topic: Basic laws of hemodynamics and their physiological interpretation.
Number of hours: 2 hours.
Educational aim:
To know: to describe the vascular system functions, the basic laws of hemodynamics (Ohm's law, Poiseuille 's law, Reynolds number, Fahraeus-Lindqvist effect) and their physiological interpretation, peculiarities of blood flow in arteries and arterioles.
Be able to: explain the method of measuring blood pressure by the Korotkov auscultation method.

Theoretical questions for self-preparation:

1. General description of the vascular system functions.
2. Basic laws of hemodynamics and their physiological interpretation. Ohm's Law, Poiseuille's Law.
3. Determination of systemic blood pressure and total peripheral resistance.
4. Types of blood flow in the vascular system. Reynolds number.
5. Blood viscosity and its effect on the blood flow in vessels.
6. Blood flow in the arteries. Blood pressure and its measurement.
7. Blood flow in arterioles and mechanisms of its regulation.

Key words and terms: Ohm's law, Poiseuille's law, Reynolds number, Fahraeus-Lindqvist effect, laminar, turbulent types of flow, pulse pressure, sphygmography, working reactive hyperemia, myogenic autoregulation of arteriol tone, external neurogenic control, external hormonal control, local reaction to damage.

Practical work:

Task 1. Measurement of human blood pressure.

Auscultatory method of measuring blood pressure by Korotkov is based on listening to the sounds that occur when blood vessels are compressed by a cuff which results in the obstruction of laminar blood flow in the narrowed area.

A spring manometer and a phonendoscope are required for work. The patient's hand is placed on the table. The cuff is tightly fixed on his naked arm, but does not compress the skin. Measurement is carried out as follows: a) screw the valve on the hand pump and by palpation determine the place of clear pulsation of the radial artery in the elbow bend; b) put a phonendoscope over this place and with the help of the hand pump gradually increase pressure in the cuff until the artery is completely compressed c) after that, easily open the valve, gradually reducing the pressure in the cuff, and follow the indicators of the pressure on the gage.

The manometer indicator at the moment of the first sound in the artery corresponds to the magnitude of the **systolic** pressure. Indicator of a manometer at the moment of a sharp weakening or disappearance of sound in the artery with a further reduction in pressure in the cuff corresponds to the magnitude of the **diastolic** pressure. The difference between the values of systolic and diastolic pressure is the **pulse pressure**.

APPLICATION №1

Definition of basic terms and concepts:

High pressure vessels - aorta and large arterial vessels, which maintain high blood pressure.
Pressure regulatory vessels - shallow arteries and arterioles, that create the main resistance to blood flow.
Distributors of capillary blood flow - terminal vessels (precapillary arterioles and precapillary sphincters).
Exchange blood vessels - capillaries and postcapillary areas of venules.
Accumulative vessels - venules and shallow veins.
The blood returning vessels - major venous collectors and hollow veins.
Shunt vessels - anastomoses that connect arterioles and venules.
Resorption vessels - the lymphatic system of the circulatory system.
The Reynolds number is a dimensionless value that reflects the flow type - laminar or turbulent. This number is directly proportional to the radius of the vessel, the average linear velocity of the blood flow, the density of blood and is inversely proportional to the viscosity of blood.

$$\mathrm{Re} = \frac{\rho v l}{\mu} = \frac{v l}{\nu}$$

Where:

v = Velocity of the fluid
l = The characteritics length, the chord width of an airfoil
ρ = The density of the fluid
μ = The dynamic viscosity of the fluid
ν = The kinematic viscosity of the fluid

APPLICATION №2

Control questions and answers on the topic: Basic laws of hemodynamics and their physiological interpretation.

1. What does the term "hemodynamics" mean? Name the five types of blood vessels according to their functional values.

Hemodynamics - a science about the causes, conditions and mechanisms of blood flow in the blood circulation system. They are: shock absorbing vessels, distributing vessels, resistance vessels, exchange vessels, capacitance or reservoir vessels, shunts or anastamoses.

2. What vessels are they called shock-absorbing and why? What is their special functional significance in the circulatory system?

The main arteries of elastic type (aorta, pulmonary trunk and large arteries that branch off of them). They provide continuity of blood flow and reduce its pulsations in the arterial system.

3. What vessels and why are they called resistance vessels (resistive)?

The arterial vessels of the muscular type (arteries and arterioles), because they form the greatest resistance to blood flow and determine the size of the total peripheral resistance.

4. What vessels and why are called exchange, and which are shunting?

The exchange vessels are called capillaries, because they provide an exchange between blood and tissues. Shunt vessels - arteriovenous anastomoses that provide blood flow from arteries to the veins bypassing the capillaries.

5. What vessels are called accumulative? What is their functional meaning and with what feature of these vessels is it connected?

They are venules and veins; they are a reservoir (depot) of blood of variable capacity.Due to high stretchability of their walls.

6. What is called the deposit of blood? What vessels carry out this function? What organs play the role of blood depots?

The hold-up of the blood (up to 45-50%) in the deposit vessels of individual organs and tissues (blood depot) and its temporary exclusion from the general circulation. They are the spleen, liver, lungs, subcutaneous vascular plexus.

7. Name the main driving force of blood flow. How is it created?

Gradient pressure between the arterial and venous ends of the vascular bed.By the work of the heart.

8. Explain why is blood continuously moving in the vessels?

During the phase of ejection, part of the kinetic energy of the heart passes into the potential energy of the stretched walls of the aorta and large arteries, reducing the elastic tension which during the diastole supports a continuous flow of blood.

9. Formulate the basic law of hemodynamics.

The volume of blood flowing through the vessels is directly proportional to the pressure gradient and inversely proportional to the hydrodynamic resistance.

10. What is systolic pressure? What is it equal to in the aorta and in the pulmonary artery?

The maximum pressure in the major arteries during systole of the ventricles. In the aorta - 110-120 mm Hg; in the pulmonary artery - 25-30 mm Hg.

11. What is diastolic pressure? What is it equal to in the aorta and in the pulmonary artery?

The minimum pressure in the major arteries at the end of the diastole of the ventricles. In the aorta 70-80 mm Hg, in the pulmonary artery - 10-12 mm Hg.

12. Explain why is arterial pressure in the pulmonary blood circulation several times smaller than in the systemic one?

Because the resistance of vessels of the pulmonary circle is about 10 times smaller than the resistance of vessels of the systemic circle due to the relatively larger diameter of the pulmonary arterioles, their greater elasticity and small length of the vascular bed of the pulmonary circle.

13. What is pulse pressure? What is its magnitude in the aorta, in the pulmonary artery? In which vessels are pulse pressure fluctuations recorded?

It is the difference between systolic and diastolic blood pressure in the arteries. In the aorta 35-40 mm Hg, in the pulmonary artery 15-20 mm Hg. It is recorded from the aorta (pulmonary artery) to the arterioles.

14. What is the mean arterial pressure? How does its value change along the vascular bed?

It is a constant (not pulsating) arterial pressure, which provides the same hemodynamic effect, as well as real pulsating pressure.It gradually decreases.

15. Write the formula for calculating the mean arterial pressure.

$$P_{mean} = P_{diast} + \frac{P_{syst.} - P_{diast}}{3}$$

16. Why is the blood pressure constantly decreasing along the vascular bed? In what part of the vascular bed does the pressure most sharply decrease and why?

Due to the energy expenditure on resistance in the blood flow through the vessels. In the arterioles, because resistance to blood flow is the greatest in these vessels.

17. List the main factors that determine the value of blood pressure.

They are: heart work, the volume of circulating blood, resistance to blood flow.

18. What factors determine the value of resistance to blood flow in vessels?

The viscosity of the blood, the length of the vessels, their radius.

19. What is the reason of Korotkov's sounds occurrence and disappearance during the measurement of blood pressure in humans?

The appearance of sounds is associated with a sharp acceleration of blood flow that occurs at the moment of systole through a compressed cuff section of the artery and the blows of this blood mass onto the vessel wall (turbulent flow) below the cuff. The sounds disappear when the pressure in the cuff becomes slightly lower than the diastolic, because the artery under these conditions is not compressed and the blood flow is laminar.

20. What is called the pulse wave? What is the average rate of its spread through the arterial vessels?

Distribution of the area of high blood pressure that arises in the arteries when the blood is ejected by the heart in the systole.It is an average of 9 m / s.

21. List the main factors that ensure the movement of blood through the veins.

They are; the pressure gradient in the venous system, the contraction of skeletal muscles, the presence of valves in the veins, negative pressure in the thoracic cavity, pulsation of the arteries, located along the veins.

22. Explain why the contraction of the skeletal muscles and the pulsation of the arteries promote the movement of blood through the veins to the heart?

The contraction of the muscles and pulsation of the arteries periodically compress the veins; at the same time, owing to the valves, the blood moves only in one direction - to the heart.

23. What is a venous return? What is it equal to?

The volume of venous blood that flows in one minute through the upper and lower hollow veins to the heart.It equals to minute volume of blood - 4-5 l/min.

24. What is venous pulse? What is its origin?

Fluctuations of the walls of large veins near the heart, due to the difficulty of blood flow to the heart during atrial systole and pulse fluctuations of the walls of large arteries, located along with the veins.

25. What is plethysmography?

It is a method of measuring of an organ's blood supply by recording changes of its volume, which depends on its inflow and outflow of blood.

26. What is central venous pressure? How is it measured? What is the normal level of CVP?

It is the pressure in the hollow veins; measured by an electromanometer during catheterization of the right heart. It is equal or slightly exceeds the blood pressure in the right atrium (from 0 ± 2-3 mm Hg). It is positive during exhalation, and negative during inhalation.

27. Explain why is careless catheterization of large veins dangerous?

During careless catheterization, the air can enter the veins, pass into the heart and vessels of the lungs (air embolism) because pressure in the large veins is lower than atmospheric pressure.

28. What is the linear and volume velocity of blood flow? How to explain the difference in the linear velocity of blood flow along the axis and near the vessel wall? How to calculate the linear velocity of blood flow, if volume velocity is known?

Linear velocity – is the distance to which blood is transmitted through a vessel per unit of time. Near the vessel walls the linear velocity is lower due to blood friction to the vessel walls. Volume velocity - is the volume of blood flowing through the cross section of the vessel per unit of time by dividing the volume velocity of the blood flow (Q) by the cross-sectional area of the vessel (S).

$$V = \frac{Q}{S}$$

29. Why is the linear velocity of blood flow different in various parts of the bloodstream?

It is due to the difference of total cross-sectional area of bloodstream in its various parts.

30. What is the essence of the reography method? What purpose is it used for?

The method of recording the electrical resistance of body tissues when high-frequency electric current is passed through them. To study the change in the velocity and volume of blood flow in various organs and tissues (from the change of their electrical resistance).

31. What is the time of blood circulation? What is its value in resting state and during intensive muscular work?

The time for a particle of blood to pass through the large and small circles of blood circulation.It is 20-23 sec at resting state, which decreases to 9 sec with muscular work.

Tasks for self-control:

1. A 37-year-old woman undergoes a CT scan of the abdomen, which reveals a large peritoneal mass. A subsequent magnetic resonance angiography study showed that the abdominal aorta was constricted to one-half of its resting diameter. As a result, resistance to blood flow through the vessel would be which of the following?

A. Increased 16-fold *
B. Decreased in half

C. Decreased 16-fold
D. Increased by 50%
E. It doubled

1. A 48-year-old sedentary obese male with four-vessel coronary occlusive disease has a massive myocardial infarction while shoveling snow. In the blizzard conditions, it takes the ambulance over an hour to reach the man's home. When the paramedics arrive, the patient's radial pulse is rapid and thready, he has pink froth coming from his mouth, and he is nonresponsive. Increasing which of the following would lead to an increased stroke volume in cardiogenic shock?
A. Ventricular contractility *
B. Heart rate
C. Venous compliance
D. Total peripheral resistance
E. Pulmonary capillary wedge pressure

2. Regarding the linear velocity of the blood flow, the following statement is correct:

A. It is directly proportional to the volume velocity of the blood flow and inversely proportional to the cross-section area of the vessels *
B. the linear velocity of blood flow is greatest in capillaries
C. it does not depend on the diameter of the vessels
D. the linear velocity of blood flow in the aorta is the smallest
E. its size in the aorta and in the capillaries is the same

METHODOLOGICAL DEVELOPMENT №18

The topic: Physiology of microcirculation and the venous system.
The number of hours: 2 hours.
The object of learning:
To know: the structure of the microcirculatory bed, hemodynamics in capillaries and its mechanisms.
To be able to: explain the mechanisms of transcapillary exchange using the Starling equation.

Theoretical questions for self-preparation

1. Structure of microcirculatory bed.
2. Hemodynamics in capillaries and mechanisms of substances` transport through the capillary wall.
3. Exchange processes in the capillaries. Starling's theory.
4. The role of venules and veins in the cardiovascular system.
5. Mechanisms of venous blood return to the heart.
6. The effect of gravity on hemodynamics.

Keywords and terms: capillary, arterioles, venules, precapillary sphincter, arteriovenous anastomosis, two-way diffusion, filtration, reabsorption, perfusion, arterial hyperemia, trans-capillary exchange, effective filtration pressure, dynamic capacitive reservoir, central venous pressure, venous return.

APPLICATION №1

Definitions of main terms and concepts:

The vessels of microcirculatory bed are: terminal arterioles, metarterioles, arteriovenous anastomoses, precapillary sphincters, capillaries, postcapillary venules.

True capillaries is the main area of the microcirculation bed, in which the most favourable conditions are formed for the exchange of substances between blood and the intercellular fluid .

Vasomotions are spontaneous periodic replacements of some functioning capillaries by others.

The Phareus-Lindqvist effect is a decrease in the viscosity of the blood in the capillaries in comparison with the arteries.

Diffusion is the transport of substances through biological membranes, which is carried out due to the concentration or electrochemical gradient.

Filtration is the transport of fluid through a semipermeable membrane due to the difference in hydrostatic pressure.

The essence of Starling's theory– at the arterial end of the capillary there is a process of filtration of the fluid, and on the venous end is the process of its reabsorption.

APPLICATION №2

Control questions on the topic and answers: "Physiology of microcirculation".

1. What vessels of the cardiovascular system are called "faucet" and why?

The final arterioles and precapillary sphincters, as their lumen is able to decrease (up to complete closure) due to contraction of circular muscles or increase with its relaxation, which dramatically changes the blood flow through the capillaries ("faucet" open or closed).

2. What is a basal tone of the vessel? What mechanism is it based on?

It is a vascular wall tension, which persists after stoppage of neurogenic and humoral influences; myogenic; automatic activity of the smooth muscles of the vessels.

3. What is working hyperemia? What causes it?

It is dilatation of the arterial vessels and increased blood flow to organs. ATP, phosphoric and lactic acid, an increase in pCO_2 and osmotic pressure in the tissues, a decrease in pH and other factors that increase metabolism in the tissues.

4. How to measure the pressure in the capillaries? Describe its technique. What is the value of blood pressure in the arterial and venous ends of the capillary?

Under the control of a binocular microscope, a thin cannula is injected to the capillary, connected to the electromanometer. At the arterial end of the capillary the pressure is 30-40 mm Hg, on the venous end it is 10-15 mm Hg.

5. What is the functional significance of relatively high pressure in the capillaries of the renal glomeruli and low in the capillaries of the lungs?

Due to this, along the entire length of the capillaries of the renal glomeruli, the fluid is filtered from the blood into the tubular part of the nephron, and and in the lungs the reabsorption of fluid from the pulmonary tissue to the blood prevails.

6. What are the "red" capillaries? How does their number change with an increase of intensity in the functioning of organs ? What is it due to?

They are functioning capillaries. It increases due to the opening of precapillary sphincters.

7. How to measure the speed of blood flow in the capillaries, what is its value?

Measuring of the speed of red blood cells in a capillary is done under a microscope with a ruler and a stopwatch; about 0.5-1 mm / sec.

8. Name the biologically active substances (BAR) having a direct vasoconstrictor effect.
They are: epinephrine, norepinephrine, vasopressin, serotonin, angiotensin.
9. Name the biologically active substances and changes in the chemical parameters of blood, which provide a direct vasodilator effect.
They are: Acetylcholine, histamine, bradykinin, ATP, organic acids, prostaglandins, decrease in pO2, increase in pCO2, decrease in pH.
10. How does histamine affect the lumen of arterioles and the permeability of capillaries? How and why does arterial pressure change with this?
Histamine expands arterioles and increases the permeability of capillaries. Blood pressure decreases as a result of depositing blood in the capillaries, mainly the abdominal cavity organs, and the movement of fluid into the intercellular space (decreasing the volume of circulating blood).
11. How and why does the lumen of precapillary sphincter change under direct action of CO2? How does it affect the blood flow of capillaries?
It increases as relaxation of the smooth muscle sphincters occurs. Hence filling of capillaries with blood increases.

Tasks for self-control:

1. How will the filtration and reabsorption equilibrium change if the oncotic pressure of the blood is reduced from 25 torr to 10 torr?
2. How will the filtration and reabsorption equilibrium change, if the oncotic blood pressure increases from 25 torr to 40 torr?
3. How will the filtration and reabsorption equilibrium change, if the hydrodynamic blood pressure at the arterial and venous end of the capillary increases by 5 torr?
4. How will the filtration and reabsorption equilibrium change if hydrodynamic blood pressure at the arterial and venous end of the capillary decreases by 10 torr?

1. Injection of a big dose of histamine to an experimental animal caused abrupt decrease in arterial pressure. What is the mechanism of the histamine action:

A. Dilatation of resistance vessels *
B. Constriction of the resistance vessels
C. Increase in heart rate
D. Decrease in heart rate
E. Decrease in heart rate and force of contraction

2. After surgery a 36-year-old woman was given an intravenous injection of concentrated albumin solution. This has intensified water movement in the following direction:

A. From the intercellular fluid to the capillaries *
B. From the intercellular fluid to the cells
C. From the cells to the intercellular fluid
D. From the capillaries to the intercellular fluid
E. No changes of water movement will be observed

3. Epinephrine can produce vasodilation of blood vessels of the skeletal muscles. What receptors will be activated by epinephrine:

A. β_1 receptors

B. $\beta_2$receptors *
C. $\beta_3$receptors
D. α_1 receptors
E. $\alpha_2$receptors

METHODOLOGICAL DEVELOPMENT №19

The topic: Regulation of the systemic blood pressure.
The number of hours: 2 hours.
The object of learning:
To know: the mechanisms of vascular tone regulation, its role in the blood supply of cells, systemic blood pressure, and the mechanisms of its short-term and long-term regulation.
To be able to: evaluate and analyze the regulatory mechanisms underlying vasodilation and vasoconstriction, analyze systemic hemodynamics after exercise, and compare results with norms.

Theoretical questions for self-preparation:

1. The main principles of systemic blood pressure regulation.
2. Mechanisms of short-term regulation of the systemic blood pressure.
3. Mechanisms of long-term regulation of the systemic blood pressure.
4. Nerve centers of the cardiovascular system.
5. Regulation of regional circulation.

Keywords and terms: systemic blood pressure, baroreceptor reflexes, chemoreceptor reflexes, brain ischemic reflex, transcapillary exchange, RAAS, vasodilators, vasoconstrictors, chemoreceptors, baroreceptors, prostaglandins, bradykinin, renin.

APPLICATION №1

Definitions of main terms and concepts:

Vasodilators are substances that have vasodilator action (cause increase in the diameter of the blood vessels). Vasodilator hormones - adrenomedullin, atrial natriuretic peptide, kinins (bradykinin, kallidin). The metabolites of vasodilators are adenosine, nitric oxide, prostacyclin, lactic acid, potassium ions, decrease in O2 tension and blood pH, increase in CO2 tension.

Vasoconstrictors are substances that have a vasoconstrictor effect (cause a decrease in the diameter of the blood vessels). Vasoconstrictor hormones - norepinephrine, angiotensin- 2, vasopressin, urotensin- 2. Vasoconstrictor metabolites are serotonin, thromboxane A2, endothelin-1.

The renin-angiotensin-aldosterone system is a mechanism of systemic hemodynamics' regulation. It affects the cardiac output, total peripheral resistance,circulatory blood volume.

Renin is an enzyme secreted by the juxtaglomerular apparatus of the kidneys. Converts angiotensinogen to angiotensin-1. Under the influence of the plasma converting enzyme, angiotensin-1 is converted to angiotensin-2. The latter narrows the blood vessels, stimulates the central sympathetic structures and stimulates the synthesis of aldosterone.

APPLICATION №2

Control questions on the topic and answers: "Regulation of systemic blood pressure".
1. What is the origin of vascular tone? How does vascular resistance change when its tone changes? What are the kinds of vascular tone regulation mechanisms ?

A certain degree of tension of the smooth muscles of the vascular walls. As vascular tone increases the resistance also increases, while a decrease in the tone decreases its resistance. They are: nervous, humoral, myogenic.

2. Where is the vascular-motor center located? Which two parts does it consist of? What are the relationships between these parts?

It is in the reticular formation of the medulla oblongata at the bottom of the fourth ventricle. It consists of the depressor and pressor areas. The depressor part has an inhibitory effect on the pressor.

3. How does the vascular-motor center irritation affect the blood vessels?

Irritation of the depressor area causes a decrease in pressure due to decreasing of the tone of the pressor area and vessels' expansion; and irritation of the pressor area causes increasing of pressure due to the narrowing of vessels.

4. How and why does the blood pressure change after disruption of the spinal cord below medulla oblongata?

It sharply decreases due to the expansion of the vessels. This proves that the vascular-motor center is located in the medulla oblongata and is in a state of tonic activity.

5. What nerve and which humoral factors support the tone of the vascular-motor center?

They are impulses from chemoreceptors of sinocarotid, aortic and cardiac reflexogenic zones, as well as spontaneous activity of the vascular-motor center neurons; humoral effects direct action of CO_2, H^+, and other products of metabolism on the neurons.

6. List two fundamentally different mechanisms of vasodilation.

1) vasodilation as a result of increased activity of the nerves that dilate vessels; 2) vasodilation due to a decrease in the tonic activity of the nerves that narrows the vessels.

7. What organs and tissues are innervated by nerves that have vasodilator action?

Sympathetic cholinergic vasodilator nerves (skeletal muscle vessels; some parasympathetic nerves: fibers of facial, glossopharyngeal (vessels of salivary glands), pelvic nerves (vessels of cavernous body), fibers of posterior roots of the spinal cord (vessels of the skin in the place of irritation).

8. How can be the sympathetic vasodilatory effect of vessels detected experimentally? What neurotransmitter is released from their terminals?

After the exclusion of the effect of sympathetic vasoconstrictor nerves by adrenoblockers, stimulation of sympathetic nerves leads to dilation of skeletal muscle vessels. It is acetylcholine.

9. What cardiovascular system reflexes are called intrinsic, which are combined?

Intrinsic reflexes are carried out from reflexogenic zones of the cardiovascular system and combined – from any other zones.

10. List the main reflexogenic zones of the cardiovascular system. What type of receptors are located in these zones?

They are: aortic, sinocarotid, pulmonary, cardiac. Baroreceptors are located in all zones and chemoreceptors – in sinocarotid and aortic zones.

11. Which segment of the cut vagus nerve and why should be irritated in order to detect its effect on blood pressure? How and why does the blood pressure change in this case?

The peripheral segment because the influence of the vagus nerve on the blood pressure is related to its direct effect on the heart. Pressure is dramatically reduced due to cardiac arrest.

12.Where is the sinocarotidreflexogenic zone located? Who and in which experiment has proved the importance of this zone in the regulation of blood pressure? What stimuli are adequate for this area?

It is in the area of the common carotid artery branching into the outer and inner artery. Hering has proved it in an experiment with irritation of the efferent nerve extending from this area. Such are changes in blood pressure and chemical parameters (pCO_2, pO_2, pH).

13. Why will the blood pressure change under bilateral exclusion of sinocarotid and aortic nerves?

There is a steady increase in blood pressure due to disappearance of an inhibitory effect on the press area of vascular-motor center and excitatory effect on the center of the vagus nerve of the vascular reflexogenic zones.

14. What type of nervous regulation is used by the body to stabilize blood pressure from the baroreceptive vascular reflex zones? What is the essence of this type of regulation?

By deviation. Compensatory reactions are activated after blood pressure deviation from its normal values: at increasing of the pressure relevant mechanisms are activated which decrease it, at decreasing – vice versa.

15. What type of regulation is used by the body to stabilize blood pressure from the reflexogenic zone of the heart? What is the essence of this type of regulation?

By perturbation. The fact that compensatory reactions are activated before changes of the systemic blood pressure preventing its deviation from the norm.

16. How and why does the blood pressure change when aortic chemoreceptors are excited?

It increases as a result of increased impulses from chemoreceptive zones.It increases the tone of the press area of the vascular-motor center, which leads to narrowing of the vessels.

17. What two types of adrenoceptors are present in the vascular system? What is the response of the vessels to their activation?

They are: alpha-adrenergic receptors (vascular narrowing) and beta-adrenergic receptors (vascular dilating).

18. How and why is the blood pressure changed when norepinephrine is released into the blood?

The blood pressure is increased due to vasoconstriction (arteries of the muscle type and arterioles) and increased heart rate. Due to alpha-adrenergic receptors of the vessels and beta-adrenergic receptors of the heart.

19. How do the metabolism products affect the vascular tone due to their central action?

Generalized vasoconstriction is caused by an increase in the tone of the pressor area of the vascular-motor center.

20. What is the physiological significance of the opposite effect of metabolites on vascular tone at their local and central action?

This provides vasodilatation and increased blood flow to intensely functioning organs (local action of metabolites) and increased blood pressure due to generalized vasoconstriction in non-functioning organs (central action).

21. How does the vascular tone of the muscle type vessels change as the pressure in their lumen increases? What is the name of this phenomenon? What happens to the tone of these vessels due to decreased pressure? How important are both effects?

It increases. It is the Bayliss effect. As blood pressure decreases the vascular tone also decreases. It provides self-regulation of blood flow (maintaining it at a constant level) during systemic blood pressure changes.

22. Where is renin formed? How and why does the systemic blood pressure change due to the presence of renin in blood?

In the juxtaglomerular apparatus of the kidneys due to the reduction of its blood supply. The blood pressure increases because renin enters the bloodstream and leads to the formation of angiotensin II, which has a vasoconstrictor effect.

23. What are the ways of transforming renin into a potent vasoconstrictor?

Under the influence of renin, angiotensinogen of blood plasma is converted to angiotensin-1, which under the influence of the enzyme is converted to active angiotensin-II.

24. What are the main mechanisms of the angiotensin vasoconstrictor influence?

It has a strong direct vasoconstrictor effect on the arteries and less strong – on the veins, excites the central and peripheral structures of the sympathetic nervous system, stimulates aldosterone synthesis, which enhances the angiotensin-II vasopressive action.

25. What is aldosterone? Where is it produced? What are the mechanisms of its participation in the blood pressure regulation?

It is an adrenal cortex hormone. Increases the reabsorption of sodium ions in the renal tubules, which leads to water retention in the body and increases blood pressure. Aldosterone also increases the sensitivity of vascular smooth muscles to the influence of vasoactive substances.

26. Where is the antidiuretic hormone produced and stored? What are the mechanisms of its participation in the blood pressure regulation?

It is secreted in the hypothalamus, accumulated and is activated in the posterior pituitary. It increases reabsorption of water in the renal tubules, affecting blood pressure through changes of circulatory blood volume; in medium and high doses it has a direct vasoconstrictor effect.

27. Through what receptors do epinephrine and norepinephrine realize their influence on the vascular tone?

Epinephrine acts on alpha and beta-adrenergic receptors, and norepinephrine acts mainly on alpha-adrenergic receptors.

28. How are alpha and beta-adrenoceptors distributed in the vascular zones? How does the response of the vessels to norepinephrine depend on it?

Both types of adrenergic receptors are present in the vessels, but their number in different vessels is varies. In most vessels, alpha-adrenergic receptors predominate and epinephrine causes them to narrow; if beta-adrenoceptors (coronary vessels, vessels of the lungs) predominate, epinephrine causes vasodilation.

29. What is the blood vessels`response to the release of epinephrine into the blood during blockage of alpha-adrenoceptors?

Vessels dilate because the vasoconstrictor effect of epinephrine through alpha-adrenoceptors is blocked. ("Distorted" reaction to adrenaline).

30. What is bradykinin? Its impact on the vessels. Duration of its action. Which vascular zones does it act on?

It is a polypeptide (from the kinin group). It has a pronounced vasodilator effect and increases capillary permeability. It is active for few minutes predominantly in the vessels of the digestive tract, sweat glands.

31. Describe the mechanism of reflectory regulation of systemic blood pressure from irritation of atria volumoreceptors during changes of the circulatory blood volume.

As blood volume increases atrial volumoreceptors are irritated and vasopressin (ADH) is inhibited, which leads to increased diuresis, decreasing of the circulatory blood volume, and decrease in blood pressure. A decreased blood volume causes an opposite effect.

32. What is the cardiovascular center of the medulla oblongata? What are its components?

It is the set of the medulla oblongata structures involved in the regulation of blood circulation. The pressor and depressor areas of the vascular center and the centers of the vagus nerves.

33. List the CNS parts involved in the regulation of the cardiovascular system activity.

They are: medulla oblongata and spinal cord, hypothalamus, limbic system, cerebral cortex.

34. List the factors that form the effector influences of the medulla oblongatas' cardiovascular center on the activity of the heart and blood vessels.

They are efferent impulses from cardiovascular and other reflexogenic zones; impulses from the upper alocated parts of the brain and the direct effect of humoral substances on the cardiovascular center.

35. What method can prove the possibility of regulatory effects of the cerebral cortex on vascular tone?

The method of conditional reflexes. With multiple combinations of unconditional stimulus (for example, warming of the skin of the hand) with a conditional stimulus (light), the vessels will expand in response to the isolated action of the signal stimulus (light).

36. What is the physiological significance of the dominant influence of the central mechanisms in the regulation of the venous vascular tone?

By changing the volume of the venous bed it allows to change the venous return of blood to the heart quickly and significantly, and consequently the minute blood flow as well.

37. What processes lead to the increase of circulatory blood volume at reduced blood pressure? In which vessels do these processes work most effectively? How and in what interval of time will this affect the value of blood pressure?

Reduction in liquid filtration from capillaries into the interstitial space and increase its reabsorption into the vascular bed. They work most effectively in skeletal muscle vessels. The pressure will rise in 5-10 minutes.

Tasks for self-control:

1. The general peripheral resistance of the vascular bed is influenced by such regulatory factors as:
   A. Urinary function of the kidneys
   B. baroreceptor vascular-motor reflexes
   C. force of gravitation
   D. blood velocity of blood vessels
   E. no answer is correct

2. How will cardiac activity change due to the treatment with beta-blockers?
   A. the minute volume of blood will increase
   B. the minute volume of blood will decrease
   C. heart rate will increase
   D. heart rate will decrease *

3. Vasoconstrictor factors include all, EXCEPT:
   A. Vasopressin
   B. Histamine *
   C. Angiotensin-2
   D. Adrenaline
   E. Norepinephrine

4. Stress causes increased blood pressure for older people. The reason is activation of:
   A. Adrenal cortex function
   B. parasympathetic vagus nerve nucleus
   C. thyroid function

D. sympatho-adrenal system *
E. pituitary gland functions

5. An athlete showed an increased blood pressure and heart rate before a competition. What parts of CNS activation can explain these changes?
A. Midbrain
B. Diencephalon
C. Medulla oblongata
D. Cerebral cortex *
E. Hypothalamus

6. High blood pressure (systolic - 155 mmHg, diastolic - 90 mmHg) is revealed in a young man of 30 years. After a few hours, blood pressure became normal. With the involvement of which reflex centers could this happen?
A. Bulbar vasomotor center
B. Spinal thoracic-lumbar centers
C. Spinal sacral centers
D. Cerebellar tonic centers
E. Intracardiac nervous system

7. How will the tone of the vessels of functioning muscle change with the injection of alpha-blockers and beta-blockers?
A. With the injection of alpha-blockers, the tone of blood vessels decreases, while injection of beta-blockers – increases it.
B. Vascular tone decreases both with the injection of alpha-blockers and beta-blockers
C. The tone of the vessels does not change in both cases
D. The tone of the vessels increases in both cases
E. With the injection of alpha blockers, the tone of blood vessels increases, with the injection of beta blockers – decreases

8. A 40 year old man had an an increased blood pressure revealed. What is the possible cause of this effect?
A. Increasing the tone of the sympathetic nervous system
B. Expansion of arterioles
C. Decrease in heart rate
D. Hyperpolarization of cardiomyocytes
E. Increasing the tone of the parasympathetic nervous system.

METHODOLOGICAL DEVELOPMENT №20

The topic: Features of regional circulation in some organs and tissues and at different functional states of the body.
The number of hours: 2 hours.
The object of learning:
To know: features of blood supply to the brain, myocardium, skin, lungs, blood circulation due to change in the body position, hemodynamics during exercise, compensatory hemodynamic reactions in case of blood loss.
To be able to: explain the value of myogenic autoregulation in the blood supply of vital organs, interpret hemodynamic changes in the orthostatic test.

Theoretical questions for self-preparation:

1. Features of blood supply of the brain.
2. Features of coronary circulation.
3. Features of circulation in the skin.
4. Features of blood supply of the lungs.
5. Blood circulation due to changes in body position.
6. Hemodynamics during physical activity.
7. Compensatory hemodynamic reactions in case of blood loss.

Keywords and terms: myogenic autoregulation, micropump function of skeletal muscles, arterio-venous anastomoses, orthostatic test, blood deposition, high degree of oxygen extraction from arterial blood, working hyperemia, hemodynamic microcellular function, hemodynamic shock.

APPLICATION №1

Definitions of main terms and concepts:

Myogenic autoregulation of vascular tone – is autoregulation that occurs due to the internal contractile response of vascular smooth muscles to stretching.

Thebesian vessels supply the thin layer of myocardium bordering the endocardium with blood.

The micropump function of the skeletal muscles is a mechanism that promotes the blood flow through the vessels of the skeletal muscle.

Arterio-venous anastomoses are connections between arterioles and venules, and are widely represented, for example, in the microcirculatory channel of the skin, where they participate in thermoregulatory reactions.

Deposited blood is blood that is excluded from systemic circulation. For example, in the vertical position of the body veins of the lower extremities deposit an additional 500 ml of blood.

An orthostatic test is a test for examination of the reliability of circulatory systems. The criterion for the evaluation of this test is the dynamics of the heart rate during change of a person's poisition from horizontal to vertical and vice versa.

Working hyperemia is an increased blood flow to different tissues in the body; in skeletal muscle and myocardium is due to local metabolites and hemodynamic micropump function.

Centralization of blood flow is redistribution of blood in favor of more important organs at a certain moment.

Hemodynamic shock occurs in the event of failure of the systems which compensate hemodynamic reactions.

APPLICATION №2

Control questions and answers on the topic: "Features of regional hemodynamics and hemodynamics at different functional states of the organism".

1. What is the pulmonary reflex zone of the cardiovascular system? How and why does the blood pressure in the large circulatory system change as the pressure in the area increases (Parin`s reflex)?

It is the baroreceptive zone of the small circulatory system vessels. Blood pressure will decrease due to the dilation of blood vessels of the large circulatory system and the reduction of heart function.

2. What is the biological significance of reflex effects from the pulmonary reflex zone on the heart and the vessels of the large circulatory system?

It prevents the blood from overflowing the lungs and developing its edema (protective reflex).

3. In the vessels of which organs do the local myogenic mechanisms of vascular tone regulation overweigh the external, nervous and humoral ones? What is the physiological significance of this fact?

In the vessels of the brain, myocardium, liver, small intestine, kidneys. It allows to keep blood supply of vital organs during considerable fluctuations of systemic blood pressure.

4. List the main physiological mechanisms that promote the increase of blood pressure and fluid retention in the body during blood loss. What factors contribute to the start of these mechanisms?

It is a reflex narrowing of resistance vessels (as a result of reduction of baroreceptors impulses and their increase from chemoreceptors of vascular reflexogenic zones). Reflectory increase of ADH synthesis (as a result of decreased impulsation from left atrial volumoreceptors). Activation of the renin-angiotensin-aldosterone system (as a result of decreased renal blood supply).

5. What are the functionally important features of coronary blood flow and its regulation.

Blood flows through the coronary vessels mainly during diastole; local mechanisms predominate in the regulation of the tone of coronary vessels.

6. How does the tone change of those pulmonary vessels, in which blood flows through the walls of poorly ventilated alveoli? What is the physiological significance of this reaction?

The tone increases sharply, the vessels narrow, the amount of blood flowing through the poorly ventilated alveoli decreases. It promotes oxygenation of arterial blood.

7. How will the blood flow change in working muscles at emotional or physical exertion? What are the mechanisms of this reaction?

It will increase as a result of vascular enlargement under the influence of CNS impulses coming through sympathetic vasodilator fibers, as well as due to the local action of metabolites on the vessels that are intensively formed during muscle contraction (working hyperemia).

Tasks for self-control:

1. When the body is in upright position, the hydrostatic pressure is greatest in the:
   A. veins of the head
   B. veins of the chest cavity
   C. arteries of the foot *
   D. veins of abdominal cavity
   E. none of the above

2. The extracardiac factors of hemodynamics include all, EXCEPT:
   A. Frank-Starling law *
   B. Henderson's respiratory pump
   C. Venous pump
   D. Micropump function of skeletal muscle
   E. Diaphragm pump

3. What factors cause vasodilation of the working vessels of the muscles?
   A. direct effect of oxygen on the vessel wall
   B. influence of the parasympathetic nervous system
   C. influence of sympathetic nervous system
   D. reducing the release of vasopressin
   E. direct effect of metabolism products on the vascular wall *

4. The features of regional circulation of the brain include:
   A. myogenic autoregulation of brain vessels *
   B. significant range of changes in blood supply at functional loads
   C. no influence of local metabolites, hypercapnia, hypoxemia and acidosis
   D. great dependence on reflex reactions of the vessels
   E. none of the above

5. Regulation of the transplanted heart activity is provided by all mechanisms, EXCEPT:
   A. myogenic mechanisms
   B. intracardiac reflexes
   C. Extracardiac nerve mechanisms *
   D. humoral influences
   E. all of the above

6. How will the cardiac activity change during irritation of sympathetic fibers that innervate it after injection of a drug that blocks alpha-adrenoceptors to an animal?
   A. Cardiac activity will not change
   B. Heart rate will decrease
   C. Increase in heart rate and strength
   D. The heart rate will decrease
   E. No answer is correct.

7. At a change of a person's position from lying to standing the following compensatory mechanism occurs:
   A. Increase in heart rate
   B. Reduction of heart rate
   C. Reduction of blood pressure
   D. Reduction of minute volume of blood
   E. Reduction of total peripheral resistance

8. Experiments revealed that the tone of the brain vessels is regulated by metabolic factors and the influence of nerve impulses. What factor plays a major role in reducing the tone of the blood vessels and an increasing of blood flow?
   A. Increased concentration of CO_2 in the blood
   B. Reduction of O_2 voltage in blood
   C. Increase in adenosine concentration
   D. Decrease in the concentration of H_+ ions
   E. Increasing tone of the parasympathetic division of the ANS

METHODOLOGICAL DEVELOPMENT № 21

The topic: General characteristics of digestion. Digestion in the oral cavity.
The number of hours: 2 hours
The object of learning:
To know: the conveyor principle of the digestive system's function, the basic processes of digestion and their characteristics. The processes of digestion in the oral cavity.
Be able to: evaluate the saliva enzymatic activity and the mechanism of its regulation.

Theoretical questions for self-preparation:

1. The conveyor principle of the digestive system's functioning.
2. The basic processes of digestion and their physiological characteristics.
3. The mechanical processing of food in the oral cavity. The actions of chewing and swallowing.
4. The physical and chemical properties of saliva and its function.
5. The regulation of salivation.

APPLICATION №1

Definitions of key terms and concepts:

Digestion is a set of processes, which is directed at transformation of nutritional structures into components that are nonspecific to any species and are able to be absorbed into the internal environment of the body.

Physical processing of food – consist of mechanical machining – crushing, dissolution, mixing.

Chemical processing of food – is the hydrolytic decomposition of proteins, lipids and carbohydrates under the action of digestive enzymes.

The digestive conveyor – is a consequent physical and chemical changes of food which provides the processing and reabsorption of necessary components for the organism and elimination of the harmful ones.

Gastrointestinal hormones - are biological active peptides that are produced by diffusely-located secretory cells of the mucous of the stomach and the small intestine.

Holocrine cells – are cells of the surface epithelium of the stomach which degenerate and convert into secrete.

Apocrine cells – release the secrete together with the particles of cytoplasm (they are the saliva cells in the period of embryogenesis).

Merocrine cells – release the secrete through specialized holes in the cell membrane without cell destruction or cytoplasm abruption.

The saliva enzyme – amylase decomposes starch to disaccharides, maltose (the disaccharides) into mono ones.

APPLICATION №2

Control questions and answers on the topic: "General characteristics of digestion. Digestion in the oral cavity"

1. What are the digestive and non-digestive functions of the gastro-intestinal (GI) tract?
   The digestive functions are taking in food, breaking down the food, absorbing nutrients; non-digestive – protective, eliminating of wastes, secretion of biological active substance.
2. What is the significance of digestion?
   It is the hydrolysis of nutrients to components that don't have species specificity which are ready to be absorbed into blood and lymph with storage of its energy potential.
3. What processing are nutrients exposed to during digestion?
   The mechanical machining – chewing, swallowing, mixing, movement of food; chemical – by the action of enzymes; physical and chemical – action of hydrochloric acid and bile.
4. What types of digestion do you know according to enzyme origin?
   Autolytic, symbiotic, digestion proper.
5. What is called autolytic, symbiotic, digestion proper?
   Autolytic digestion is carried out by enzymes of nutrients; symbiotic – enzymes of symbionts (microbes, protozoa); digestion proper – enzymes that are synthesized by digestive glands.
6. What is the classification of digestion according to localization?
   It can be intracellular and extracellular digestion; there are two types of extracellular digestion: cavity and membrane digestion.
7. Which components are formed as a result of decomposition of proteins, lipids, carbohydrates in the GI tract?

Proteins are decomposed to amino acids, lipids – to glycerol and fatty acids, carbohydrates – to monosaccharides.

8. What are the main functions of the digestive center and where are its neurons located?
   Formation and regulation of feeding behavior, coordination of activities of the digestive tract. It is located in the medulla oblongata, reticular formation, hypothalamus, limbic system, cerebral cortex.
9. What is the significance of digestion in the oral cavity?
   It is in the mechanical processing, damping, dissolution of food and formation of a food bolus.
10. What is "sensory saturation" and what is its mechanism?
    It is a natural reflex feeling of fullness (satisfaction), that appears after food intake as a result of irritation of the mouth's and stomach's receptors and the arrival of afferent impulses to the CNS, resulting in the activation of the saturation center and inhibition of the hunger center.
11. What is called "metabolic saturation" and what is its mechanism?
    It is saturation which arises after the nutriens have arrived into blood (appears 1,5-2 hours after food intake).
12. What method is used to research the work of the salivatory glands?
    The method of Leshli-Krasnogorskogo capsules allows to collect saliva separately from each salivary gland.
13. What are the digestive functions of saliva?
    They are: mechanical and enzymatic processing of food, dampening, dissolving, and forming of a food bolus.
14. What are the non-digestive functions of saliva?
    Protective (the antibacterial effect of lysozyme), it is involved in articulation, excretory, thermoregulatory functions.
15. What is the main enzyme of saliva and what substances does it affect?
    It is alpha amylase and it affects polysaccharides (starch).
16. What stimuli can cause saliva secretion?
    Any irritants, that affect the oral mucosa.
17. What is the main mechanism of salivary gland regulation?
    The reflectory mechanism (unconditional and conditional reflexes).

Gland	Acinar Type	Viscosity	Percentage of Whole Unstimulated Daily Saliva
Parotid	Serous	Watery	25
Submandibular	Mixed	Semiviscous	71
Sublingual	Mucous	Viscous	3-4
Minors	Mucous	Viscous	Trace

Innervation of salivary glands

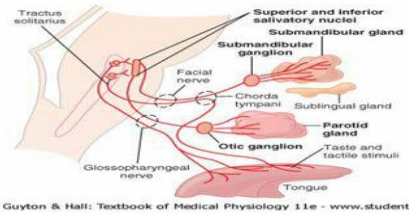
Saliva production is controlled by salivary center in medulla through autonomic nervous system. Salivary secretion is the only digestive secretion that controlled only by neural factors

*Excitation of parasympathetic nerve fibers causes:

Copious (present in large quantity) watery secretion rich in electrolytes and enzymes

*Excitation of sympathetic nerve fibers causes:

-slight increase in viscid saliva (containing mucus)



Salivary secretion is increased by
1. Tactile stimuli in mouth
   - Acid in the mouth
   - Stimulating oral touch receptor
2. Thinking & smelling of appetizing food

Salivation is increased when there is imminent vomiting

Table 21.1 Functions of Digestive Tract and Accessory Organ Secretions

Fluid, Enzyme, or Hormone	Source	Function
Mouth		
Saliva	Salivary glands	Moistens and lubricates food
Salivary amylase	Salivary glands	Digests starch (conversion to maltose and isomaltose)
Lingual lipase	Salivary glands	Begins lipid digestion (< 10%)
Lysozyme	Salivary glands	Weak antibacterial action
Esophagus		
Mucus	Mucous glands	Lubricates esophagus; protects esophageal lining from abrasion and allows food to move easily through the esophagus
Stomach		
Hydrochloric acid	Gastric glands (parietal cells)	Converts pepsinogen into pepsin, kills bacteria
Pepsin	Gastric glands (chief cells)	Activated pepsinogen, digests protein into smaller peptide chains
Gastric lipase	Gastric glands (chief cells)	Digests a minor amount of lipid
Mucus	Mucous cells	Protects stomach lining from stomach acids and digestive enzymes
Intrinsic factor	Gastric glands (parietal cells)	Binds to vitamin B_{12}, aiding in its absorption
Gastrin	Gastric glands (endocrine cells)	Increases stomach secretions and motility
Small Intestine and Associated Glands		
Bile salts	Liver	Emulsify fats, form micelles, contain waste products (bilirubin, cholesterol)
Bicarbonate ions	Pancreas, liver	Neutralize stomach acid
Pancreatic amylase	Pancreas	Digests starch
Pancreatic lipase	Pancreas	Digests lipid
Trypsin	Pancreas	Activated trypsinogen, digests proteins
Chymotrypsin	Pancreas	Activated chymotrypsinogen, digests proteins
Carboxypeptidase	Pancreas	Activated procarboxypeptidase, digests proteins
Nucleases	Pancreas	Digest nucleic acid
Sucrase	Small intestine	Digests sucrose
Lactase	Small intestine	Digests lactose
Maltase	Small intestine	Digests maltose
Isomaltase	Small intestine	Digests isomaltose
Lipase	Small intestine	Digests lipid
Peptidases	Small intestine	Digest polypeptide
Mucus	Duodenal glands and goblet cells	Protects duodenum from stomach acid and digestive enzymes
Secretin	Small intestine	Inhibits gastric secretions, stimulates secretion of aqueous component (bicarbonate ions) of pancreatic juice, increases bile secretion (bicarbonate ions), decreases gastric motility
Cholecystokinin	Small intestine	Inhibits gastric secretion, stimulates secretion of enzymatic component of pancreatic juice, decreases gastric motility, stimulates gallbladder contraction and sphincter relaxation

Tasks for self-control

1. Put in the missing words. The introduction of atropine … the elimination of saliva, because it effects…

   A. increases, beta-adrenoreceptors
   B. decreases, beta-adrenoreceptors
   C. increases, M-cholinoreceptors
   D. decreases, M-cholinoreceptors *
   E. increases, beta-1 adrenoreceptors

2. What is the pH of saliva?
   A. 0,8- 1,5
   B. 7,4- 8,0
   C. 6,4- 8,0
   D. 7,1- 8,0
   E. none are correct *

3. Put in the correct missing words. The stimulation of parasympathetic nerves…..the quantity of saliva with ……concentration of organic. substances.
   A. increases, low *
   B. decreases, high
   C. increases, high
   D. decreases, low
   E. does not change

4. Several ulcers were found in the mucous sheath of the patient in his oral cavity. The reason is: the decreased level of .....in the saliva.
   A. – calcium
   B. – alpha-amylase
   C. – lysozyme *
   D. – bicarbonates
   E. – phosphates

5. A patient is suffering from inflammation of the trigeminus nerve. Which of the digestive processes will be disturbed most of all?
   A. salivation
   B. taste feeling
   C. swallowing
   D. chewing *
   E. all of them

METHODOLOGICAL DEVELOPMENT № 22

Topic: Digestion in the stomach.
The number of hours: 2 hours
The object of learning:

To know: the morphological and functional peculiarities of the stomach, its function, digestive properties of stomach juice, the regulation of its secretion, motility of the stomach and its regulation.
To be able to: explain the digestive action of the gastric juice, identify the optimal conditions of the activity of proteolytic enzymes, the role of hydrochloric acid.

Theoretical questions for self-preparation

1. The morpho-functional structure and functions of the stomach.
2. The digestive properties of the gastric juice and regulation of its secretion.
3. The role of (acidic chlorine) hydrochloric acid in digestion.
4. The phases of gastric secretion and its characteristics.
5. The motility of stomach and its regulation.
6. Structural features of the secretory glands in different parts of the stomach.

Key words and terms: mucous cells, cheif cells, parietal cells, enterochromaffin-like cells (ECL), G-cells, pepsinogen, pepsin, histamine, gastrin, intrinsic factor.

APPLICATION №1
Definitions of key terms and concepts

The stomach is a J-shaped sacklike chamber lying between the esophagus and the small intestine. It is divided into three sections based on structural and functional distinctions.

Types of secretory cells of the stomach:

1. **Exocrine cells**
   a) *Mucous cells* secrete alkaline mucus and protect mucosa against mechanical and acid injury of pepsin;
   b) *Chief cells* secrete pepsinogen after the activation of which protein digestion begins;
   c) *Parietal cells* secrete hydrochloric acid, which activates pepsinogen, denaturates proteins and kills microorganisms; they secrete intrinsic factor, which facilitates absorption of vitamin B12.
2. **Enteroendocrine cells**
   a) *Enterochromaffin-like (ECL) cells* secrete histamine, which stimulates parietal cells;
   b) *G cells* secrete gastrin, which stimulate parietal cells;
   c) *D cells* secrete somatostatin, which inhibit parietal, G and ECL cells.

APPLICATION №2

Control questions and answers on the topic: "Digestion in the stomach"

1. What are the three major types of cells of the gastric glands? What substances do they produce?
   Mucous cells produce alkaline mucus, chief cells – pepsinogen, parietal cells – hydrochloric acid.
2. What types of enzymes of the gastric juice do you know?
   Proteolytic enzymes: pepsin, gastryksyn, pepsin B; and lipolityc – gastric lipase.
3. Specify the optimum of pH for pepsin group I and II.
   Optimum pH for pepsin group I is 1,5-2, for pepsin group II – 3,2-3,5.
4. What are the secrets of the stomach? What secretion does the stomach produce?
   The secretions of the stomach are called **gastric juice**.
   As food enters the stomach, it is mixed with the gastric juice to become a semifluid mixture called **chime**.

Secretions from the gastric glands include mucus, hydrochloric acid, pepsinogen and intrinsic factor. A thick layer of mucus lubricates and protects the epithelial cells of the stomach wall from the damaging effect of the acidic chime and pepsin.
Irritation of the stomach mucosa stimulates the secretion of a greater volume of mucus.
Hydrochloric acid produces a pH of about 2.0 in the stomach.
Pepsinogen is a precursor of the enzyme pepsin. Hydrochloric acid converts pepsinogen to the active enzyme pepsin, which digests proteins by breaking them down into smaller peptides. A peptide is two or more amino acids united by a peptide bond. Pepsin exhibits optimum enzymatic activity at a pH of about 2.0. Low pH also kills microorganisms.
Intrinsic factor binds with vitamin B12 and makes it absorbable by the small intestine. Vitamin B12 is important in the synthesis of deoxyribonucleic acid (DNA) and red blood cell production. Gastrin and histamine help regulate stomach secretions.

5. What fat can be hydrolized by gastric lipase? Explain the mechanism.
   Gastric lipase hydrolyses only emulsified fats (fats of milk), because there are no conditions to emulsify fats in stomach.
6. How much gastric juice is secreted in the human stomach per day? What is its pH value?
   It is 2-2.5 liters of gastric juice per day, pH – 1.5-2.0.
7. What are the phases of gastric secretion?
   They are the cephalic phase, the gastric phase and the intestinal phase.
8. List the main methods of gastric motility investigation in humans.
   They are: different versions of X-ray, radionuclide methods and electrogastrogram.
9. Why do we use probe methods to know secretory activity of the stomach in humans?
   We use it to obtain juice in order to research its content by pH-probe, pH- measurement, endoscopy.
10. What digestive hormones stimulate the secretion of pepsinogen in the stomach?
    They are gastrin, bombezyn, motilin, cholecystokinin-pancreozymin.
11. What is the impact of cholecystokinin-pankreozymin on the digestive system?
    It stimulates the secretion of pancreatic enzymes, stomach, stimulates the gallbladder.
12. What impact does bombezin have on gastrointenstinal hormones?
    Increases the release of gastrin, cholecystokinin-pankreozymin, pancreatic polypeptide and neurotensin.
13. What is the impact of histamine on the secretory activity of the stomach?
    Histamine causes the release of large amounts of gastric juice with low content of enzymes and high acidity.

CLINICALBOX

Gastroesophageal Reflux Disease or heartburn, is a painful or burning sensation in the chest associated with the reflux of acidic chyme into the esophagus. The pain is usually short-lived but may be confused with the pain of an ulcer or a heart attack. Overeating, eating fatty foods, lying down immediately after a meal, consuming too much alcohol or caffeine, smoking, and wearing extremely tight clothing can all cause heartburn. A hiatal hernia can also cause heartburn, especially in older people. Drugs that neutralize gastric acid or reduce gastric acid production can effectively treat GERD.

Cephalic Phase

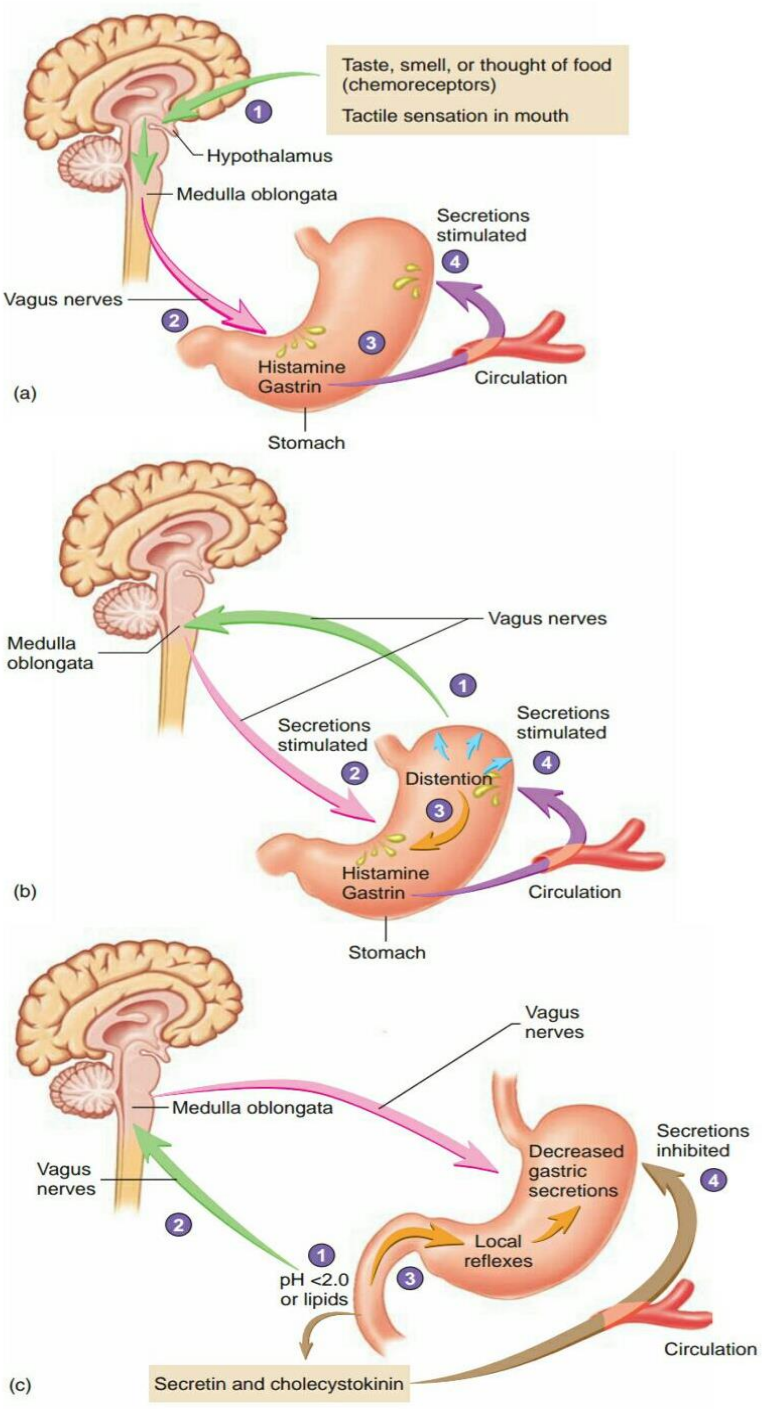
1. The taste, smell, or thought of food or tactile sensations of food in the mouth stimulate the medulla oblongata (*green arrows*).
2. Parasympathetic action potentials are carried by the vagus nerves to the stomach (*pink arrow*), where enteric plexus neurons are activated.
3. Postganglionic neurons stimulate secretion by parietal and chief cells and stimulate gastrin and histamine secretion by endocrine cells.
4. Gastrin is carried through the circulation back to the stomach (*purple arrow*), where, along with histamine, it stimulates secretion.

Gastric Phase

1. Distention of the stomach stimulates mechanoreceptors (stretch receptors) and activates a parasympathetic reflex. Action potentials generated by the mechanoreceptors are carried by the vagus nerves to the medulla oblongata (*green arrow*).
2. The medulla oblongata increases action potentials in the vagus nerves that stimulate secretions by parietal and chief cells and stimulate gastrin and histamine secretion by endocrine cells (*pink arrow*).
3. Distention of the stomach also activates local reflexes that increase stomach secretions (*orange arrow*).
4. Gastrin is carried through the circulation back to the stomach (*purple arrow*), where, along with histamine, it stimulates secretion.

Gastrointestinal Phase

1. Chyme in the duodenum with a pH less than 2.0 or containing fat digestion products (lipids) inhibits gastric secretions by three mechanisms (2–4).
2. Chemoreceptors in the duodenum are stimulated by H^+ (low pH) or lipids. Action potentials generated by the chemoreceptors are carried by the vagus nerves to the medulla oblongata (*green arrow*), where they inhibit parasympathetic action potentials (*pink arrow*), thereby decreasing gastric secretions.
3. Local reflexes activated by H^+ or lipids also inhibit gastric secretion (*orange arrows*).
4. Secretin and cholecystokinin produced by the duodenum (*brown arrows*) decrease gastric secretions in the stomach.



Process Figure 21.12 Phases of Stomach Secretion

Treatment of Excess Acid Secretion

Antacids are bases, such as CaCO3, Al(OH)3, and Mg(OH)2, that neutralize gastric acid when ingested. They are fast acting but have relatively short duration effect. Antacids are effective for up to 30 minutes on an empty stomach and neutralize acid for 2 to 3 hours when taken with food. Long-term self-treatment with antacids should be avoided because the cause of excess acid production should be determined. Also, there are more effective treatments.

H2-receptor antagonists are drugs that block the histamine receptor on parietal cells. Recall that histamine, gastrin, and acetylcholine stimulate parietal cells to secrete acid and that histamine has

the greatest stimulatory effect. H2 receptors are a type of histamine receptor on parietal cells. Cimetidine (Tagamet), ranitidine (Zantac), and famotidine (Pepcid) are H2-receptor antagonists that bind reversibly to H2 receptors. They suppress 24-hour gastric acid secretion by approximately 70%. The H2 receptors are different from the H1 receptors involved in allergic reactions. Antihistamines that block allergic reactions do not affect histamine-mediated gastric acid secretion, and vice versa.

Proton pump inhibitors bind irreversibly with the H+–K+exchange pump in parietal cells. The pump is inactivated, and acid secretion does not resume until a new pump molecule is manufactured and inserted into the plasma membrane. Proton pump inhibitors effectively reduce acid secretion for 24 to 48 hours.

Tasks for self-control

1. Put in the missing figures. During 24 hours ……..(quantity) of gastric juice is formed in the human body with pH……
   A. 1,0-2,0 l 0,5-1,0;
   B. 3,4-4,0 l 5,0-6,0;
   C. 2,0-2,5 l 1,5-1,8; *
   D. 0,1-0,5 l 4,0-6,0;
   E. none of them is correct

2. The mucus of the gastric juice is formed by … and has a ……..PH:
   A. parietal cells, neutral;
   B. chief cells, acidic;
   C. chief cells, neutral;
   D. mucocytes, acidic;
   E. mucocytes, alcalic *

3. Examination of a 35 year old patient revealed the gastric juice with high acidity.What receptors should be blocked in order to reduce it?
   A. alpha-1 adrenoreceptors;
   B. ECL – hystaminreceptors; *
   C. beta 1 – adrenoreceptors;
   D. beta 2 – adrenoreceptors;
   E. all of them

4. What component of the gastric juice is necessary for the denaturation of proteins?
   A. pepsin;
   B. mucus;
   C. acidic chlorine; *
   D. bile;
   E. all of them

5. Put in the proper words . In case of increased secretion of secretin … the gastric secretion…..
   A. by the duodenum, increases;
   B. by the duodenum, decreases; *
   C. by the pyloric part, increases;
   D. by the pyloric part, doesn’t change;
   E. by the antrum, increases;

6. A part of the stomach of the patient was resected (a part of the stomach was removed by operation). How must he change his food intake:
   A. little portion 6-8 times a day; *
   B. big portions two times a day;
   C. eat at night;
   D. a big portion once a day;
   E. can remaine unchanged.

7. For a patient with hypersecretion of gastric juice the doctor advised to eat soups made from meat and vegetables. It stimulates the gastric secretion by the following mechanism:
   A. irritates the taste receptors;
   B. irritates the mechanoreceptors of the stomach;
   C. stimulates the production of secretin by the duodenum;
   D. stimulates the production of gastrin by the G-cells; *
   E. all of them

8. It is necessary to take the gastric juice by a gastric tube.
   Which product that decreases the production of gastric juice cannot be used for this aim?

   A. fat; *
   B. histamin;
   C. dry bread
   D. alcohol;
   E. the juice of the cabbage

METHODOLOGICAL DEVELOPMENT №23

Topic: The role of the pancreas, liver and gallbladder in digestion.

The object of learning:

To know: the role and mechanism of regulation of the secretory function of pancreas, liver and gallbladder, their importance in digestion.

To be able to: evaluate the secretory function of these glands in experimental conditions.

Theoretical questions for self-preparation:

1. Composition and properties of pancreatic juice.
2. The enzymes of pancreatic juice and their impact on chime.
3. Regulation of pancreatic secretion.
4. Functions of the liver.
5. The composition and properties of bile. The role of bile in digestion.
6. Regulation of secretion and excretion of bile.

Key words and terms: pancreatic juice, trypsin, chymotrypsin, elastase, lipase, phospholipase, lecithinase, esterase, alpha-amylase, maltase, lactase, ribonuclease, desoxyribonuclease, chime, bile, salts, bile pigments, bilirubin, steatorrhea, icterus.

APPLICATION №1

Definitions of key terms and concepts

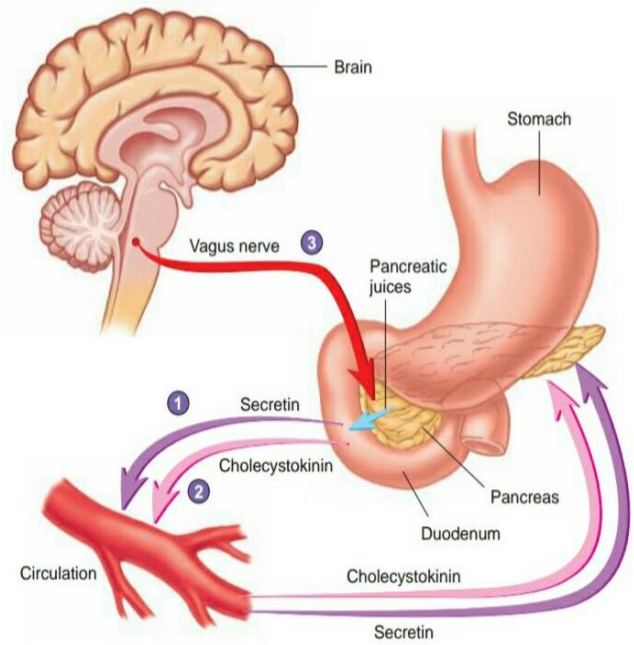
Steatorrhea is the presence of excess fat in the stool. It is caused by a lack of bile acids and defects in pancreatic enzymes.

Jaundice (icterus) is a yellowish pigmentation of the skin, of the conjunctival membranes over the sclera (whites of the eyes) and of other mucous membranes caused by a high level of bilirubin in the blood.

APPLICATION №2

Control questions on the topic: "The role of the pancreas, liver and gallbladder in digestion"

1. What glands release their secrets into the cavity of the duodenum?
   They are the pancreas, the liver and the duodenal (Brunner) glands.
2. What substances are degraded by the enzymes of the pancreas?
   They are proteins, fats, carbohydrates and products of their hydrolysis.
3. Which pancreatic enzymes hydrolyze proteins?
   They are: trypsin, chymotrypsin, elastase, carboxipeptydase A and B.
4. Which pancreatic enzymes hydrolyze fats?
   They are: lipase, phospholipase, lecithinase, esterase.
5. Which pancreatic enzymes hydrolyze carbohydrates?
   They are: alpha-amylase, maltose, lactose.
6. Which pancreatic enzymes hydrolyze nucleic acids?
   They are ribonuclease, deoxyribonuclease.
7. Which gastrointestinal hormones stimulate exocrine activity of pancreas?
   They are: gastrin, secretin, cholecystokinin, bombesin, substance P.
8. Which gastrointestinal hormones inhibit the secretion of pancreatic juice?
   They are: enteroglucagon, enkephalins, somatostatin.
9. What are the main components of bile?
   There are: bile salts 61%, bile pigments 3%, fatty acids 12%, cholesterol 9%, phospholipids 3%, mucus. The liver produces and secretes about 600-1000 mL of bile each day. Bile contains no digestive enzymes, but it is important because it neutralizes and dilutes gastric acid and emulsifies fats.
10. What foods stimulate the secretion of bile into the intestine?
    Egg yolk, milk, meat and fats.
11. What is the difference between the bile taken from the liver and taken from the gallbladder?
    The bile taken from the gallbladder is more concentrated, because of reabsorption of water from it and has a darker colour.
12. What is the influence of the vagus nerve on bile secretion?
    It increases the bile secretion because it constricts the gallbladder and relaxes it's sphincter.
13. How can you explain the anti toxic function of the liver?
    It eliminates the infectional agents and toxic substances, which get into the organism from outside or were formed inside during metabolism as by products.



1. Secretin (*purple arrows*) released from the duodenum stimulates the pancreas to release a watery secretion rich in HCO_3^-.
2. Cholecystokinin (*pink arrows*) released from the duodenum causes the pancreas to release a secretion rich in digestive enzymes.
3. Parasympathetic stimulation from the vagus nerve (*red arrow*) causes the pancreas to release a secretion rich in digestive enzymes.

Process Figure 21.23 Control of Pancreatic Secretion

Functions of the Liver

Metabolic

Detoxification/breakdown

- Toxins
- Hormones
- Drugs

Synthesis

- Bile – for emulsification of fats in the lumen of the GI tract
- Protein
  - Production – including amino acids, clotting factors, vitamins, albumin and various other hormones.
  - Activation
- Carbohydrate – including gluconeogenesis.
- Lipid – including cholesterol and triglyceride production.
- Red blood cells – normal in the foetus but 'pathological' in adults

Storage

Nutrients – Glucose

Vitamins and minerals – including Vitamin A/D/B12, iron and copper.

Immunological

Kupffer cells lining sinusoids act as antigen presenting cells

Control of Bile Secretion and Release

1. Secretin, produced by the duodenum (*purple arrows*) and carried through the circulation to the liver, stimulates bicarbonate secretion into bile (*green arrows inside the liver*).
2. Cholecystokinin, produced by the duodenum (*pink arrows*) and carried through the circulation to the gallbladder, stimulates the gallbladder to contract and sphincters to relax, thereby releasing bile into the duodenum (*green arrow outside the liver*).
3. Vagus nerve stimulation (*red arrow*) causes the gallbladder to contract, thereby releasing bile into the duodenum.
4. Bile salts stimulate bile secretion. Over 90% of bile salts are reabsorbed in the ileum and returned to the liver (*blue arrows*), where they stimulate additional secretion of bile salts.

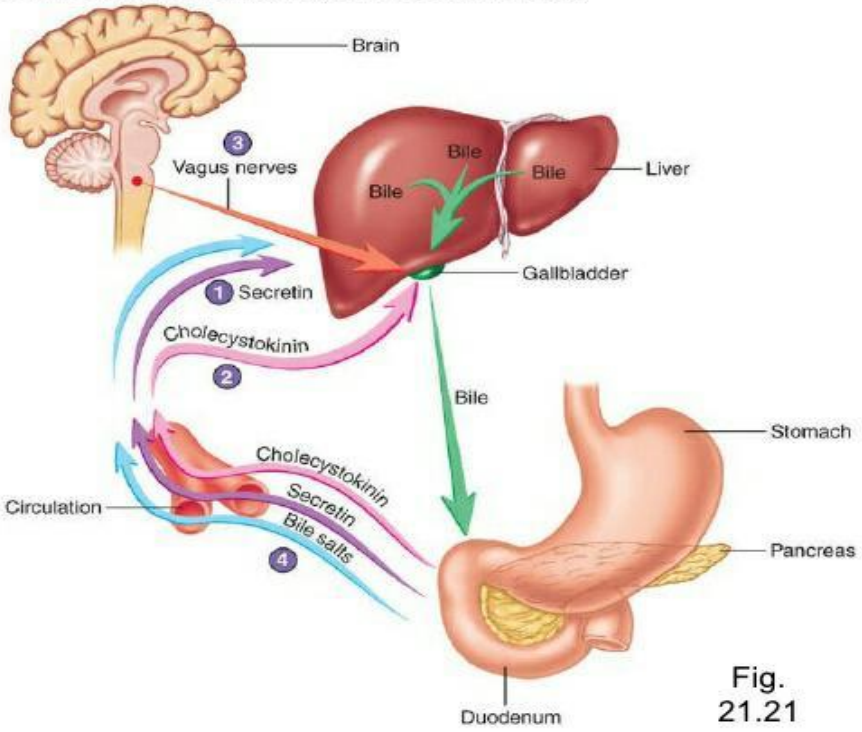
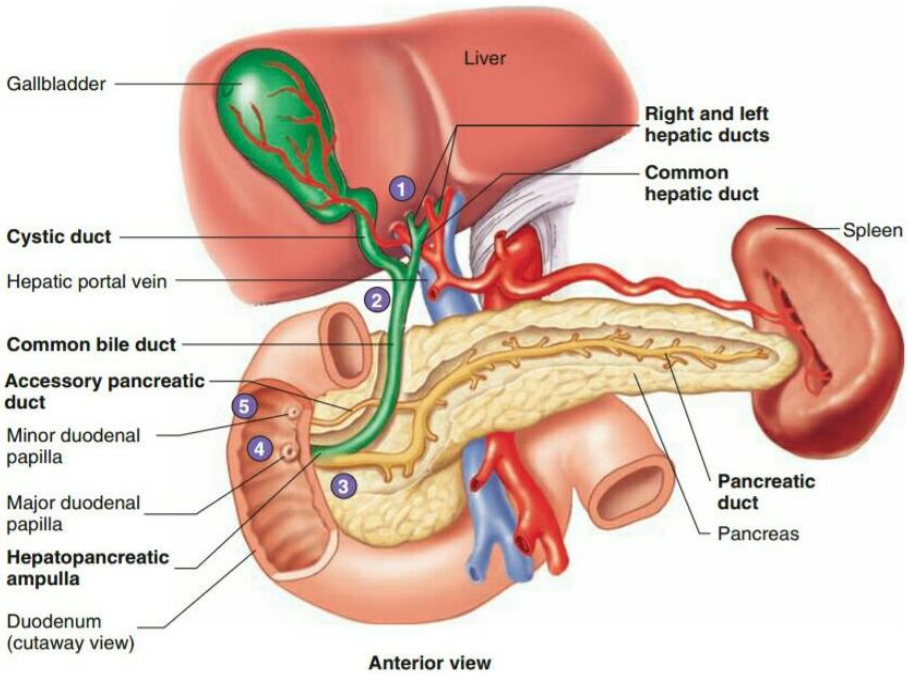


Fig. 21.21

1. The hepatic ducts, which carry bile from the liver lobes, combine to form the common hepatic duct.
2. The common hepatic duct combines with the cystic duct from the gallbladder to form the common bile duct.
3. The common bile duct and the pancreatic duct combine to form the hepatopancreatic ampulla.
4. The hepatopancreatic ampulla empties bile and pancreatic secretions into the duodenum at the major duodenal papilla.
5. The accessory pancreatic duct empties pancreatic secretions into the duodenum at the minor duodenal papilla.



Anterior view

Tasks for self-control:

1. During 24 hours a quantity of ……pancreatic juice is produced with the pH of …
   A. 1,2-2 l and 7,8-8,4 *
   B. 0,5-1 l and 6,0-6,5
   C. 2,0-3 l and 8,5-9,0
   D. 0,1-0,5 l and 4,0-6,0
   E. 2,5-3 l and 5,0-7,0

2. The role of gallbladder is:
   A. production of cholesterine
   B. production of pepsin
   C. production of cholecystokinin
   D. storage of bile *
   E. storage of tripsin

3. During a long diet with carbohydrates, the pancreatic juice contains more:
   A. lipase
   B. amylase *
   C. tripsin
   D. pepsin
   E. glucagon

4. Hydrolysis of what nutrients will be disturbed in the case of gallbladder stones?
   A. carbohydrates
   B. proteins
   C. nucleic acid
   D. fats *
   E. all of them

5. A patient has had a resection of a part of the pancreas. What diet is necessary for him?
   A. soups
   B. cookies
   C. beans
   D. chocolate
   E. vegetables and fruits *

6. What substance is the activator of chymotripsin?
   A. tripsin *
   B. enterokinase
   C. pepsin
   D. bile salts
   E. acidic chlorine

7. A 30 year old patient had a decreased content of bicarbonates in the duodenum revealed. What hormone can increase the quantity of bicarbonates in the pancreatic juice?
   A. cholecystokinin
   B. gastrin
   C. secretin *
   D. enterokinase
   E. villikinin

METHODOLOGICAL DEVELOPMMENT №24

Topic: Digestion in the small and large intestine.
The number of hours: 2 hours
The object of learning:
To know: functions of the small and large intestines, mechanisms of secretory and motor regulation of the intestine.
To be able to: explain the importance of the hollow and membrane digestion, the role of bacterial flora in the large intestine.

Theoretical questions for self-preparation:

1. The relationship between the hollow and membrane digestion.
2. The enzymatic and secretory function of the small intestine and its regulation.
3. The motor function of the small intestine and its regulation.
4. The role of the large intestine in digestion. The bacterial flora of the large intestine.

APPLICATION №1

Definitions of key terms and concepts:

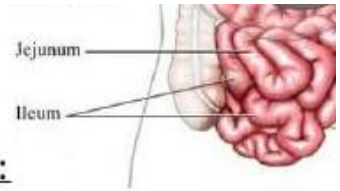
Hollow digestion - occurs in special digestive cavities of the gastro-intestinal tract by enzymes secreted by cells of the digestive glands or cells that are located in these cavities (mouth, stomach, small intestine).
Membrane digestion - occurs on the surface of microvilli in the small intestine, completing the hydrolysis of intermediate substances from hollow digestion.
Glycocalyx - a component of the enterocytes' membrane formed by mucopolysaccharide's filaments connected by calcium bridges. Various enzymes are adsorbed on the membrane which perform hydrolysis of intermediate substances from hollow digestion.
Lieberkhune intestinal glands are deep crypts near the basal part of the villi. These glands produce an intestinal juice, rich in mucus which helps to absorb the chyme monomers into the villus stem vessels.
Payer patches are clusters of limphoid tissue in the submucous layer of the small intestine.
Brunner glands are specialized glands in the submucous layer of the duodenum which produce alkaline mucus that protects the mucous layer against the aggressive acidic chyme coming from the stomach.
Enterokinase is a special enzyme that activates the proteolytic enzyme of pancreatic juice-trypsinogen.

APPLICATION №2

Control questions on the topic: "Digestion in the small and large intestine."

1. What are the main functions and structures of the small intestine?

- Function
  - chemical digestion
    - digestive enzymes
  - absorption through villi & microvilli:
    - finger-like projections
    - increase surface area for absorption
    - over 6 meters!
    - small intestine has huge surface area = 300m² (~size of tennis court)
    - most nutrients are absorbed across the epithelium of the small intestine
- Structure
  - 3 sections
    - duodenum = most digestion
    - jejunum = absorption of nutrients & water
    - ileum = absorption of nutrients & water



2. What are the main enzymes of intestinal juice?

Intestinal Enzymes		
Peptidase	Mucosal cells	Breaks down peptides into amino acids
Sucrase, maltase, lactase	Mucosal cells	Breaks down disaccharides into monosaccharides
Intestinal lipase	Mucosal cells	Breaks down fats into fatty acids and glycerol
Enterokinase	Mucosal cells	Shortens trypsinogen into trypsin

Goblet cells of the intestinal glands secrete major components of mucus in response to chemical and mechanical stimulations.

3. Describe the movements in the small intestine.

The small intestine carries out mixing movements and peristalsis. The major mixing movement is segmentation, in which small, ringlike, periodic contractions cut the chyme into segments and move it back and forth. Peristaltic waves propel chyme through the small intestine. These waves are usually weak, and they stop after pushing the chyme a shor distance. Consequently, chyme moves slowly through the small intestine, taking from three to ten hours to travel its length.

4. What is the membrane digestion?

It is digestion performed by enzymes that are fixed in the area of glycocalyx and on the plasmatic membrane of the microvilli of the small intestine.

5. Which experiment can prove the existance of membrane digestion?

In an experiment where parts of small intestine are inserted in test tubes with starch and amylase, resulting in dramatically accelerated hydrolysis of starch.

6. What is the adaptive nature of the intestinal glands? List the enzymes of the intestinal juice.

In changing of the amount of juice and its relative content of its individual enzymes (or their groups) depending on the quantity and quality of food. They are: sucrose, enterokinase, alkaline phosphatase, lactase.

7. Describe the main features of nervous regulation of secretion in the small intestine.

The main role belongs to local nerve mechanisms and hormonal factors in the regulation of secretion. The central nervous system has a trophic effect, regulating the formation of intestinal enzymes.

8. What are the main local excitatory mechanisms of intestinal glands?

The mechanisms implemented by local reflexes or local humoral factors (tissue hormones GIT).

9. What stimuli increase the secretion of digestive juice upon contact with the mucous membrane of the intestine?

Mechanical and chemical, components of intestinal chime.

10. Is the ileocecal sphincter open or closed during periods beyond food intake? How does it change after eating? By what mechanism?

It is closed. It opens at regular intervals of time (every 0.5-1 min) after eating by reflex.

11. What is the role of the large intestine in digestion apart of the value of the microflora?

The final hydrolysis of undigested food residues, water absorption, the formation of feces.

12. How important is the flora of the large intestine?

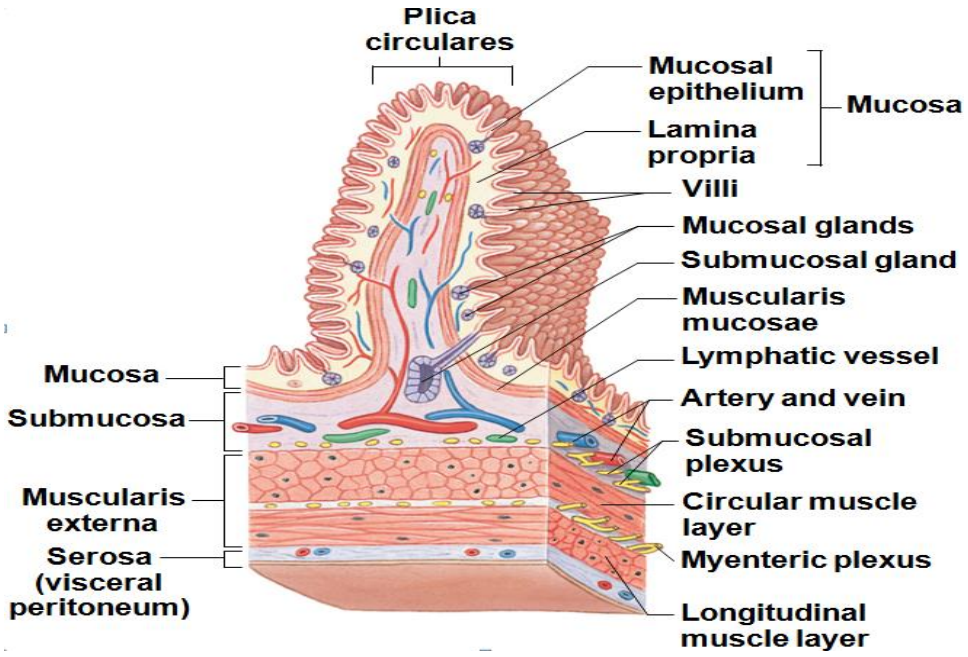
It has a protective function (creating immune barrier, inhibiting pathogenic microflora), a role in the synthesis of vitamins (K and B), synthesis of enzymes that hydrolyze cellulose.

13. What is the duplication in the digestive channel (give an example)? What is the biological essence of this phenomenon?

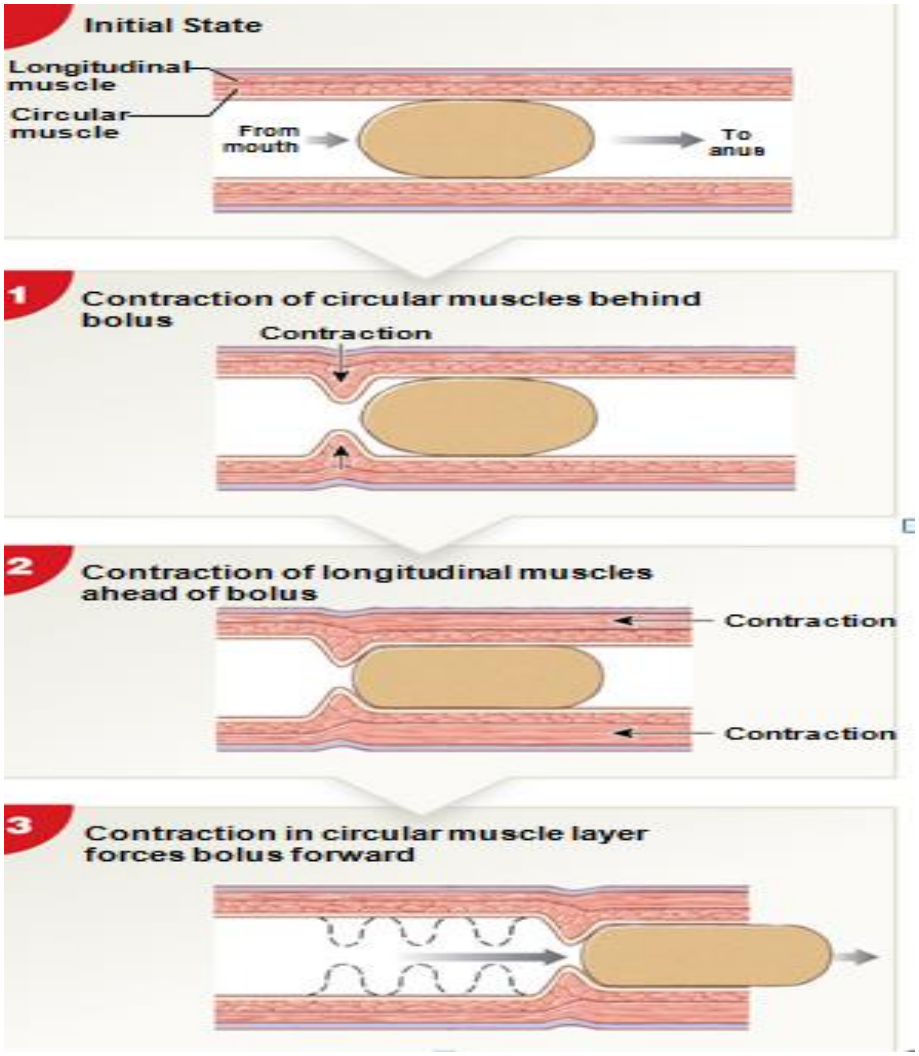
It is the presence of similar in nature nutrient enzymes in different parts of the gastrointestinal tract (eg, peptidases, pepsinogen, trypsinogen, chemotrypsinogen). This increases the reliability of digestion.

14. What is the physiological significance of the motor function of the digestive tract?

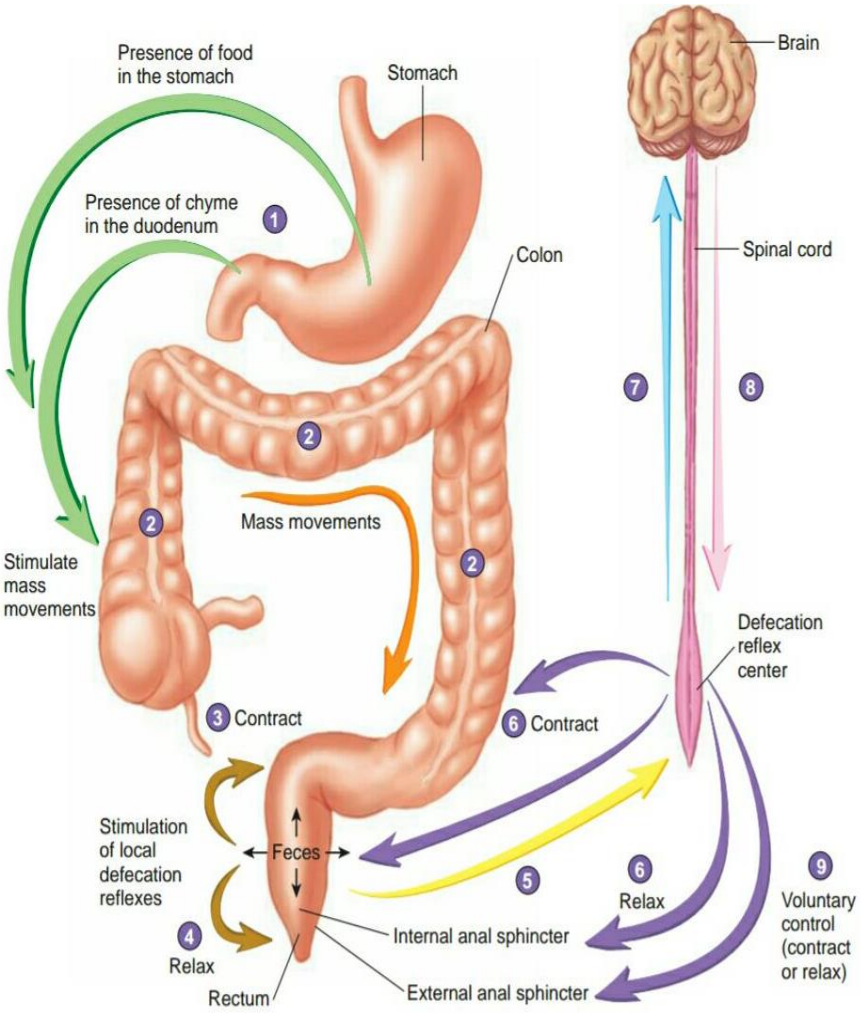
It promotes digestion by crushing, mixing, moving of the chime in the gastrointestinal tract and provides excretion of undigested residues and unnecessary body products.



The process of peristaltic waves



1. The thought or smell of food, distention of the stomach, and the movement of chyme into the duodenum can stimulate the gastrocolic and duodenocolic reflexes (*green arrows*).
2. The gastrocolic and duodenocolic reflexes stimulate mass movements in the colon, which propel the contents of the colon toward the rectum (*orange arrow*).
3. Distention of the rectum by feces stimulates local defecation reflexes. These reflexes cause contractions of the colon and rectum (*brown arrow*), which move feces toward the anus.
4. Local reflexes cause relaxation of the internal anal sphincter (*brown arrow*).
5. Distention of the rectum by feces stimulates parasympathetic reflexes. Action potentials are propagated to the defecation reflex center located in the spinal cord (*yellow arrow*).
6. Action potentials stimulate contraction of the colon and rectum and relaxation of the internal anal sphincter (*purple arrows*).
7. Action potentials are propagated through ascending nerve tracts to the brain (*blue arrow*).
8. Descending nerve tracts from the brain regulate the defecation reflex center (*pink arrow*).
9. Action potentials from the brain control the external anal sphincter (*purple arrow*).



Process Figure 21.25 Control of Defecation

Tasks for self-control:

1. Which of these is not a function of the large intestine?
   A. absorbtion of fats *
   B. absorbtion of water and salts
   C. chime converted to feces
   D. production of mucus
   E. all of the above

2. Defecation:
   A. can be initiated by stretch of the rectum
   B. can occur as a result of mass movements
   C. involves local reflexes
   D. involves parasympathetic reflexes mediated by the spinal cord.
   E. all of the above *

3. The final products of the carbohydrates digestion are:
   A. amino-acids
   B. CO2 (carbodyoxide) and water
   C. monosaccharides *
   D. fatty acids and glycerol
   E. vitamins

4. How will atropine (an M-cholinoblocator) change the motor function of the intestine?
    A. it will increase it
    B. there will be no changes
    C. the motility of the small intestine increases and the motility of large intestine doesn't change
    D. it will decrease it *
    E. the motility of the small intestine increases and the motility of large intestine decreases

5. The motility of the villi is regulated by:
    A. histamine
    B. villikinin *
    C. secretin
    D. adrenalin
    E. gastrin

6. During a prolonged antibiotic treatment the patient felt an increased gas formation in the intestine, swelling. It can be caused by:
    A. long starving
    B. overeating
    C. alcohol
    D. disbacteriosis *
    E. no anwer is correct

7. The motility of the villi in the intestine is regulated:
    A. by an undermucous's nerve plexus (Meissner's) *
    B. by n. vagus
    C. by the undermuscle's nerve plexus (Auerbach's)
    D. by sympathetic nerves
    E. all of them

METHODOLOGICAL DEVELOPMENT №25

Topic: Absorbtion in the gastrointestinal tract. Regulation of digestion.
The number of hours: 2 hours
The object of learning:
To know: the types and the significance of the processes of absorption.
To be able to: explain the mechanisms of the absorption of different nutrients, the activity of the centres of hunger-satisfaction.

Theoretical questions for self-preparation:

1. The role of different parts of the digestive tract in absorption.
2. Mechanisms of reabsorption of water and mineral salts.
3. Reabsorption of hydrolyzed carbohydrate products.
4. Reabsorption of hydrolyzed protein products.
5. Reabsorption of hydrolyzed fat products.
6. The centres of hunger-satisfaction.

Key words and definitions: diffusion, osmosis, villikinin, antiport, micella, chylomicrone, pynocytosis.

APPLICATION №1

Definitions of key terms and concepts:

Endocytosis – is a transport of macromolecules by phagocytosis and pinocytosis.
Persorbtion – is a transport of substances through the intercellular area.
Villikinin – is a humoral stimulator of villous motility, is formed in the duodenum.
Ferritin – is the main depot of iron ions in the body.
Hyperfagia – is an excessive food intake in the case of damage of the saturation center of hypothalamus (ventro-medial nuclei).

APPLICATION №2

Control questions and answers on the topic: **"**Absorption in the gastrointestinal tract. Regulation of digestion".

1. What physical and chemical mechanisms provide the absorption of substances in the intestine?
   They are diffusion, facilitated diffusion, osmosis.
2. In what part of the intestine are the hydrolyzed products of proteins and carbohydrates absorbed?
   The amino-acids and monosaccharides are absorbed in the upper part of the small intestine.
3. What hydrolyzed products of carbohydrates do you know?
   Monosaccharides: glucose, saccharose, lactose, fructose.
4. In what part of the intestine and in what forms are the hydrolyzed fat products absorbed?
   In the form of monoglycerides and fatty acids coupled with bile acid salts which fors micellas; they are most actively reabsorbed in the duodenum and the upper (proximal) part of the small intestine .
5. How do the villi and microvilli influence the processes of reabsorption?
   The presence of the villi and microvilli increases the contact surface of the intestine with the chime. The contraction of the microvilli promote better absorption.
6. How is water absorbed?
   Water is absorbed passively due to the osmotic or hydrostatic (filtration) gradients (difference).
7. With the transport of what substances and ions is water absorption connected?
   With the transport of sodium, chlorine ions, monosaccharides, amino-acids, which are actively absorbed.

TABLE 17.10 | Intestinal Absorption of Nutrients

Nutrient	Absorption Mechanism	Means of Transport
Monosaccharides	Facilitated diffusion and active transport	Blood in capillaries
Amino acids	Active transport	Blood in capillaries
Fatty acids and glycerol	Facilitated diffusion of glycerol; diffusion of fatty acids into cells	
	(a) Most fatty acids are resynthesized into fats and incorporated in chylomicrons for transport.	Lymph in lacteals
	(b) Some fatty acids with relatively short carbon chains are transported without being changed back into fats.	Blood in capillaries
Electrolytes	Diffusion and active transport	Blood in capillaries
Water	Osmosis	Blood in capillaries

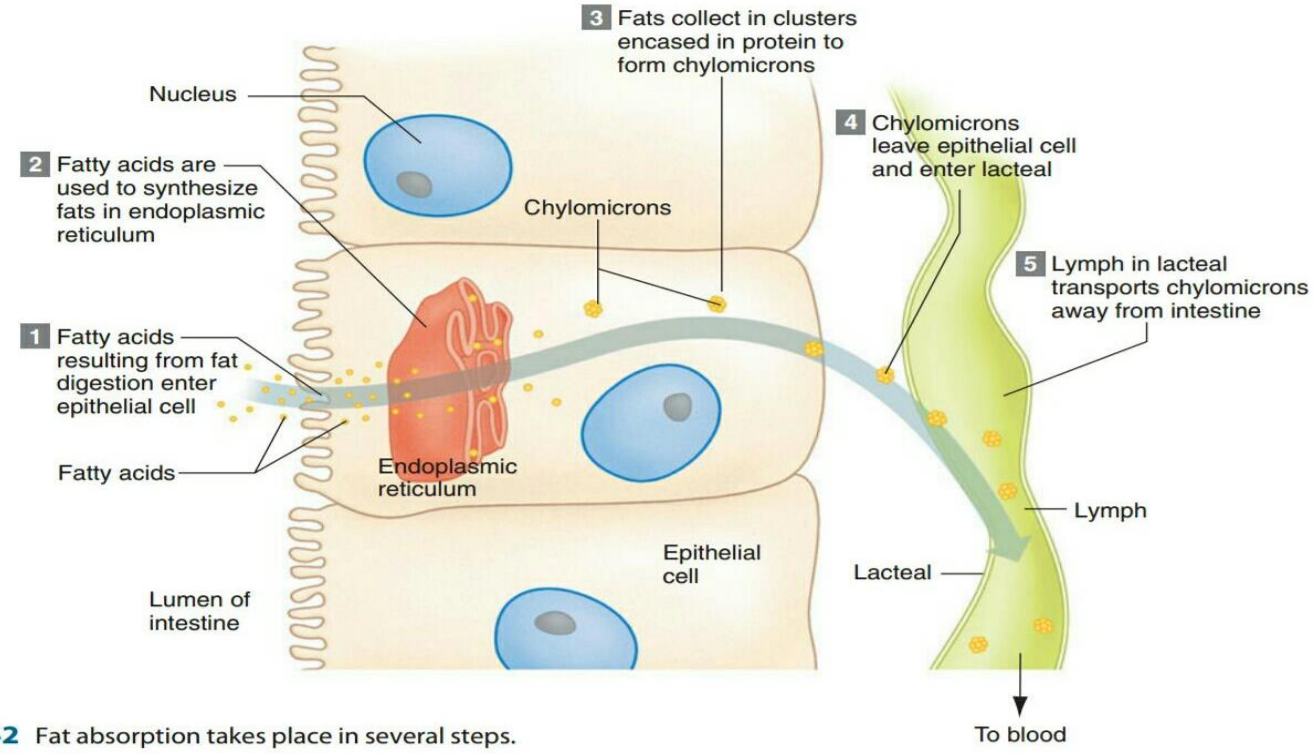


FIGURE 17.42 Fat absorption takes place in several steps.

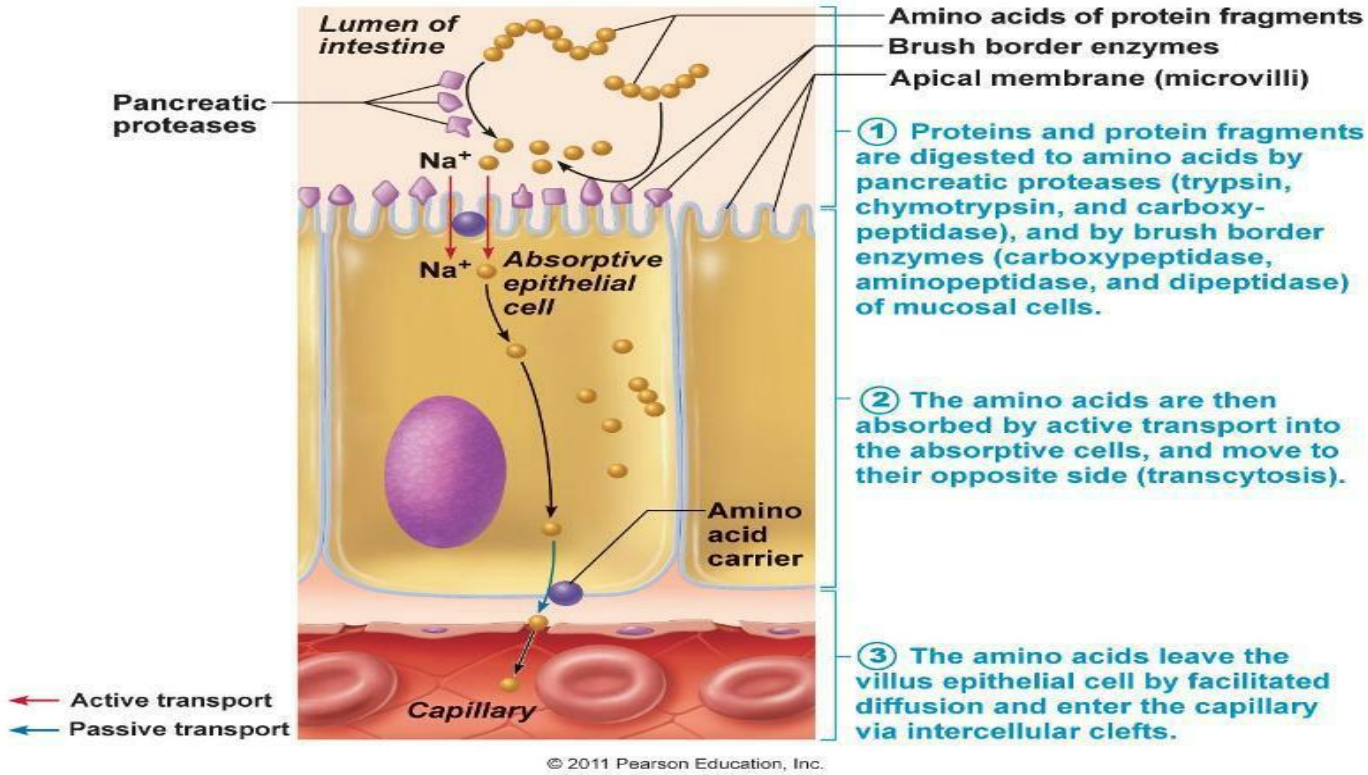


TABLE 18.2 | Substances That Control Appetite

Substance	Site of Secretion	Function
Insulin	Pancreas	Stimulates adipocytes to admit glucose and store fat; glycogen synthesis
Leptin	Adipocytes	Suppresses appetite and increases metabolic rate after eating
Neuropeptide Y	Hypothalamus	Enhances appetite
Ghrelin	Stomach	Enhances appetite

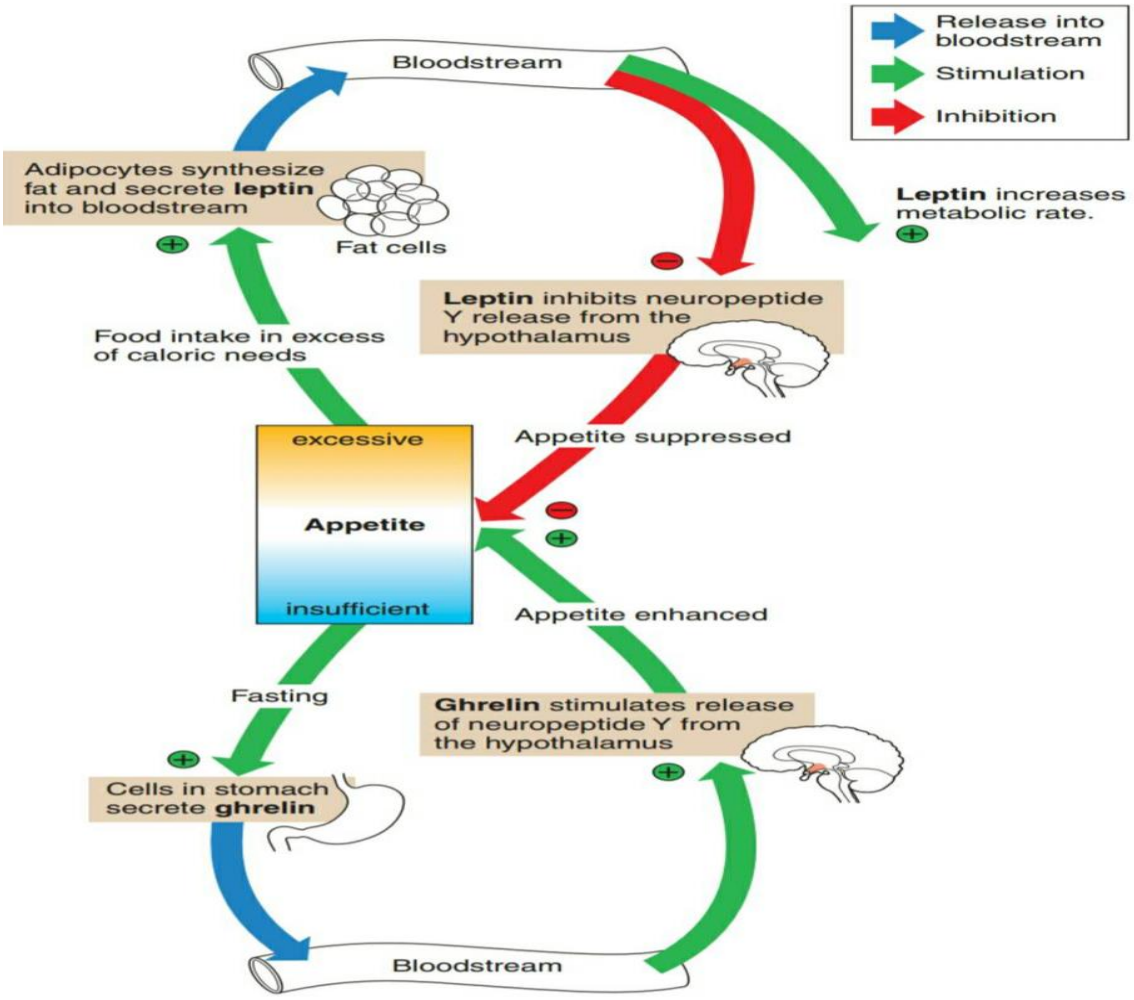


FIGURE 18.1 Appetite control is complex. Illustrated here are the effects of leptin and ghrelin on appetite.

- Regulation of digestion involves:
  - Intrinsic control via mechanical and chemical stimuli
  - Endocrine control
    - Hormones from brain or other GI organs
      - Secretin, gastrin, CCK, GIP
  - Extrinsic control by CNS centers
    - Parasymp. (vagus nerve) stimulates peristalsis and secretion
    - Symp. inhibits peristalsis and secretion; stimulates contraction of sphincters

CLINICAL BOX

Anorexia nervosa is an eating disorder which involves dieting to the point of starvation. The "rule of thumb" is that you are seriously underweight if you are more than 15% below your ideal weight. Anorexics often use vomiting and laxatives, just like the bulimics. They have an intense fear of being fat and are obsessed with being thin. They often have a distorted body image, meaning that when they look in the mirror, they tend to see someone overweight, when others see them as walking skeletons. Anorexics often come from very competitive, demanding families, and are often perfectionists with a strong need to control all aspects of their lives. Physiologically, anorexia has been linked to abnormal levels of the neurotransmitter serotonin, which is involved in eating regulation.

Bulimia nervosa, also known as simply bulimia, is an eating disorder characterized by binge eating followed by purging. Binge eating refers to eating a large amount of food in a short amount of time. Purging refers to the attempts to get rid of the food consumed. This may be done by vomiting or taking laxatives.

Tasks for self-control

1. In the case of bile absence the motility of the intestine will be:
   A. increased
   B. decreased *
   C. without change
   D. sometime decreased and sometime increased
   E. none of them

2. What influence will an ingestion of a large amount of hypertonic solution into the intestine perform?
   A. it will cause constipation
   B. it will cause diarrhea *
   C. it will cause feeling of hunger
   D. it will cause no changes
   E. It will cause vomiting

3. Reabsorption of glucose takes place … and for its reabsorption the ion of … is necessary.

A. in the stomach, sodium
B. in the stomach, chlorine
C. in the large intestine, sodium
D. in the large intestine, magnesium
E. in the small intestine, sodium *

4. Put in the proper words. The gastrointestinal hormones belong to … and regulate …..
   A. steroids, only the composition of the secrets
   B. steroids, only the amount of the secrets
   C. derivates of amino-acids, composition of the secrets
   D. derivates of amino-acids, the amount of the secrets
   E. polypeptides, the composition and amount of secrets *

5. A coprological examination of a 56-year old patient had a disorder of protein digestion and absorption established. What is the main mechanism of amino-acids absorption?
   A. a secondary active transport *
   B. a simple diffusion
   C. osmosis
   D. a primary active transport
   E. facilitated diffusion

6. The water is absorbed in the intestine due to:
   A. active transport
   B. facilitated diffusion
   C. osmosis *
   D. filtration
   E. exocytosis

7. A 42-years old patient after an operation of stomach resection suffered from anemia. The reason can be:
   A. insufficiency of the intrinsic factor (Castle) *
   B. insufficiency of the iron ions
   C. insufficiency of vitamin C
   D. insufficiency of vitamin B6
   E. Insuffiency of vitamin D

8. A 38 years old patient, who suffered from a stomach ulcer had an operation of vagotomy (the vagus nerve was cut through). What changes occurred in the gastrointestinal tract after it?
   A. increased motility
   B. increased secretion
   C. decreased motility and secretion *
   D. no changes occured
   E. all of them

9. The center of hunger-saturation is located in the:
   A. cerebellum
   B. thalamus
   C. pons
   D. cerebrum cortex
   E. hypothalamus *

10. After a damage to the center of hunger in the lateral part of the hypothalamus the experimental animal has:
    A. bulimia
    B. hyperphagia
    C. polydipsia
    D. aphagia *
    E. no changes

11. After a damage to the center of saturation in the ventro-medial part of the hypothalamus the experimental animal has:
    A. bulimia *
    B. aphagia
    C. polydipsia
    D. polyuria
    E. glucosuria

METHODOLOGICAL DEVELOPMENT №26

Topic: The role of kidneys in the processes of excretion.
The number of hours: 2 hours
The object of learning:
To know: functions and the role of the excretion system, in particular, the kidneys in providing homeostasis and the implementation of adaptive reactions of the organism.
Be able to: describe the processes in different parts of the nephron; calculate and evaluate the indicators of the functional state of the kidneys and renal hemodynamics (the rate of glomerular filtration, renal plasma flow).

Theoretical questions for self-preparation:

1. The physiological role of excretory processes in metabolism. The functions of kidneys.
2. The morphofunctional features of the kidneys. The structure of a nephron.The features of blood supply to the kidneys.
3. The general characteristics of urine formation processes.
4. Glomerular filtration and its mechanisms.
5. Control mechanisms of the glomerular filtration rate.
6. Clearance and its importance for assessment of the renal function.

Key words and terms: nephron, kidney cortex, medulla, renal pyramids, cortical and juxtamedullary nephrons, vascular glomerulus, Bowman's capsule, renal tubules, juxtaglomerullar apparatus, glomerular ultrafiltration, filter, tubular reabsorption, tubular secretion, clearance.

APPLICATION №1

Definition of basic terms and concepts:

Tubular ultrafiltration is the formation of primary urine from blood plasma, water and components of low molecular weight through the structures of a glomerular filter.
Tubular reabsorption is reverse absorption of water and substances (which are necessary for the body) back to the blood from the primary urine in the tubules of the nephron.
Tubular secretion is active transport of substances from the blood, or from the cells of the tubular epithelium to the urine.

Primary urine is an ultrafiltrate of blood plasma, which has no proteins, and is almost identical to the plasma by its chemical composition.

APPLICATION №2

Control questions and answers on the topic: "The role of the kidneys in the processes of excretion".

1. What does the excretion process mean?

It is the release of end products of metabolism from the body, such as foreign substances and excess water, salts and organic compounds that came with food or formed during metabolism.

2. What organs are involved in the processes of excretion and their significance for the body.

The kidneys, lungs, sweat glands, gastrointestinal tract.They provide homeostasis.

3. What are the functions of the kidneys?

They are: excretory, homeostatic, incretory, metabolic.

4. What is the functional unit of a kidney, its structural and functional elements.

It is the nephron: glomerulus (malpigie), a body consisting of a glomeruli of capillaries and a Shumlyansky-Bowman capsule; proximal convoluted tubule; Henle's Loop; distal convoluted tubule; collecting duct.

5. What constants of body homeostasis are supported by the kidneys?

They are: osmotic pressure, volume of water in the body, ionic composition of blood plasma, pH, arterial pressure.

6. Name the biologically active substances that are produced in the kidneys.

The are renin, bradykinin, prostaglandins, urokinase, vitamin D3, erythropoietin.

7. Give examples of kidney involvement in the metabolism of proteins, fats and carbohydrates (metabolic function of the kidneys).

Kidneys are involved in the exchange of proteins - pinocytosis in the tubular epithelium of proteins and peptides that have passed into the primary urine, their hydrolysis in the interstitium of the kidneys and the return in the form of amino acids into the blood. In the exchange of carbohydrates - gluconeogenesis, especially during a fasting period, when about 50% of glucose, triglycerides and phospholipids that enter the bloodstream are synthesized by the kidneys as well.

8. List processes that provide urine formation. Indicate the value of blood pressure in the capillaries of the renal glomeruli.

They are filtration, secretion, reabsorption.It is about 70 mmHg.

9. What factors influence the filtration pressure in the renal glomeruli? Write the formula of its calculation.

   Such are: the value of hydrodynamic pressure (HDP), blood oncotic pressure (OP) in the capillaries of the glomerulus, as well as pressure inside the capsule (KP-kidney pressure) of the primary urine. FP = HDP - (OP + KP) mm Hg.

10. Why does the size of glomerular filtration not change under conditions of significant fluctuations of systemic blood pressure (from 80 to 180 mm Hg)?

Owing to the mechanisms of self-regulation: the blood pressure in the capillaries of the glomerulus remains almost unchanged, because with the increase of systemic arterial pressure the tone of the afferent arteriole increases, and when the system pressure decreases its tone decreases (the effect of Beilis).

11. The method of obtaining urine from Shumlyansky-Bowman capsule. Composition of primary urine.

With the help of a micro-pipette, which is injected into the middle of the capsule. Primary urine is identical to blood plasma and free of proteins.

12. What is the volume of primary and final (definitive) urine per day? What is the quantitative difference associated with?

Primary urine is about 180 liters per 24 hours, the final one is about 1.5 liters. Most of the urine is reabsorbed when it passes through the tubules of the nephron.

13. How can we determine the size of glomerular filtration? What are the substances by which you can determine glomerular filtration.

By studying the clearance (purification factor) of a substance. The substance must be physiologically inert, easily filtered by the glomeruli, not secreted and not reabsorbed in the tubules. For example by inulin or creatinine.

14. What is the clearance (purification factor) of a substance?

The amount of blood plasma that is purified by the kidneys from substance in 1 minute.

15. Write a formula by which you can calculate the clearance factor for inulin.

$C = (U / P) \times V$

where:
C is clearance,

U - concentration of substance in urine,

P - concentration of substance in blood plasma,
V – diuresis per minute.

16. What requirements should the substance correspond to fulfill in order to calculate the renal blood flow through its clearance? Give an example of such a substance.

The substance must be physiologically inert; the blood should be completely cleared of it after passing through the kidney. For example, a para-aminohippuric acid.

17. Write the formula for calculating the renal blood flow (RBF) for clearance of para-aminohippuric acid (PAH).

$$RBF = \frac{Upah \times Vurine \times 100\%}{Ppah \times (100\% - Ht)}$$

where:

Upah - concentration of PAH in the final urine; V urine - the volume of the final urine (in ml), which is formed in 1 minute; Ppah - is the concentration of PAH in the blood plasma; Ht - hematocrit index.

Tasks for self-control:

1. As a result of long-term starvation the glomerular filtration of a man was accelerated by 20%. The most probable cause of filtration changes under such conditions is:

A. Fall of oncotic pressure of blood plasma *
B. Rise of systemic arterial pressure
C. Increased permeability of renal filter
D. Growth of the filtration coefficient
E. Increase of renal plasma flow

2. A patient is 44 years old. Laboratory examination of his blood revealed that content of proteins in plasma was 40 g/l. What influence will be exerted on the transcapillary water exchange?

A. Filtration will be increased, reabsorption – decreased *
B. Both filtration and reabsorption will be increased
C. Both filtration and reabsorption will be decreased
D. Filtration will be decreased, reabsorption – increased
E. Exchange will stay unchanged

3. A diabetic patient was presented with a blood glucose concentration of 600 mEq/L. Which of the following values would likely be above normal in case of hyperglycemia?

A. Urine flow *
B. Arterial pH
C. Alveolar PCO2
D. Intracellular volume
E. Plasma sodium concentration

4. A 69-year-old male was presented with symptoms of thirst and dizziness, and physical evidence of orthostatic hypotension and tachycardia, decreased skin turgor, dry mucous membranes, reduced axillary sweating, and reduced jugular venous pressure. He was recently placed on an angiotensin-converting enzyme inhibitor for his hypertension. Urine analysis reveals a reduction in the fractional excretion of sodium and the presence of acellular hyaline casts. The resident suspects acute renal failure of prerenal origin, which has increased renin secretion by the kidney. A stimulus for increasing renin secretion is an increase of which of the following?

A. Sympathetic nerve activity *
B. Mean blood pressure
C. Glomerular filtration rate
D. Circulating angiotensin II
E. Atrial natriuretic peptide secretion

5. Which of the following is most likely to cause an increase in the glomerular filtration rate?

A. Dilation of the afferent arterioles *
B. Contraction of mesangial cells
C. Blockage of the ureter
D. Release of renin from the juxtaglomerular apparatus
E. Volume depletion

6. If a substance appears in the renal artery but not in the renal vein, which of the following is true?

A. Its clearance is equal to the renal plasma flow *
B. It must be filtered by the kidney
C. It must be reabsorbed by the kidney
D. Its clearance is equal to the glomerular filtration rate
E. Its urinary concentration must be higher than its plasma concentration

7. A 35-year-old male with polycystic kidney disease has a decrease in both glomerular filtration rate (GFR) and renal blood flow (RBF). The nephrologist wants to administer a drug that will increase both GFR and RBF. GFR and RBF would both increase if which of the following occurred?

A. The efferent and afferent arterioles are both dilated *
B. The efferent and afferent arterioles are both constricted
C. Only the afferent arteriole is constricted
D. Only the efferent arteriole is constricted
E. The afferent arteriole is constricted and the efferent arteriole is dilated

METHODOLOGICAL DEVELOPMENT №27

Topic: Urine formation processes.
Number of hours: 2 hours.
The object of learning:
To know: mechanisms of tubular reabsorption, secretion, significance of Henle's loop in reabsorption of water and electrolytes.
Be able to: appraise the indicators of the functional state of the kidneys and renal hemodynamics (the value of tubular reabsorption, tubular secretion, renal blood and plasma circulation).

Theoretical questions for self-preparation:

1. Tubular reabsorption and its mechanisms.
2. Specifics of reabsorption of water and electrolytes in the distal segment of the nephron.
3. Mechanism of reabsorption of water and electrolytes in the loop of Henle (counter-current mechanism).
4. Tubular secretion and its physiological mechanisms.
5. Composition and properties of primary and secondary urine.
6. Micturition and its mechanism.

Key words and terms: kidney threshold reabsorption, counter-current system, diuresis, antiport.

APPLICATION №1
Definition of basic terms and concepts:

Antiport - the ability of the epithelium of distal tubules to secrete H + ions into the urine in exchange for the reabsorption of Na + ions.
The kidney excretion threshold - is a substance concentration in the blood at which it can not be completely reabsorbed in the tubules of the nephron and is excreted with the final urine.
Secretion - is the process opposite to reabsorption and is aimed at transporting substances from the blood to urine through the tubular cells.
Tubular reabsorption - is the reverse absorption of water and most of the substances in the tubules necessary for the body.

APPLICATION №2

Control questions and answers on the topic: "Urine formation processes".

1. What are the main processes of urine formation in the proximal convoluted tubules of the nephron, how does the volume of urine change with it?

Most of the components of the primary urine are reabsorbed with an equivalent amount of water in the proximal convulated tubules (the volume of primary urine decreases by about 2/3); and organic acids and bases are secreted.

2. What are the components of primary urine which are completely reabsorbed in the proximal convulated tubules? What experiment proves it?

They are : proteins, amino acids, glucose, vitamins, trace elements. This can be proved by an analysis of the filtrate obtained by puncture of the proximal convoluted tubules.

3. What substances are called "thresholds"? Give examples.

Substances that are completely reabsorbed in the renal tubules and appear in the final urine only if their concentration in the blood exceeds a certain value - the threshold of excretion. For example, glucose, amino acids.

4. What substances are called "non-threshold"? Give examples.

Substances which are not reabsorbed and almost entirely excreted with urine at any concentration in blood plasma. These are the end products of metabolism that are to be excreted from the body (eg creatinine, sulfates).

5. What is the specific function of Henle's loop in the process of urine formation, what is its importance?

Creation of high osmotic pressure in the kidney's medulla, which provides reabsorption of water from collecting tubules and the formation of final concentrated urine.

6. What substances, actively or passively, are transported in the descending limb of the loop of Henle? Why?

They are: water, sodium and chlorine; passively, because the loop wall is permeable to them, and there are no active mechanisms of ionic transport in the descending limb.

7. What ions, actively or passively, are reabsorbed in the ascending limb of the loop of Henle? Is water reabsorbed there and why?

Sodium, chlorine (actively). Water is not reabsorbed, because the ascending limb of the loop of Henle is impermeable to water.

8. How is the osmotic pressure gradient created in Henle's loop?

At each level of the Henle's loop from the ascending limb to the interstitium, sodium chloride is actively removed, but water does not flow out of the tubule (because the wall is impermeable to it).

9. As a result of what process a large gradient of osmotic pressure is formed in the kidney's medulla: from 300 mosm / l at the border with the cortex to 1200 mosm / l at the top of the renal papilla?

As a result of frequent repetition of the summation of the osmotic pressure gradients due to the upstream movement of the urine in the descending and ascending limbs of the Henle's loop and the active removal of NaCl in the interstitium of the ascending limb, which is impermeable to water.

10. Specify the direction and explain the mechanism of sodium and chlorine circulation in the loop of Henle. What is the significance of this fact?

From the ascending limb of the loop of Henle, sodium and chlorine are actively removed to interstitium, then passively, according to the concentration gradient, penetrate the descending limb, and again from it to the ascending limb with the next portion of urine thus creating high osmotic pressure in the kidney's medulla.

11. What is reabsorbed and secreted in the distal convoluted tubules of the kidney, how does the osmotic pressure of urine change there?

The ions of sodium, calcium, phosphates, bicarbonates, water are reabsorbed. Ions of hydrogen and potassium, ammonia are secreted. Hypotonic urine is converted to isotonic.

12. How does the hypotonic urine that enters the distal convoluted tubules turn into isotonic?

Due to the permeability of the distal tubular walls for water, part of it passes into the interstitium of the cortex layer from hypotonic urine, because it is isotonic. The bulk of water follows sodium.

13. What is the role of the collecting ducts in the process of urine formation, due to what is it carried out?

The formation of the final (concentrated) urine occurs in the collecting ducts, mainly due to regulated reabsorption of water. A part of urea is also reabsorbed here.

14. Explain the mechanism of water reabsorption from collecting ducts to the interstitium of the kidney's medulla. What is the mechanism for regulating this process?

Water passes into interstitium in accordance with the law of osmosis, because there is a higher concentration of substances there. It is hormonal.

15. What is the effect of antidiuretic hormone on water reabsorption? In which parts of the nephron is its effect realized?

It increases reabsorption of water in the terminal part of the distal convoluted tubules and in the collecting ducts of the nephron as a result of increasing their water permeability.

16. Describe briefly the mechanism of increasing the permeability of distal convoluted tubules and collecting ducts of the nephron for water under the influence of ADH.

ADH launches a chain of enzymatic transformations that activate protein kinases and hyaluronidase, acting on the membrane, respectively, and increases the permeability of the distal nephron.

17. What is the effect of aldosterone on the reabsorption of sodium and potassium, in which sections of the nephron is it realized, what is the mechanism of this effect?

It increases sodium reabsorption and potassium secretion in the distal tubules and collecting ducts by activating the sodium-potassium pump.

18. What is the significance of urea circulation between the collecting ducts and the ascending limb of the Henle's loop? Explain the mechanism of transition of urea from the collecting ducts to the interstitium.

Preserving high osmolarity in the interstitial of the inner part of the kidney's medulla. Urea passes by the law of diffusion, because its concentration in the collecting ducts becomes greater due to the outflow of water from them.

Tasks for self-control:

1. Atria of an experimental animal were superdistended by blood that resulted in decreased reabsorption of Na^+ and water in renal tubules. This can be explained by the influence of the following factor upon kidneys:

A. Natriuretic hormone *
B. Aldosterone
C. Renin
D. Angiotensin
E. Vasopressin

2. A patient has a decreased vasopressin synthesis that causes polyuria and as a result of it evident organism dehydration. What is the mechanism of polyuria development?

A. Reduced tubular reabsorption of water *
B. Reduced tubular reabsorption of Na ions
C. Reduced tubular reabsorption of protein
D. Reduced glucose reabsorption
E. Acceleration of glomerular filtration

3. A 92-year-old man is presented with dehydration after four days of persistent diarrhea. Under these circumstances, hypotonic fluid would be expected in which of the following?

A. Loop of Henle *
B. Glomerular filtrate
C. Proximal tubule
D. Cortical collecting tubule
E. Distal collecting duct

4. A 63-year-old hospitalized woman becomes oliguric and confused. Her blood glucose is found to be only 35 mg/dL. A IV access is obtained and an ampule of 50% dextrose is given followed by a continuous infusion of 10% dextrose. Most of the glucose that is filtered through the glomerulus undergoes reabsorption in which of the following?

A. Proximal tubule *
B. Descending limb of the loop of Henle
C. Ascending limb of the loop of Henle
D. Distal tubule
E. Collecting duct

5. Active transport of sodium and chloride from the lumen of the kidney occurs in which of the following?

A. Proximal tubule *
B. Descending limb of the loop of Henle
C. Thin ascending limb of the loop of Henle
D. Cortical collecting duct
E. Medullary collecting duct

6. A patient with multiple rib fractures requires intubation and mechanical ventilation. Mechanical ventilation causes an increase in the patient's vasopressin secretion and plasma levels. Which of the following is the effect of vasopressin on the kidney?

A. Increased permeability of the distal nephron to water *
B. Increased diameter of the renal artery
C. Increased glomerular filtration rate
D. Increased excretion of Na+
E. Increased excretion of water

7. In addition to increasing the permeability of the collecting duct to water, ADH increases the permeability of the collecting duct to which of the following?

A. Urea *
B. Hydrogen
C. Ammonium
D. Potassium
E. Sodium

8. The secretion of H+ in the proximal tubule is primarily associated with which of the following?

A. Reabsorption of bicarbonate ion *
B. Excretion of potassium ion
C. Excretion of hydrogen ion
D. Reabsorption of calcium ion
E. Reabsorption of phosphate ion

METHODOLOGICAL DEVELOPMENT № 28

Topic: Neuroendocrine mechanisms of urine formation regulation. Sweating.
Number of hours: 2 hours.
The object of learning:
To know: the composition of the final urine.
***Be able to*:** explain neuroendocrine mechanisms for maintaining the constancy of the internal environment of the body by the kidneys.

Theoretical questions for self-preparation:

1. Regulation of renal blood circulation.
2. Regulation of reabsorption of water and electrolytes in the distal nephron.
3. The incretory function of the kidneys. Renin-angiotensin system.
4. Mechanism of micturition (urination).
5. Excretory function of sweat and sebaceous glands and regulation of their activity.

Key words and terms: obligatory, facultative reabsorption, micturition, sweat glands, incretory functions of the kidney.

APPLICATION №1

Definition of basic terms and concepts:

Obligatory reabsorption occurs in the proximal tubules and the loop of the nefrons, slightly depends on the water load and regulation mechanisms.
Facultative (dependent) reabsorption of water and ions occurs in distal convoluted tubules and collecting ducts; is under constant control of hormones, depending on the balance of water and electrolytes.
Perspiration - evaporation of water from the surfaces of the lungs, mucous membranes, skin, which is always moist.

APPLICATION №2

Control questions and answers on the topic: "Neuroendocrine mechanisms of urine formation regulation. Sweating."

1. What influence does the antidiuretic hormone have on water reabsorption? In which parts of the nephron and how is it realized ?

It increases reabsorption of water in the final sections of distal convoluted tubules and collecting ducts of the nephron due to increased water permeability.

2. Describe briefly the mechanism for increasing the permeability of water in distal convoluted tubules and convoluted ducts of the nephron under the influence of ADH.

ADH launches a chain of enzymatic transformations that activate protein kinases and hyaluronidases, which act accordingly on the membrane and increase the permeability of these parts of the nephron .

3. What mechanism has aldosterone on the reabsorption of sodium and potassium, in which parts is it realized?

It increases sodium reabsorption and potassium secretion in the distal tubules and collecting ducts by activating the sodium-potassium pump.

4. Where are the reflexogenic zones necessary for the regulation of renal function located? What receptors are sensitive to them?

They are: mechano- and chemoreceptors of the kidneys, mechanoreceptors of the aortic arc and carotid sinus, osmoreceptors of the liver and hypothalamus, atrial volumoreceptors.

5. At what level of the spinal cord are sympathetic centers involved in the regulation of renal function? What effect do sympathetic nerves have on the kidneys?

Th5-L3 segments. Stimulate the formation of renin, increase the reabsorption of sodium and water.

6. Name the nuclei and the hormone of the hypothalamus, with the help of which efferent effects of osmo- and volumoreceptors on renal functions are realized?

They are supraoptical and paraventricular nuclei of the hypothalamus. The hormone is ADH.

7. What is the reaction of a denervated kidney to a painful stimulus? Due to the secretion of which substances is this reaction realized?

Reduced diuresis. This reaction is carried out by secretion of ADH and catecholamines.

8. What is the main mechanism of regulation of the functions of kidneys? Endocrine or nervous? Why?

It is endocrine. A fully-denervated kidney can perform its functions quite effectively (for example, a kidney transplant).

9. In the regulation of which physiological constants does RAAS take part?

In the regulation of blood pressure, the amount of fluid in the body, ions, osmotic pressure.

10. Describe a chain of processes that explain the mechanism of regulation of osmotic pressure in the body with the help of ADH.

Changes in osmolarity - violation of osmoreceptors of the liver, other organs and the hypothalamus - secretion of inactive ADH by the hypothalamus - its accumulation and activation in the posterior pituitary gland - change in the amount of ADH in the blood - change in the intensity of reabsorption of water in the kidney.

11. What hormones that act upon various parts of the nephron provide regulation of the stability of the ionic composition of blood?

They are: aldosterone, natriuretic hormone, thyreocalcitonin, parathyroid hormone.

12. Describe the main stages of the kidney's response to decreased blood pressure, resulting in narrowing of the blood vessels.

In case of decreased blood pressure - renin secretion: under its influence transformation of angiotensinogen into angiotensin-1 - transformation of the latter into angiotensin-2 (under the influence of the enzymes of plasma and tissues) as a result - narrowing of vessels.

13. What ion and what substance is secreted into the lumen of the renal tubule in the process of pH regulation? In what parts of the tubular nephron is it taking place ?

They are: ions of hydrogen and ammonia. In all parts of the nephron.

14. In what parts of the nephron does the regulation of urinary production by aldosterone and ADH take place?

Aldosterone - in all parts of the tubules, except for the descending limb of the Henle’s loop; ADH - in the final parts of distal convoluted tubules and collecting ducts.

15. Describe main stages of the blood volume and arterial pressure regulation process by irritation of atrial volumoreceptors.

The stages are: change in the volume of blood entering the heart – change in the activity of atrial volumoreceptors – change in the neurosecretion of ADH in the hypothalamus – change in the amount of inactive ADH in the posterior pituitary gland – change in the amount of active ADH secreted to blood and the intensity of its action on the kidney – change in the volume of excreted water – change in the volume of circulating blood and the value of arterial pressure.

16. Describe the formation of hydrogen ions in the epithelium of the nephron. What ion enters the epithelium from the lumen of the tubule in exchange for secreted hydrogen?

Carbonic acid is formed from carbon dioxide and water by carbonic anhydrase in the epithelium of the nephron, after the dissociation of which hydrogen ions are secreted into the lumen of the tubules in exchange for sodium ions - the latter is reabsorbed into the interstitium.

17. What compounds interact with hydrogen in the lumen of the tubules in the process of blood pH regulation by the kidney?

They are: ammonia, $NaHCO_3$, Na_2HPO_4.

18. What hormone of the kidney stimulates erythropoiesis? What factors stimulate or inhibit this process?

It is erythropoietin. Insufficient oxygenation of the kidney stimulates its development, and increased oxygenation inhibits the production of erythropoietin.

19. What substance of the kidney is involved in the process of fibrinolysis. What is its role?

The enzyme urokinase, which stimulates the transformation of plasminogen into the plasmin, causes the hydrolysis of fibrin.

20. What biologically active substances are produced by the kidney? Specify their fuctional value.

They are: renin - stimulates the formation of angiotensin-2, which narrows vessels; bradykinin - dilates vessels; prostaglandins - intracellular hormones; urokinase - plasminogen activator; erythrogenin - erythropoietin activator; vitamin D, calcitriol.

21. What is the working principle of the device, which in clinical pactice is known as "artificial kidney"?

This device is a dialyser, in which, through the pores of a semipermeable membrane, the blood is cleared of toxic products of metabolism, foreign substances and its composition is normalized (hemodialysis, hemosorption).

Tasks for self-control:

1. A patient is presented with muscle weakness, cramping, irritability, and neuromuscular excitability. Electrolytes reveal hypokalemia and a higher than- normal plasma bicarbonate concentration. Which of the following conditions can cause metabolic alkalosis?

A. Diuretic therapy *
B. Hypoxemia
C. Renal failure
D. Hypoaldosteronism
E. Diarrhea

2. A 23-year-old girl is admitted to the hospital with a 3-month history of malaise and generalized muscle cramps. Laboratory results reveal: serum sodium of 144 mmol/L, serum potassium of 2.0

mmol/L, serum bicarbonate of 40 mmol/L, and arterial pH of 7.5. Which of the following is the most likely cause of this patient's hypokalemic alkalemia?

A. Hyperaldosteronism *
B. Hyperventilation
C. Persistent diarrhea
D. Renal failure
E. Diabetes

3. An 18-year-old male is presented with muscle weakness, cramps, and tetany. Blood pressure is normal and no edema is present. Laboratory analysis reveals hypokalemic alkalosis, hyperaldosteronism, and high plasma renin activity, with diagnosis of Bartter's syndrome. Which of the following statements about renin is true?

A. It converts angiotensinogen to angiotensin I *
B. It is secreted by cells of the proximal tubule
C. Its secretion leads to loss of sodium and water from plasma
D. Its secretion is stimulated by increased mean renal arterial pressure
E. It converts angiotensin I to angiotensin II

4. A 36-year-old male is presented with low renin hypertension. Renin released from the juxtaglomerular apparatus is normally inhibited by which of the following?

A. Increased pressure of the afferent arterioles*
B. β-adrenergic agonists
C. Prostaglandins
D. Aldosterone
E. Stimulation of the macula densa

5. A patient undergoing surgery had an increased secretion and plasma level of ACTH, cortisol and aldosterone revealed. Which of the following statements about aldosterone is correct?

A. It effects increased permeability of sodium in distal tubuls. *
B. It effects by activating cAMP.
C. It causes an increased reabsorption of hydrogen ions.
D. It effects mainly the proximal tubuls.
E. It is secreted in response to an increased blood pressure.

6. Aldosterone secretion is increased when there is a decrease in the plasma concentration of which of the following?

A. Sodium *
B. Renin
C. Angiotensin II
D. ACTH
E. Potassium

7. A patient with atherosclerosis shows signs of chronic renal failure attributed to poor renal perfusion and ischemic necrosis of the nephrons. Which of the following endogenous substances causes renal blood flow to decrease?

A. Angiotensin II *
B. Nitric oxide
C. Atrial natriuretic peptide
D. Acetylcholine
E. Dopamine

8. A patient with renal failure develops symptoms caused by the loss of a hormone produced by the kidney. Which of the following is the most likely diagnosis?

A. Anemia *
B. Edema
C. Hypertension
D. Uremia
E. Acidosis

METHODOLOGICAL DEVELOPMENT №29

Topic: Physiology of metabolism and nutrients.
Number of hours: 2 hours.
The object of learning:
To know: the role of metabolism in providing the plastic and energy needs of the organism, the physiological role of nutrients, metabolism of proteins, lipids, carbohydrates and its regulation, the role of vitamins and minerals in the human body.
Be able to: explain the mechanisms of metabolism regulation, vitamins, minerals and water in the body.

Theoretical questions for self-preparation:

1. A general description and the importance of metabolism in the human body.
2. Nutrients and their physiological role.
3. Protein metabolism and its regulation.
4. Carbohydrate metabolism and its regulation.
5. Metabolism of lipids and its regulation.
6. Vitamins, minerals and their physiological role.
7. Basic physiological principles of rational nutrition.

Key words and terms: metabolism, negative and positive nitrogen balance, nutrients, catabolism, anabolism, hypovitaminosis, avitaminosis, macro-, microelements.

Practical work:

Determination of the amount of proteins, fats, carbohydrates, vitamins and microelements in a daily ration.

In a table of the following form, record the number (in grams) of the products the student consumed during the previous day. As a result, the student should end up with a table of the following form:
Average daily set of products for students:

Products	Amount in grams	Products	Amount in grams	Products	Amount in grams
Rye bread	250		320	Animal fat	35
Wheat bread	150	Vegetables	340	Vegetable oil	22
Dry bread (crackers)	5	Fruits, fresh juices	50	Meat, by-products	240
Wheat flour	20	Eggs	36	Fish	64

Pasta	15	Milk and Sour-dairy products	400	Cheese	15
Groats, legumes	60	Curd cheese	24	Tea	2
Sugar, confectionery	95	Dried fruit	16		

For employees working until 3-4 p.m., the daily rate of food is recommended to be distributed as follows:

1. The first breakfast - between 7-8 a.m., containing approximately 25% of the total diet;
2. The second breakfast - around 12 p.m.: 15% of the total diet;
3. Lunch - between 3-4 p.m.: 45% of the diet;
4. Dinner – min. 2 hours before going to bed: 15%.

APPLICATION №1

Definition of basic terms and concepts:

Metabolism and energy - is a complex of biochemical and related energy processes that underlie the life of a living organism. Living cells are open systems that exchange material and energy with the environment.

Nitrogen balance - a state of nitrogen exchange, in which the amount of nitrogen that enters and is released from the body is equal.

Azothemia (azotaemia) – (nitrogen + greek. haima blood, synonym - hyperazotemia) high concentration of end products of nitrogen metabolism in the blood. Azothemia is observed in case of renal insufficiency, increased decay of proteins in the body, disorders of urine flow through the urinary tract, continious vomiting.

Nitrogen retention - nitrogen retention in the body.

Biologically valuable proteins - are proteins containing the entire set of amino acids necessary for the vital functions of the body.

APPLICATION №2

Control questions and answers on the topic: **"**Physiology of metabolism and nutrients".

1. What does the term "organism is an open system" mean?

A system whose stability is supported by the exchange of substances and energy with the environment.

2. What is metabolism?

A set of processes connected with substances that enter the body, their digestion, and elimination of waste products to the environment.

3. What is assimilation and anabolism?

Assimilation is a set of processes that ensure the flow of substances into the body and the synthesis of cellular structures of the body. Anabolism is a part of assimilation, a collection of intracellular processes that provide the synthesis of cellular structures of the body from substances that enter the cell.

4. What is dissimilation (catabolism). What biological value does it have?

The set of processes of cell structure decomposition resulting in a release of energy necessary for the activity of all organs and systems of the body and the synthesis of cell structures.

5. What function of proteins is more important: plastic or energetic? Why?

Plastic, because of all nutrients only proteins are sources of essential amino acids, without which the proteins of the body can not be synthesized.

6. What is the quantity of a daily decomposed protein, what is it equal?

The amount of protein that breaks down in the body during a day with a protein-free diet, sufficient for calories due to fat and carbohydrates (protein starvation). About 23 grams per day.

7. What is the daily requirement of protein minimum intake, what is it equal to in comfortable rest conditions?

Minimum amount of protein in food, at which it is possible to maintain nitrogen balance. About 0.75 g protein per kilogram of body weight per day.

8. What proteins are inadequate and why? Animal or plant proteins are considered to be perfect for the body, why?

Proteins that do not contain at least one essential amino acid, as this leads to a violation of the synthesis of proteins. Animal proteins, because they are in the amino acid composition closer to human proteins and contain a complete set of essential amino acids.

9. How do thyroid hormones, insulin and glucocorticoids affect protein metabolism?

Hormones of the thyroid gland, insulin increase the synthesis of proteins. Glucocorticoids increase the breakdown of proteins, especially in muscle and lymphoid tissues, but stimulate the synthesis of proteins in the liver.

10. What determines the biological value of fats entering the body?

The presence of non-essential and, especially, essential fatty acids in fats, the ratio of fats of animal and vegetable origin, the content of vitamins A and D, tocopherols.

11. What should be the ratio of animal and vegetable fats in the diet? What part of the body's energy consumption (in percentage) should be covered at the expense of fats?

The optimal option is 70% of animal fats, 30% of vegetable fats.

12. What hormones are mobilizing fats from fat depots?

Adrenaline, norepinephrine, thyroxine, growth hormone.

13. How do the sympathetic and parasympathetic nervous system affect the processes of assimilation and dissimilation?

Sympathetic stimulates the processes of dissimilation, parasympathetic - assimilation.

14. What are the basic microelements necessary for a person?

They are: copper, zinc, fluorine, iodine, cobalt, boron, iron.

15. What is the role of vitamins in metabolic processes?

As they are components of enzymes, they participate in various chemical reactions underlying metabolism.

Tasks for self-control:

1. Which of the following vitamin is absorbed primarily by diffusion?
   A. Vitamin D *
   B. Vitamin C
   C. Folate
   D. Niacin
   E. Vitamin B12

2. An 18-month-old boy is presented with delayed dentation, short stature, difficulty and painful walking, and bowing of the legs. In case of vitamin D deficiency, what process can cause bone defects?
   A. Calcification of the bone matrix *

B. Bone formation by osteoblasts
C. The composition of bone collagen
D. Bone resorption by osteoclasts
E. The blood supply to the haversian canals

3. Atherosclerosis contributes to increased concentration in the blood of:
A. low density lipoprotein *
B. chlorine ions
C. urea
D. high density lipoprotein
E. carbohydrates

4. Specify the ratio of proteins, fats and carbohydrates in a daily diet with a balanced diet of an adult:
A. 1: 1: 4 *
B. 1: 3: 2
C. 2: 3: 4
D. 1: 1: 6
E. 3: 2: 4

5. Which mineral has antioxidant protection and participates in thyroid hormone metabolism?
A. Selenium *
B. Calcium
C. Sodium
D. Zinc
E. Magnesium

6. Which vitamin participates in blood clotting process?
A. Vitamin K *
B. Vitamin A
C. Vitamin D
D. Vitamin E
E. Vitamin C

7. What is the other name of folic acid (Folate)?
A. Vitamin B12
B. Vitamin B2
C. Vitamin B3
D. Vitamin B6
E. Vitamin B9 *

METHODOLOGICAL DEVELOPMENT №30

Topic: The energy balance of the organism. Thermoregulation and its mechanisms.
Number of hours: 2 hours.
The object of learning:
To know: the energy balance and its components, basal metabolism and factors that determine it, instrumental methods for determining basal metabolism, heat supply and heat transfer mechanisms, fever, hyperthermia.

Be able to: determine the basal metabolism of a person by the tables of Harris-Benedict, to make up a diet for a student.

Theoretical questions for self-preparation:

1. Energy balance and its components.
2. Basal metabolic rate and factors that determine it. Instrumental methods for determining the basal metabolic rate.
3. Structure of daily energy expenditure of the body. Principles of diet prescription.
4. The temperature of the human body and its daily oscillations.
5. Mechanisms of heat production and heat loss. Reflex regulation of balance between mechanisms of heat production and heat loss.
6. Fever and hyperthermia.

Key words and terms: basal metabolism, energy balance, work supplement, specific dynamic action.

Practical work:

Task 1: Definition of basal metabolism according to the tables of Harris-Benedict.

It is determined on the basis of indicators of weight, height, gender and age. Two tables are used for men and women (A and B, respectively, see below). To do this, you need the value of a weight of a person from table A, and add it up with the value for age and height found in the table B. The amount gives the normal number of calories per day, which will be the indicator of the basal metabolic rate.

Task 2. Calculation of the value of the basal exchange with the help of an approximate formula.

It is known that for 1 hour the value of the basal metabolic rate is approximately 1 kcal per 1 kg of mass (M), thus the value of basal metabolism per day is BM = 1 kcal x M x 24.

Task 3. Calculation of specific-dynamic action of food.

Estimated value of specific-dynamic action of food (SDA) is an average of 15% of the estimated value of the basal metabolic rate.You can calculate the value of the SDA based on the value of the basal metabolic rate, calculated with the help of the Harris-Benedict tables.

Task 4. Calculation of the value of total metabolism for a day.

General metabolism = basal metabolism + SDA + work supplement. The student work supplement is approximately 1000 kcal or 4184 kJ per day.

APPLICATION №1

Definition of basic terms and concepts:

Basal metabolic rate is the minimum level of energy needed to maintain the vital activity of an organism in conditions of complete physical and emotional rest.

Energy balance is the ratio of the energy arriving from food to the body and the energy released in the form of heat.

Direct calorimetry is based on the direct measurement of the amount of heat released in a thermally insulated chamber where the subject is put for a defined period of time.

Indirect calorimetry is based on the assumption that all energy in the human body is obtained during the aerobic oxidation of nutrients and therefore is directly proportional to the volume of oxygen consumed per unit of time.

Respiratory coefficient is the ratio of the amount of carbon dioxide eliminated to the volume of oxygen consumed.

Specific Dynamic Action of Food (SDA) is the energy consumption of the body necessary to carry out digestive processes (secretion of digestive juices, absorption, motor function of the digestive tract, etc.)

Central thermoreceptors are located in the medial preoptic area of the hypothalamus and perceive the temperature of the blood that washes this area.

Fever is a prolonged increase in the temperature of the body core, due to the displacement of the set point of the hypothalamus thermoregulation center towards higher values (in extreme cases, to 41-42 degrees of Celsius).

Heat stroke occurs as a result of the sudden shutdown of the mechanisms of heat transfer in extreme environments (high temperature, lack of convection, high humidity, which limits the evaporation of sweat).

APPLICATION №2

Control questions and answers on the topic: "The energy balance of the organism. Thermoregulation and its mechanisms".

1. Describe the essence of the method of physical calorimetry.

In a calorimeter, a certain mass of the product is burned, and then the gradient of the heating temperature of the calorimeter calculates the released energy.

2. What are the physical and physiological caloric equivalent of nutrients?

The amount of heat released during combustion of 1 gram of substance in a calorimeter and in the body, respectively.

3. How much heat is released when you oxidize 1 g of protein, 1 g of fat and 1 g of carbohydrates?

1 g of proteins - 4.1 kcal (17.2 kJ), 1 g of fats - 9.3 kcal (38.9 kJ), 1 g of carbohydrates- 4.1 kcal (17.2 kJ)

4. Name the main methods (according to the authors) to determin the energy expenditure of the body. Indicate which of these methods is direct or indirect.

Methods of calorimetry can be: direct (method of Etueter-Benedict), indirect, (methods of Krog, Shaternikov, Douglas-Haldane).

5. What is the principle of indirect calorimetry?

It is based on a calculation of the amount of energy released by gas exchange (absorbed O2 and released CO2 per day).

6. What coefficients are used to calculate the energy consumption by indirect calorimetry?

They are respiratory coefficient and caloric equivalent of oxygen.

7. What is the respiratory coefficient of proteins, fats and carbohydrates oxidation to their end products?

At oxidation of proteins - 0,8, fats - 0,7, carbohydrates - 1,0.

8. What is the caloric equivalent of oxygen?

The amount of heat released by the body at 1 liter of O2 consumtion.

9. What is the caloric equivalent of oxygen by oxidation of proteins, fats and carbohydrates in the body (in the process of dissimilation)?

For proteins - 4.48 kcal (18.8 kJ), for fats - 4.69 kcal (19.6 kJ), for carbohydrates - 5.05 kcal (21.1 kJ).

10. Describe briefly the determination of energy consumption by Douglas-Haldane (full gas analysis).

The patient inhales atmospheric air for several minutes, and the exhaled air is collected into a special bag, then its amount is measured and analyzed to determine the volume of oxygen consumed and the CO2 released. The respiratory coefficient is calculated by finding the caloric equivalent of O2 in the table, which is then multiplied by the volume of O2 consumed in a given time interval.

11. Calculate the energy consumption in one minute if it is known that the patient consumed 300 ml of O2. The respiratory coefficient is 1.0.

RC = 1.0, it corresponds to the caloric equivalent of oxygen, equal to 5.05 kcal (21.12 kJ). So, the energy consumption per minute = 5.05 kcal x 0.3 = 1.5 kcal (6.3 kJ).

12. Why is basal exchange determined under standard conditions of maximum muscular and emotional rest with an empty stomach, at comfort temperature?

Because physical activity, emotional stress, food intake and change in the temperature of the environment affect the intensity of metabolic processes in the body.

13. What factors determine the value of the normal (average) basal metabolic rate of a healthy person?

Gender, age, height and weight of the body.

14. What is the value of the basal metabolic rate for men and women per day, as well as per one kg of weight per day?

Men have 1500-1700 kcal (6300-7140 kJ), or 21-24 kcal (88-101 kJ) / kg / day. The values are about 10% less for women.

15. List the factors that increase the energy consumption of the body. What are the specific-dynamic effects of food?

They are: physical and mental load, emotional stress, change of temperature and other environmental conditions. Specific-dynamic action of food is an increased energy expenditure after eating.

16. How do high protein food, fats and carbohydrates increase the energy consumption of the body?

After taking protein foods - by 20 - 30%, mixed foods - by 10-12%.

17. What do you call muscular efficiency of the body during muscular work?

The percentage of energy equivalent to the useful mechanical work, expressed in percentage, corresponds to all energy spent for this work.

18. What animals are called poikilothermic and homeothermic?

Poikilothermic animals (cold-blooded) with a non-constant body temperature, which depends on the temperature of the environment; homeothermic (warm-blooded) animals with a constant body temperature that does not depend on the temperature of the environment.

19. What is the significance of the body temperature constancy? In which organs is the process of heat formation most intensive?

It provides a high level of life regardless of the temperature of the environment. In the muscles, lungs, liver, kidneys.

20. How does the lumen of the vessels of the skin change when the temperature decreases and when the ambient temperature rises? What is the biological significance of this phenomenon?

When the temperature decreases the blood vessels of the skin are narrowed. With the increase of the temperature the vessels of the skin are dilated, which, by heat transfer regulation, contributes to maintaining a constant body temperature.

21. In what parts and structures of the central nervous system are thermoreceptors located?
In the hypothalamus, reticular formation of the middle brain, in the spinal cord.

22. What structure of the central nervous system is the highest center of thermoregulation?
Hypothalamus.

Table 1

Calculation of the basal metabolic rate (BMR) by weight

In men						**In women**					
Weight, kg	kcal	Weight, kg	kcal	Weight, kg	kcal	Weight, kg	kcal	Weight, kg	kcal	Weight, kg	kcal
47	713	***63***	933	***79***	1158	***47***	1105	***63***	1259	***82***	1439
48	727	***64***	947	***80***	1167	***48***	1114	***64***	1267	***83***	1449
49	740	***65***	960	***81***	1180	***49***	1124	***65***	1277	***84***	1458
50	754	***66***	974	***82***	1194	***50***	1133	***66***	1286	***85***	1468
51	768	***67***	988	***83***	1208	***51***	1143	***67***	1296	***86***	1478
52	782	***68***	1002	***84***	1222	***52***	1152	***68***	1305	***87***	1487
53	795	***69***	1015	***85***	1235	***53***	1162	***69***	1315	***88***	1497
54	809	***70***	1029	***86***	1249	***54***	1172	***70***	1325	***89***	1506
55	823	***71***	1043	***87***	1263	***55***	1181	***71***	1334	***90***	1516
56	827	***72***	1057	***88***	1277	***56***	1191	***72***	1344	***91***	1525
57	850	***73***	1070	***89***	1290	***57***	1200	***73***	1353	***92***	1535
58	864	***74***	1084	***90***	1304	***58***	1210	***74***	1365	***93***	1544
59	878	***75***	1098	***91***	1318	***59***	1219	***76***	1382	***94***	1554
60	892	***76***	1112	***9***	1332	***60***	1229	***78***	1401		
61	905	***77***	1125	***93***	1345	***61***	1238	***80***	1420		
62	919	***78***	1139	***94***	1359	***62***	1248	***81***	1430		

Table 2

Calculation of the basal metabolic rate by height and age

In men		**In women**	
Heigh,	Age, years	Heigh,	Age, years

cm	**17**	**19**	**21**	**23**	**25**	**27**	**29**	cm	**17**	**19**	**21**	**23**	**25**	**27**	**29**
140	553	528	-	-	-	-	-	***144***	171	162	-	-	-	-	-
144	593	568	-	-	-	-	-	***148***	187	178	-	-	-	-	-
148	633	608	-	-	-	-	-	***152***	201	192	183	174	164	155	146
152	673	664	619	605	529	578	556	***156***	215	206	190	181	172	162	153
156	713	678	639	625	612	598	585	***160***	229	220	198	188	179	170	160
160	743	708	659	645	631	618	605	***164***	243	234	205	196	186	177	168
164	773	738	679	665	652	638	625	***168***	255	246	213	203	194	184	175
168	803	768	699	685	672	658	645	***172***	267	258	20	221	201	192	188
172	823	788	719	705	692	678	665	***176***	279	270	227	218	209	199	190
176	843	808	739	725	718	698	685	***180***	291	282	235	225	216	207	197
180	863	826	759	745	732	718	705	***184***	303	294	224	233	223	214	204
184	883	848	779	765	752	738	725	***188***	313	304	250	240	231	221	215
188	903	868	799	785	772	758	745								
192	923	888	819	805	792	778	765								
196	-	908	839	825	812	798	785								
200	-	-	859	845	832	818	805								

Tasks for self-control:

1. A person felt thirsty after staying in heat for a long time. Signals of what receptors caused it first of all?
   A. Osmoreceptors of hypothalamus *
   B. Sodium receptors of hypothalamus
   C. Osmoreceptorsof the liver
   D. Glucoreceptors of hypothalamus
   E. Baroreceptors of aortic arch

2. A preventive radioprotector was given to a worker of a nuclear power station. What mechanism from the below mentioned is considered to be the main mechanism of radioprotection?
   A. Inhibition of free radicals formation *
   B. Prevention of tissue's hypoxia
   C. Activation of oxidation reactions
   D. Increasing of tissue blood supply
   E. Increasing of respiration

3.Energy expenditure of a young man increased from 500 to 2000 kJ per hour. What can be the cause of it?
   A. Physical exercise *

B. Raise of outer temperature
C. Mental activity
D. Food intake
E. Transition from sleep to wakefulness

4. Respiratory coefficient was studied in the patient who strictly kept to a certain diet for 10 days. It was determined that it is 1. What diet does the patient follow?
A. With domination of carbohydrates *
B. With domination of proteins and fat
C. With domination of fat and carbohydrates
D. Mixed
E. With domination of proteins and carbohydrates

5. The temperature of the ambient environment is 38 deg.C and relative air humidity is 50%. What ways of heat emission provide the maintenance of a constant temperature of the human body?
A. Evaporation *
B. Radiation
C. Heat conduction
D. Convection
E. Convection and conduction

6. A lightly dressed man is standing in a room, air temperature is $+14^{o}C$, windows and doors are closed. In what way does he lose heat most actively?
A. Heat radiation *
B. Heat conduction
C. Convection
D. Evaporation
E. Perspiration

7. What type of heat loss is the most effective if a man under conditions of air moisture of 80% and a temperature of $+35^{0}C$?
A. Evaporation *
B. Radiation
C. Heat conduction
D. Convection
E. -

8. A human body cools in water much faster that in the air. What way of heat emission in water is much more effective?
A. Heat conduction *
B. Convection
C. Heat radiation
D. Sweat evaporation
E. –

9. Energy expenditure of a man was measured at an empty stomach, in the lying position, under conditions of physical and psychic rest at a comfortable temperature. At what time will energy expenditure be the highest?

A. 5-6 p.m. *
B. 7-8 a.m.
C. 10-12 a.m.
D. 2-3 p.m.
E. 3-4 a.m.

10. During a measurement of energy expenditure of a man by the method of indirect calorimetry the following results were obtained: 1000 ml oxygen consumption and 800 ml carbon dioxide release per minute. What respiratory coefficient does the man have ?

A. 0,8 *
B. 1,25
C. 0,9
D. 0,84
E. 1,0