Federal State Budgetary Educational Institution of Higher Education

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Ministry of Health of the Russian Federation

Department of physiology named after professor A.T.Pshonik

**GUIDELINES FOR STUDENTS**

**for individual study**

**in**

**Normal Physiology.**

**Specialty 31.05.01 – General medicine**

**TO THE PRACTICAL LESSON**

**From 30.03.2022 to 05.04.2022**

**TOPIC:**

**EXCHANGE OF SUBSTANCES AND ENERGY. PHYSIOLOGY OF THERMOREGULATION**

**(in an interactive format –**

**individual preparation of presentations**

**according to the following questions)**

*Questions for presentations:*

1. The concept of energy metabolism. Anabolic and catabolic processes.

The plastic and energetic role of nutrients.

2. Methods for studying the body's energy expenditures: a) direct calorimetry, b) indirect calorimetry (respiratory and caloric coefficients, their significance in the study of energy metabolism).

3. Distribution of daily energy expenditure: a) basal metabolism and factors that determine it; b). the specific dynamic action of food and theories explaining this phenomenon;

4.Work exchange, energy expenditure of the body in various types of labor.

5. Physiological nutritional standards and dietary requirements.

6. The concept of homeothermy, poikilothermy and heterothermy. Body temperature as an important homeostasis constant. Temperature "scheme" of the body.

7. Mechanisms of thermoregulation. The concept of the center of thermoregulation. Influence of humoral factors on thermoregulation.

8. Mechanisms of heat production and heat transfer: a) mechanisms of chemical thermoregulation, b) mechanisms of physical thermoregulation.

9. Hyperthermia. Heat and sunstroke. Fever. Its positive and negative effects on body functions.

10. Hypothermia and its use in medicine.

**Practical work No. 1** «EVALUATION OF THE STATE OF METABOLISM AND ENERGY OF HUMAN BY BODY MASS INDEX»

**Equipment:** scales, height gauge, the object of study (human).

**Purpose of the work:** evaluate the state of metabolism and energy of a person by his body mass index.

Overweight is one of the risk factors for the development of diseases. The intensity of this factor increases from 4% with satisfactory adaptation to 52% with unsatisfactory adaptation and up to 46% with its failure.

The most commonly used diagnostic criterion for obesity is the ratio of overweight to standard. Recently, quite often uses the indicator of the ideal body weight. This indicator was developed by order of health insurance companies. The ideal mass (Quetelet index) is determined, taking into account the human constitution (normosthenic, asthenic, and hypersthenic).

The Quetelet index is the ratio of body weight in kilograms to a person's height in meters.

**Procedures:**

1. Measure the body weight of the subject in kilograms and his height in meters.
2. Measure the body mass index (BMI) in kg/m2, by the formula:

BMI = *W/H2,*

where *W is* body weight in kg; *H* is height in m.

3. Fill the results in the table 1.

Table 1.

|  |  |  |
| --- | --- | --- |
| Quetelet index | Evaluation of the body weight | Index of the object |
| 20-23  24-29  30 and more | Perfect  Excessive Obesity |  |

4. Evaluate the obesity rate by obtained body mass index.

**Practical work No. 2** «DETERMINATION OF THE BASAL METABOLIC RATE BY THE BODY SURFACE AREA»

**Procedures**: Determine height using the height meter. According to the nomogram "growth - body surface area" determine the body surface area (BSA) (S, м2). Then, calculate the basal metabolic rate (BMR) in one day: BMR = S \* k \* 24, where k - energy consumption coefficient (per 1 m2 per hour, equal to 38-40 calories for men aged 20-50 years, 36-38 calories for women), 24 - the number of hours per day.

**Practical work No. 4 «**COMPOSITION OF A FOOD DIET BY FOOD COMPOSITION TABLES»

**Equipment:** Tables of the recommended intake of energy, proteins, fats, and carbohydrates for adult working-age population by activity groups. table of the chemical composition of food products and their energy value.  
**Procedures:** Compose a daily food ration to meet the body's needs for energy and food in accordance with physiological nutritional standards.

**ANNOTATION (A BRIEF SUMMARY OF THE TOPIC)**

As a result of metabolism in the human body, energy constantly gets absorbed and consumed. Suffice it to say that about 5000 calories spend on the formation of one nucleotide bond during the assembly of a nucleic acid. Thus, a colossal amount of energy is spending on the vital activity of the organism; the same amount of it should be formed; that is, there should be a balance between the formation and consumption of energy in the form of a stable state. The source of this energy is fats and carbohydrates, and also partially proteins. As a result of metabolic reactions in the body, several types of energy are forming: chemical, electrical, mechanical (muscle work), heat, and others. It is important to know that in the end, all types of energy turn into heat, and the latter is not used by the body for its own needs. Scientists, to study the energy consumption of the body, proposed to determine the energy consumption as the amount of heat that is given off by the body to the environment.

There are two methods used to study energy expenditure of the body, two methods are in use: indirect and direct calorimetry. The direct calorimetry method is associated with the determination of the amount of heat that is directly released by the body. For this method, calorimetric chambers are used. The calorimetric chamber is a structure that consists of two chambers, one of the walls of which is made up of zinc to prevent heat loss. On the inner surface of the chamber, there are pipes through which water flows. Knowing the temperature of the water, which flows in and out of the chamber, and the amount of it passing through the chamber per unit time, one can find (determine) the heat given off by the body. Direct calorimetry is a very accurate but cumbersome method.

The method of indirect calorimetry is based on the study of gas exchange, i.e., the consumption of oxygen and the release of carbon dioxide from the body of gas per unit of time. Description for this method lies in the fact that all substances burn in oxygen, while a strictly defined amount of heat is released per unit of its consumption. Oxygen consumption is accompanied by the release of an equivalent amount of carbon dioxide. From here, knowing the amount of oxygen consumed, it is possible to calculate the body's energy expenditures. For this purpose, you need to know:

1. The caloric equivalent of a gas is the amount of thermal energy that is released when one liter of oxygen is consumed and 1 gram of fats, proteins, and carbohydrates are burned. So, when one liter of oxygen is burned and 1 gram of fat is consumed, 4.7 kcal are released, 1 gram of protein - 4.6 kcal, 1 gram of carbohydrates - 5.05 kcal. All the difficulties in determining the energy expenditure of the body lie in the fact that we do not know what substances are burned up.
2. To find out the value of the caloric gas equivalent, we need to determine the respiratory quotient. The respiratory quotient (respiratory coefficient) is the ratio between the amount of carbon dioxide emitted to the amount of oxygen consumed. If carbohydrates are burned, the respiratory quotient (RQ) is 1.0, fats is 0.7, proteins is 0.8. Different RQ values ​​for different nutrients are associated with different amounts of oxygen entering the molecules of proteins, fats, and carbohydrates. It is known that for the oxidation of a substance, not only the external oxygen is used, but also that contains oxygen in the oxidized substance. Therefore, the more endogenous oxygen, the less consumed from the outside, and the higher RQ will be.

3) The amount of oxygen consumed. Several methods can be used to determine the amount of oxygen consumed: Shaternikov's chamber, a spirograph, and the Douglas-Holden method. To determine the oxygen consumed by the body by the Douglas-Holden method, you must have a Douglas bag, a gas clock, and a Holden gas analyzer. A gas clock is used to determine the amount of air passing through the lungs in one minute. Douglas bag is used - for air intake; gas analyzer - to determine the amount of oxygen and carbon dioxide in the exhaled air. However, RC does not always correctly represent the body's energy expenditures. For example, at the end of muscular work, it cannot be used as an indicator reflecting which substances are mostly burned - fats, proteins, or carbohydrates. The study of the change in RC during muscular work shows that during the muscular effort the RC gradually approaches one, after its end it becomes more than one, then after a time, it sharply decreases. A significant increase in RC at the end of work is because a large amount of lactic acid is released from the muscles into the blood, which binds with sodium bicarbonates. The carbon dioxide released as a result of this reaction is released to the outside of the body; therefore, the RC also increases. After a time, the opposite reaction occurs: lactic acid is oxidized, and the released sodium binds carbon dioxide, forming bicarbonates. The release of carbon dioxide from the body decreases, so the RC drops sharply.

The total energy expenditure (TEE) can be divided into three parts: basal metabolic rate (BMR), energy used in physical activity or the thermic effect of physical activity (TEPA), and the thermic effect of food (TEF).

Basal metabolic rate or resting metabolic rate is the amount of energy that is needed to support the body's most basic functions when at rest. For a healthy adult, it is about 1300 - 1600 kcal/day. Basal metabolic rate is determined when the following conditions are met: on an empty stomach, i.e. 12-14 hours after the last meal, at normal body temperature (36-37 0С), in a state of complete muscular and mental rest, at an ambient temperature of 18-20 0С and an atmospheric pressure of 760 mmHg. The energy of the basal metabolism goes to the work of pumps, the function of the heart, respiratory, excretory, and other systems, as well as to maintain the body temperature at a normal level. (ATP synthesis is 900 kcal, maintenance of a concentration gradient of is 215 kcal, heart functioning is 270 kcal, the rest goes to maintain the function of other organs and systems and body temperature). The basal metabolism is individual and depends on some endogenous and exogenous factors. Endogenous factors include height, body weight, age, sex, body temperature, individual characteristics of the nervous and endocrine systems. Exogenous factors include ambient temperature and barometric pressure, climatic conditions, and human nutritional status. The basal metabolism up to 40 years of age is stable in its value, then - decreases. To estimate the basal metabolism it is required to determine the standard and experimental basal metabolism. To determine the standard basal metabolism, we need calculations per body surface unit for 1 m2, according to special tables. It is shown that women lose 36-38 kcal from 1 m2, men - 38-40 kcal per hour. Direct and indirect calorimetry methods are used to determine the experimental basal metabolism. The standard and the experimental basal metabolism determined by different methods are compared, and the basal metabolism is considered as normal if the deviation of the experimental value does not more than 10% of the value of the standart one.

Demonstrations of the specific dynamic action of food are that after a meal, energy expenditure increases in 15-30 minutes, reaches a maximum after 3-6 hours, and continues for 10-12 hours. Different nutrients have different specific dynamic effects. So, after eating a protein meal, the basic metabolism increases to 30-40%, carbohydrates to 12-15%, fats, according to most researchers, have almost no such effect (4-6%). There are several theories in physiology concerning the explanation of the specific dynamic action of food:

1. The authors of the first theory explain the increase in energy expenditure after a meal by an increase in (gastrointestinal tract) GIT function due to motor activity and secretion.
2. The second theory explains the increase in energy expenditure of the body by the direct effect of products of hydrolysis of proteins, fats and carbohydrates directly on cells (glucose, deamination products).
3. Academician Braunstein believes that the increase in metabolism after a meal is due to the conversion of amino acids into proteins and of glucose into glycogen. These processes naturally require energy.
4. Academician Ugolev believes that after eating, the body produces specific substances, most likely of hormonal nature, which indirectly through the hypothalamic center increase energy expenditure.

Active metabolism. It is related to a person's profession and depends on many factors. Taking into account a person's occupation, gender, and age, scientists suggest the following energy consumption rates:

**Group I.** It includes people whose work requires little physical effort (mental workers, students, designers, accountants, etc.). Their daily needs are 2800-3000 kcal for 18-40 years old men, and 2400-2800 for 18-40 years old women; 2600-2800 kcal for 40-60 years old men, and 2200-2250 for 40-60 years old women.

**Group II.** It includes workers of mechanized labor whose activity does not require much physical effort (workers of automatic lines, instrument making, radio electronics; sales clerks, sanitary workers, nurses, etc.). Their daily needs are 3000-3300 kcal for 18-40 years old men, and 2500-3000 for 18-40 years old women; 2800-3200 kcal for 40-60 years old men, and 2300-2700 for 40-60 years old women.

**Group III.** This group includes workers of mechanized labor and service sphere, whose activity is connected with considerable physical effort - machine operators, transport drivers, workers of food industry, agriculture, etc.). Their daily needs are 3200-3700 kcal for 18-40 years old men, and 2500-3000 for 18-40 years old women; 2900-3200 kcal for 40-60 years old men, and 2500-2800 for 40-60 years old women.

**Group IV.** It includes workers of non-mechanized or partially mechanized labor (miners, metallurgists, drivers of heavy machinery, some agricultural workers, etc.). Their daily needs are 3700-4200 kcal for 18-40 years old men, and 3100-3600 for 18-40 years old women; 3400-3800 kcal for 40-60 years old men, and 3400-3600 for 40-60 years old women.

**Group V.** Heavy physical labor. More than 4000 - 4500 kcal.

Energy metabolism is regulated by nucleus, which is located in the hypothalamus area. Cortical centers also have a certain importance. It is known that nervous stress causes a significant expenditure of energy, which is followed by a loss of human weight. In the I.P. Pavlov Institute (St. Petersburg), interesting experiments were conducted. They showed the role of the cerebral cortex in the regulation of the body's energy expenditures. The experiment involved conductors of passenger trains that were scheduled to go either to the south of our country or to the north. One group of conductors was told that they were going south, but in fact, they were going north. The waiting of a warm climate, despite their northern route, was accompanied by a decrease in energy expenditure, while the guides leaving for the south, who were told that they were going to the north, had an increase in the body's energy expenditure. These studies suggest an influence on the energy metabolism of the cerebral cortex.

Human nutrition is important because it is related to human health and is strictly individual in nature (nutrition of athletes, the sick, child nutrition, etc.).

When talking about human nutrition, there are a number of factors to consider:

1. The coefficient of absorption of nutrients. It is known, for example, that animal proteins are absorbed much better than plant proteins. For example, out of 18.75 grams of protein contained in 100 grams of meat, 18 grams (98%) are absorbed, while out of vegetable protein contained in bread (8.5 grams) only 4 grams (50%) are absorbed.
2. The caloric quotient of proteins, fats and carbohydrates should be considered when prescribing meals, which are 4.1 kcal (proteins), 9.3 kcal (fats), 4.1 kcal(carbohydrates).
3. The daily protein, fat, and carbohydrate requirements. A person needs to consume up to 80 to 100 grams of protein per day, at least 30% of which should be proteins of animal origin, which contain essential amino acids necessary for normal body activity.  
   The daily requirement for carbohydrates is 350-400 grams, and for fats is 60-80 grams. There are special requirements for fats as well as for proteins. A person's diet should include fats that contain essential unsaturated fatty acids, such as linoleic, linolenic, and arachidonic acids. This group of unsaturated fatty acids is very important in the vital functions of the body. In addition, these acids prevent the development of atherosclerotic processes by engaging in oxidative processes.

4. A person's food should be varied, containing the necessary amount of salts (fruits, vegetables) and vitamins.

**9.Test assignments on the topic with sample answers**

**SUBSTANCE AND ENERGY METABOLISM**

23–1. The energy consumption of the body in conditions of physiological rest in the supine position, on an empty stomach, at a temperature of comfort is called:

1. non-resting energy expenditure
2. metabolism
3. catabolism
4. basal metabolism\*
5. thermic effect of food

23–2. The energy of the basic metabolism doesn't spend on:

1. blood circulation
2. cell metabolism
3. respiration
4. specific dynamic action of food \*
5. maintenance of membrane potential

23–3. The ratio of the volume of emitted carbon dioxide to the volume of absorbed oxygen is called:

1. the caloric value of the nutrient
2. caloric oxygen equivalent
3. respiratory quotient \*
4. the gas constant
5. tidal volume

23–4. The daily requirement of a middle-aged person for carbohydrates is:

1. 70–100 g
2. 150–200 g
3. 400–450 g\*
4. 40–60 g
5. 10–30 g

23–5. The daily requirement of a middle-aged person for proteins is:

1. 150–200 g
2. 400–450 g
3. 80–130 g\*
4. 40–70 g
5. 10–30 g

23–6. The daily fat requirement of a middle-aged person is:

1. 100–150 g
2. 400–450 g
3. 70–100 g\*
4. 40–70 g
5. 10–40 g

23–7. The predominant effect on carbohydrate metabolism is exerted by the hormone:

1) testosterone

2) aldosterone

3) antidiuretic

4) glucagon \*

5) parathyroid hormone

23–8. The predominant effect on protein metabolism is exerted by:

1) insulin

2) adrenaline

3) antidiuretic hormone

4) growth hormone (GH) \*

5) oxytocin

23–9. Hormone that stimulates protein synthesis in the tissues:

1. hydrocortisone
2. adrenaline
3. growth hormone (GH) \*
4. vasopressin
5. insulin

23–10. The formation of complex organic compounds from simple ones with the expenditure of energy is called:

1. basic exchange
2. working exchange
3. dissimilation
4. assimilation \*
5. the specific dynamic action of food

23–11. The breakdown of complex organic compounds to simple ones with the release of energy is called:

1. assimilation
2. energy balance
3. basic exchange
4. dissimilation \*
5. the specific dynamic action of food

23–12. Dietary proteins DO NOT function as:

1. a supplier of essential amino acids for the body
2. a source of amino acids for constructive metabolism
3. an energy source
4. the main source of glucose \*
5. suppliers of complex proteins

23–13. Most strongly the state of "nitrogen balance" is influenced by the number of …….received with food:

1. protein \*
2. carbohydrates
3. lipids
4. minerals
5. vitamins

23–14. Food lipids do not function as

1. suppliers of essential amino acids for the body \*
2. suppliers of essential unsaturated fatty acids for the body
3. a source of amino acids for constructive metabolism
4. an energy source
5. metabolic assistant

23–15. Prolonged hyperfunction of the thyroid gland is associated with:

1) increase in body weight

2) decrease in body weight\*

3) no change in body weight

4) decrease in the amount of liquid in the body

5) increase in the volume of liquid in the body

23–16. The leading role in the regulation of energy metabolism belongs to the:

1) thalamus

2) hypothalamus\*

3) reticular formation

4) medulla oblongata

5) spinal cord

23–17. Carbohydrates DON’t function as:

1. a monosacharide source for DNA and RNA building
2. an energy source

3) a source of essential amino acids

4) a source of fats

5) metabolite

23–18. The main glycogen storage in the body:

1) liver\*

2) heart

3) kidneys

4) lungs

5) muscles

23–19. Normal blood glucose concentration (mmol/L):

1) 6,6-7,7

2) 3,3-5,5\*

3) 2,1-4,4

4) 0,5-2,1

5) 8,2-10,3

23–20. The greatest volume of water in the body is contained in:

1) intracellular fluid\*

2) in tissue fluid

3) blood plasma

4) in muscles

5) in CNS

1. BASAL METABOLISM AFTER A FATTY MEAL:

1) Will decrease by 15%\*.

2) Will not change

3) Increase by 30 %

4) Increase by 4-6%

1. THE AMOUNT OF PROTEIN THAT ASSISTS IN MAINTAINING NITROGEN BALANCE IN THE BODY IS CALLED:

1) Positive nitrogen balance

2) Negative nitrogen balance

3) Protein minimum

4) Protein maximum

1. THE LEVEL OF METABOLISM TYPICAL OF THE RESTING STATE UNDER

COMFORTABLE CONDITIONS, ON AN EMPTY STOMACH AND IN THE AWAKE STATE, IS:

* 1. Total energy expenditure
  2. Basal metabolism\*
  3. Heat metabolism
  4. Thermic effect of physical activity

1. PROTEIN LOSS AT REST DURING COMPLETE STARVATION IS...

1) 30 g per day

2) 12.5 to 25 g/day\*

3) 0.028 - 0.075 g/kg weight per day

4) 5 g/kg weight per day

1. DEPOSITION OF FAT IN THE STORAGE IS PROMOTED BY...

1) Glucocorticoids

2) thyroxine

3) noradrenaline

4) somatotropic hormone

1. The caloric value of 1 g of carbohydrates when they are oxidized in the organism is...

1) 0.8 kcal

2) 4.1 kcal\*

3) 9.3 kcal\*

4) 5.8 kcal

1. THE RESPIRATORY COEFFICIENT FOR FATS IS:

1) 1,0

2) 0,8

3) 0,7 \*

4) 0,66

1. THE AMOUNT OF PROTEIN THAT ASSISTS IN MAINTAINING NITROGEN BALANCE IN THE BODY IS CALLED

1) Positive nitrogen balance

2) Negative nitrogen balance

3) Protein minimum

4) Protein maximum

1. WITH AGE, THE AMOUNT OF INTRACELLULAR WATER...

1) Does not change

2) increases

3) decreases

4) Increases until puberty, then decreases

1. RUBNER'S LAW OF BODY SURFACE - ....

1) The smaller the body surface per kg of weight, the higher the metabolism

2) The greater the body surface per kg of weight, the higher the metabolism\*.

3) The intensity of metabolism per 1 kg of weight does not depend on the size of the body surface at the same weight

4) The more convex the body surface, the higher the metabolism

**Practical work in the classroom;**

**Practical work No.1.** Influence of physical activity on the processes of heat production and heat loss.

**Procedures:** A sheet of thermal paper is placed on the subject's forehead and palm for 5 seconds. The test is repeated after 20 squats. The amount of sweating before and after physical activity is evaluated, the number of sweat glands, and the intensity of sweating on the forehead and palm are compared.

**Brief summary of the topic**

The thermoregulation system is understood as a set of organs and tissues regulating and maintaining the temperature stability of the "core" of the body. Metabolism and metabolic processes are possible only at a certain temperature, because all the enzymatic systems of humans and higher animals work only under these conditions. The vast majority of animals lack physiological mechanisms capable of keeping their body temperature relatively constant regardless of changing ambient temperature. Their body temperature is as variable as the ambient temperature. Such animals with variable body temperature are called poikilothermic. In poikilothermic animals, seasonal fluctuations in the levels of metabolic processes are observed. Mammals, which have physiological thermoregulatory mechanisms that keep their body temperature relatively constant despite fluctuations in the ambient temperature, are another case. This constancy of body temperature is called isothermy, and animals are called homothermic.

Isothermia evolved gradually in the course of evolution. In a newborn baby, the ability to maintain a constant body temperature is far from perfect. This can result in hypothermia (hypothermia) or overheating (hyperthermia) if the ambient temperature changes. Therefore, the body temperature of the newborn depends on the temperature of the outside environment.

From a medical point of view, the concept of "body temperature pattern" is important, which is determined by different levels of metabolism in different organs. Body temperature in the axilla is 36.8 ° C, on the palm surfaces of the hand is 25-34 ° C, in the rectum is 37.3-37.5 ° C, in the oral cavity is 36.9 ° C. The lowest temperature is noted in the toes of the lower limbs, and the highest in the liver. At the same time, even in the same organ there are significant temperature gradients, and its fluctuations are from 0.2 to 1.2°С. For example, in the liver the temperature is 37.8-38°C, and in the brain it is 36.9-37.8°C. Significant changes in internal temperature occurs under certain influences: staying in a bath with a water temperature of 40 ° C causes a person to increase the temperature of the brain by 2 ° C, and the rectum - by 1.5 ° C. Significant temperature fluctuations are observed during muscular exertion. In humans, intensive muscular work leads to an increase in brain temperature by 0.4-0.6°C, and the temperature of contracting muscles by 7°C.

Body temperature does not remain constant; it fluctuates during the day. Daily variations in body temperature average 0.5-0.7°С and show a certain regularity: the minimum body temperature falls at 4-6 a.m., the maximum at 4-6 p.m.

The body temperature depends on the intensity of heat production and the amount of heat loss.

Heat production**.** Heat is generated in the process of metabolism. The level of heat production depends on: 1) basal metabolism 2) muscle activity (shivering thermogenesis), including muscle contractions during shaking 3) the effect of hormones (T4, adrenaline, noradrenaline, STH, testosterone), 4) sympathetic stimulation; 5) nonshivering thermogenesis, i.e. heat production by decoupling oxidation and phosphorylation, including in brown fat cells.

Heat loss**.** Most heat is generated in the liver, brain, heart, and skeletal muscles as they work. Then, heat gets transferred to the skin, where it dissipates to the air and the environment. The rate of heat loss depends on two factors: the rate of heat transfer (mainly with blood flow) from the places of heat generation to the skin and the rate of heat transfer from the skin to the environment.

Mechanisms of thermoregulation. Thermoregulation can be chemical and physical. Chemical thermoregulation is performed by increasing or decreasing the production of heat, i.e. by increasing or decreasing the intensity of metabolism. Physical thermoregulation is performed by changing the intensity of heat output.

Heat is transferred to the environment by radiation, conduction, convection and evaporation. Thermal radiation refers to the property of a surface heated to a certain temperature to emit heat in the form of radiant energy (infrared radiation). Thermal radiation gives off about 60% of all heat. Heat conduction refers to heat transfer in which a heated body gives off heat to the surrounding body particles, to the air (convection), or by contact with objects that have a lower temperature than the body temperature. The amount of heat lost in this way will depend not only on the temperature difference between the body and the medium, but also on the thermal conductivity of the surroundings. Therefore, at the same outside temperature, the amount of heat given off in the water will be greater than in the air. Heat conduction makes up 15% of the total heat output of a human being. The next highest amount of heat is the evaporation of water by the skin and lungs at 27%. The remaining 3% of heat is spent on heating exhaled air and excretion of feces and urine. Evaporation of water depends on the relative humidity of the air. In air saturated with water vapor, evaporation cannot take place. Therefore, high temperature in high humidity is more difficult to handle. In air saturated with water vapor (in a bathhouse) sweat is produced in large quantities, but it does not evaporate, but trickles down. Such perspiration does not assist in the heat transfer.

So, regulation of body heat is carried out by combined action of mechanisms regulating metabolism (chemical regulation) and mechanisms regulating blood supply to the skin, sweating and breathing (physical regulation).

The regulation of body temperature stability is based on two mechanisms: neuroreflexive and humoral. The concept of a nerve center of thermoregulation includes a group of neurons located in different CNS sections that regulate body temperature (spinal cord, medulla oblongata, hypothalamus, large brain cortex). The superior thermoregulation center is located in the hypothalamic region: the chemical thermoregulation center is located in the lateral hypothalamic nuclei (heat production center), and the physical one in the area of the anterior commissure and crossing of visual pathways (heat dissipation center). In natural conditions, the heat-forming center is excited when the body is cooled in two ways: 1) cold irritates the center reflexively through nerve endings of the skin; 2) blood, flowing through capillaries of cooled skin, changes the temperature, under the influence of this decrease in blood temperature irritates the thermoregulation center (if thermoregulation centers were irrigated by cold blood, the body temperature of the animal increases). Inhibition of the heat generation center occurs when the ambient temperature increases, also by nerve reflexes (skin receptors) and humoral (increase in blood temperature).

Humoral regulation of temperature constancy depends on the state of endocrine glands, in particular thyroid and adrenal glands. Thyroid hormones that increase metabolism increase heat production. Adrenal glands influence increase heat production through adrenaline hormone, which increases oxidative processes in tissues, in particular in muscles, and simultaneously decreases heat production, because it narrows skin blood vessels.

If a person stays for a long time in conditions of significantly increased or decreased ambient temperature, the mechanisms of physical and chemical regulation of heat, which in normal conditions maintains the stability of body temperature, may be insufficient; if the body overheats it causes hyperthermia, or if the body overcools hypothermia occurs.

Hyperthermia is a condition in which the body temperature rises above 37°C. It occurs with prolonged exposure to high ambient temperatures, especially humid air, and therefore little effective perspiration. Hyperthermia can also occur under the influence of some endogenous factors that increase heat production in the body (thyroxine, fatty acids, etc.) Sharp hyperthermia, in which the body temperature reaches 40-41 ° C, is accompanied by a severe general condition of the body and is called heat stroke. Hyperthermia should be distinguished from temperature changes when the external conditions are unchanged, but the thermoregulation process itself is disturbed, most often under the influence of microorganisms. An example of such a disorder is infectious fever. One of the reasons for its appearance is that hypothalamic centers of heat exchange regulation are highly sensitive to some chemical compounds, in particular bacterial toxins.

Hypothermia is a condition in which the body temperature is below 35°C. Hypothermia occurs most quickly when immersed in cold water. At first, there is stimulation of the sympathetic division of the autonomic nervous system and the heat output is reflexively limited and heat production is increased. This is assisted by a contraction of the muscles - a muscle tremor. After a while, the body temperature does begin to fall. At the same time, there is a condition similar to anesthesia, the disappearance of sensitivity, weakening of reflex reactions, decrease in excitability of nerve centers. The intensity of metabolism sharply decreases, respiration slows down, heartbeats become slower, cardiac output decreases, and blood pressure falls (at 24-25°C, it may be equal to 15-20% of the initial temperature). Currently, artificially created hypothermia with body cooling to 24-28°C has wide practical application in surgical operations on the heart and CNS. The point of this measure is that hypothermia significantly reduces the brain metabolism, and therefore the need for this organ for oxygen. Therefore, longer bleeding of the brain becomes tolerable (instead of 3-5 minutes at normal temperature up to 15-20 minutes at 25-28°C), which means that in hypothermia patients more easily endure temporary cardiac arrest and respiratory arrest. Hypothermia is stopped by rapidly warming the body.

Thermoregulation is performed by a special functional system. The perceptive part of this system is the skin and hypothalamus thermoreceptors, the performing mechanisms are the thermoregulation center and humoral factors, the executing organs are the skin vessels and organs of heat production and heat emission.

Test Questions

**THERMOREGULATION**

25–1. Chemical thermoregulation (heat production) does not include:

1) heat transfer during vasodilation of the skin \*

2) the effect of adrenaline on the mobilization and utilization of glucose and fatty acids

3) the effect of thyroid hormones on metabolism

4) the effect of glucocorticoids on carbohydrate metabolism

5) contractile thermogenesis

25–2. Hormone-dependent process is not:

1) metabolism

2) mobilization of fatty acids

3) utilization of fatty acids

4) perspiration

5) contractile thermogenesis of skeletal muscles \*

25–3. Physical thermoregulation (heat transfer) is:

1) change in the intensity of metabolic processes

2) change in the transfer of heat from internal organs to the surface of the body

3) regulation of the rate of heat transfer from the body surface \*

4) change in the transfer of heat from internal organs to the surface of the body and regulation of the rate of heat transfer from the surface

5) radiation of heat from the surface of the body

25–4. The main sources of heat production at rest are:

1) kidneys

2) heart

3) brain

4) muscles

5) liver, stomach, intestines \*

25–5. Homoyothermia is:

1) changes in body temperature along with changes in ambient temperature

2) the constancy of the temperature of the "core" of the body with significant fluctuations in the temperature of the environment \*

3) deviation of body temperature from normal value

4) an increase in body temperature with emotional stress

5) an increase in body temperature during physical work

25–6. Heat production with a decrease in ambient temperature in warm-blooded organisms:

1) decreases

2) increases \*

3) leave unchanged

4) there is no right answer

5) decreases with a decrease in the ambient temperature, but the normal temperature of the "core" and "shell" of the body

25–7. Contractile thermogenesis is mainly associated with:

1) a change in tone and phase contractions of skeletal muscles \*

2) changes in the activity of the smooth muscles of the gastrointestinal tract

3) cutaneous blood flow

4) the work of the respiratory muscles

5) the work of internal organs

25–8. At ambient temperatures above skin temperature, the main heat transfer pathway is:

1) convection

2) evaporation \*

3) radiation

4) conducting

5) redistribution of heat in the body

25–9. At rest, the main heat transfer pathway is:

1) convection

2) holding

3) evaporation

4) radiation \*

5) redistribution of heat in the body

25–10. The greatest amount of heat during physical activity is formed:

1) in the lungs

2) in the kidneys

3) in skeletal muscle \*

4) in connective tissues

5) in the brain

25–11. The thermoregulation center is located in ………………………………

1) basal nuclei

2) hypothalamus \*

3) the medulla oblongata

4) the spinal cord

5) midbrain

25–12. Conditioned reflex thermoregulation is primarily provided by ………………………

1) hypothalamus

2) cerebral cortex \*

3) spinal cord

4) basal nuclei

5) cerebellum

25–13. Heat dissipation ……………………….by evaporation at 100% relative humidity.

1) high

2) stops \*

3) there is no right answer

4) decreases, then increases

5) increases, then decreases

25–14. With artificial (medical) hypothermia, the body temperature is reduced to 30 ° C. In this condition ………………………………. .

1) oxygen consumption increases to compensate for cooling

2) oxygen consumption decreases and tissue resistance to oxygen deficiency increases \*

3) the excitability of nervous and muscle tissues increases

4) the heart rate increases

5) the tone of the sympathetic nervous system increases.

**Course textbooks and manuals**

1. Dunn, R. B. USMLE Step 1. Lecture Notes. Physiology / R. B. Dunn ; ed. D. E. Fitzovich. - [S. l.] : Kaplan, 2006. - 576 p.

2. Hall, J. E. Guyton and Hall Textbook of Medical Physiology / J. E. Hall. - 13th ed., Int. ed. - Philadelphia : Elsevier, 2016. - 1145 p.

3. Sherwood, L. Fundamentals of Human Physiology / L. Sherwood. – 4th ed. – Belmont, CA, USA: Brooks/Cole, 2012. – 764 p.

4. Silbernagl, S. Color Atlas of Phisiology / S. Silbernagl, A. Despopoulos. - 7th ed. - Stuttgart : Thieme, 2015. - 458 p.

5. Wilson, L.B. USMLE Step 1. Lecture Notes. Physiology / L.B. Wilson. - Kaplan, 2013. - 423 p.