ENERGETIC METABOLISM

The energetic expenditure represents a characteristic of living beings, stopping of using energy in a living body leading to death. The primary source of energy for human beings and animals is represented by the food. Food is oxidized until carbon dioxide, water and other products, supplying the energy necessary for maintaining the structural integrity of cells and some specific cellular activities (mobility, secretion, and excitability). Totality of chemical and energetically transformations that carry on into the organism is named metabolism. The degradation / break down reactions of the nutritive substances or of living matter itself, followed by release of energy represent the catabolism. The energy may be deposited/stored up into the organism as rich-energy products (ATP) or lipids, glycogen and proteins. The formation of new tissues and deposit energy substances is realized with energy expenditure and represents the anabolism. During the human beings development there is not a perfect balance between the anabolism and catabolism. In childhood predominates the anabolism, in elderly people the catabolism and in adults, there is a balance between the two processes.

The chapter which deals with the energetic transformations in the living beings is named biological thermodynamics (bioenergetics). Bioenergetics applies the general laws of energetics to the living beings.

The first law of thermodynamics asserts that in an energetic system, the energy is neither lost nor gained. The chemical energy released by food is transformed into mechanic, electric and thermic energy. According to the first law of thermodynamics there is not loss of energy during the transformation from energy to other.

In the second law of thermodynamics it is showed that only a part of energy system may be transformed into work, the remainder is transformed irreversibly into the heat. All the energy released into the organism of an immobile person, being in the digestive rest appears under the form of heat.

The amount of energy released by the burning of some foods or by the organism being in the activity is measured in calories or in joules. A calorie represents the amount of heat necessary to increase the temperature of 1 gram of water with 1^oC, namely from 15^oC to 16^oC. In biology is used kilocalorie (a unit of 1000 times greater).

The international unit of measure for energy is the joule.

The assessment of energetic expenditure

The measurement of metabolic expenditure may be realized by direct and indirect methods.

The direct method consists of lying down a person in a thermic isolated chamber (calorimeter) and the measurement of heat that is released /ceded to a certain volume of water, which circulates through a spiral tube, inside of calorimeter.

Indirect methods are represented by the: method of nutritive balance and the method of gaseous exchanges.

1) By the nutritive balance method is established the energetic value of diet able to maintain the person to a constant body weight, for several days.

The heat liberated by burning of 1 gram of foodstuffs outside of the body was assessed into the bomb calorimeter and is:

- 4,1 kcal/g for glucids
- 9,3 kcal/g for lipids → **physical isocaloric coefficients**
- 5,3 kcal/g for proteins

Into the human body the proteins are not metabolized until the carbon dioxide and water, but into catabolites (urea, ammonia, uric acid, creatinine), which although contain some energy, they are excreted. Taking into account of the burning of foodstuffs in the organism, it is used the practical isocaloric coefficients for calculation which are:

- 4 kcal/g for glucids
- 9 kcal/g for lipids → **practical isocaloric coefficients**
- 4 kcal/g for proteins

The establishment of energetic expenditure is performed by calculation, taking into account of the amount of consumed foods in 24 hours, the content of foods in proteins, lipids and glucids and the practical isocaloric coefficients of them.

2) The method of gaseous exchanges is based on the finding/observation that over 95% of energy expended in organism derives from the oxidative reactions. Therefore the metabolism can be calculated by the oxygen consumption. By fixing of 1litre of oxygen on the glucides, which are metabolized into the body results 5, 05 kcal, on lipids – 4, 69 kcal and on proteins- 4, 48 kcal. These represent the isocaloric coefficients of oxygen.

The amount of oxygen need for combustion depends on the proportion of C and O of the three categories of foodstuffs. In a mixed alimentation, by burning of 1liter of O_2, 4,825 kcal are liberated. Using the isocaloric coefficient of oxygen, one can calculate the metabolism from the amount of O_2 retained in a certain period of time.

Information about the foodstuffs used in the organism is supplied by the respiratory quotient (RQ), namely the ratio between the exhaled CO_2 and the O_2 consumed in the unit of time. When in organism, glucose is oxidized; RQ is 1, due to the fact that oxygen and hydrogen are in the molecule in the same proportion as in the water and the entire amount of oxygen combine with carbon

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6\,CO_2 + 6\,H_2O$$

$$RQ = \frac{6CO_2}{6\,O_2} = 1$$

A lower RQ is noted during the burning of lipids, because in the molecule of lipids there is less oxygen in comparison with hydrogen, so the consumed oxygen is used not only to form CO_2, but also H_2O.The oxidation of triasterin shows that RQ is 0,7.

$$2C_{57}H_{110}O_6 + 163\,O_2 \rightarrow 114\,CO_2 + 110\,H_2O$$

$$RQ = \frac{114\,CO_2}{163\,O_2} = 0,7$$

For proteins was established a RQ= 0, 8**.**

	Glucides	**Lipids**	**Proteins**
RQ	1,00	0,70	0,82
Kcal/LO_2	5,05	4,69	4,48

Example:

Let′s suppose that a person (in resting conditions) consumes 280 ml O_2/min and the RQ is 1. The metabolism is calculated multiplying the oxygen consumed by the isocaloric coefficient of oxygen- 0,280 x 5,05 = 1,414 kcal/min and per day 1,414 x 60 x 24 = 2036 kcal/day.

In a mixed nutrition, the RQ is 0,85.

The incapacity of organism to use glucose in diabetes mellitus results in decrease of RQ. After the administration of insulin, RQ increases until 1.

The volume of CO_2 exhaled and the oxygen inspired may also be changed by other factors, not only by those metabolic. For instance- the hyperventilation leads to elimination in excess of CO_2 and to increase of RQ. During physical effort, due to the hyperventilation, formation of lactic acid and contraction of oxygen debt at the beginning of the contraction, the RQ may reach the value of 2. Metabolic acidosis is accompanied by the increase of RQ and alkalosis by the decrease of RQ.

Devices used for indirect measurement of metabolism

Gaseous exchanges are usually measured by means of some closed circuit devices made of a spirometer (Benedict, Krogh), whose bell oxygen is introduced. A person inspired oxygen from the spirometer and the exhaled air is also led under the bell, but first it passes through a receiver, where there is a CO_2 and H_2O absorber. The movements of bell, synchronous with the respiration are recorded on a drum. The line that links the extremities of movements of spirometer, gives information about the volume of consumed O_2. For the calculation of metabolism it is used the average coefficient of oxygen = 4,825 kcal/l. This method does not permit of the establishment of respiratory coefficient.

There are more improved devices (Oxycon, Bohlau) which establish simultaneously the consumption of oxygen and the carbon dioxide exhaled and they permit of rapid finding of value of metabolism.

Basal metabolism (BM)

Usually for comparison the metabolism of different persons, the measurement is realized in standard conditions, which eliminate the energetic expenditure related to the physical activity.

The standard conditions are:

- absolute rest in lying down position with 30 minutes before the examination
- awake state, mental relaxation
- fasting with 12 hours before the examination
- The room temperature = 20 – 25°C.

Basal metabolism represents the minimum consumption of energy necessary for maintaining the vital functions (circulation, respiration, nervous activity), in resting conditions and in awake state.

Liver and the skeletal muscles provide about 50% of the caloric energy of BM. Due to the fact that muscular tonus is reduced during the sleep, the metabolism of person who sleeps or is narcotized falls below the BM.

Practically BM is established by determination of oxygen consumption for 2-6 minutes, in standard conditions. Multiplying the volume of oxygen consumed in a minute by the isocaloric

coefficient of O_2 results the value in kcal/min and then after multiplying by 60 and 24 one obtains the value /day.

Because the production of heat in animals is proportional to their body surface, BM is related to the m^2 body surface. The body surface can be calculated knowing the weight and the height of the person or from the Du Bois nomogram.

The evaluation of results is realized by comparison with those written in some standard tables. Deviation from the standard values is expressed in percentages and is considered normal the variations of ± 15%.

In a young adult, BM is:

- 40 kcal/m^2/hour – in male
- 36 kacl/ m^2/hour – in female
- 1 – 1,2 kcal/kg/hour

and it needs about 200- 250 oxygen/minute

In 24 hours the BM reaches the 1700 – 1800 kcal in male and 1400kcal in female.

Factors that influence the basal metabolism

BM varies according to the sex, age, height, weight, body temperature, climate, concentration of circulating hormones.

- BM is lower with 6 -10% in female than in male. That is due to the muscular mass more reduced and the fat tissue more abundant in females.
- An increase of BM with up to 25% is noticed beginning with the seventh month of pregnancy, increase that persists 2 weeks after delivery.
- New born babies have a BM reduced, of about 30 kcal/m^2/h. In the first months of life, BM increases, reaching a maximum at 1, 5 years old (53 kcal/ m^2/h). After the age of 1,5 years , BM decreases gradually throughout the life
- Prolonged starvation decreases the BM with 20-30 %, due to the inhibition of sympathetic nervous system and of thyroid gland. Just the reduction of BM after a few days of starvation, explains why the rhythm of weight loss is greater in the first days of a slimming diet.
- During the sleep the BM is lower with 10-15% then in awake state, due to the diminuation of muscular and sympathetic tonus.
- The tropical climate induces a decrease of BM with 10-20%, due to the reduction of thyroid gland activity. In the cold region thyroid gland intensifies its activity; therefore the hyperthyroidism is more spread in the region with low temperature.
- The feverish increases the BM with 13% for every 1°C above the body temperature. By increase of body temperature the enzymes become more active and the chemical reactions are speed up.
- Thyroid hormones influence to a great extent the BM. The maximum secretion of thyroid gland increases the BM with 100%, and the of secretion decreases the BM with 40%. Assessment of BM helps firstly to find the thyroid disturbances.
- Stimulation of sympathetic nervous system (SNS), which causes the release of norepinephrine and epinephrine, increases the BM with 25% in adult and with 100% in new born babies. The metabolic effect of SNS is rapidly produced, has short lasting and

is explained by the direct action of mediators on the cells, where it amplifies the glycogenolysis.

- Male sexual hormones increase the BM with 10-15% and the growth hormone with 15 – 20%.
- In the shock, the BM decreases below the normal values, because of the insufficient circulation in the peripheral vascular territory.

Variable energetic expenditure (above normal) during the daily physical activity

Besides to the energetic expenditure of the BM, during daily activities is added variable energetic expenditure, necessary for supporting of physical activity, absorption of ingested foods and maintaining constant of body temperature.

Physical activity/effort increases considerably the energetic expenditure. Maximum muscular activity may increase the production of heat of 20 times. Even the maintenance of sitting position needs 2000- 2250 kcal/day, unlike 1850kcal/day, which is necessary for the same person in lying down/supine position. Energetic expenditure reaches the value of 6000 – 7000 kcal/day in strenuous effort like: climbing/ alpinism, wood cutting with ax, mowing.

The recently ingested foods increase the energetic expenditure for a period of time of 3-6 hours due to the specific dynamic action (SDA). SDA represents the obligatory energy expenditure that occurs during its assimilation into the body. (The extra amount of heat above the caloric value of that foodstuff).

Thus an amount of proteins that contains 100kcal (25g), by metabolisation liberate 130 kcal. The extra 30 kcal represents the SDA of proteins. The ingestion of proteins increases the metabolism after 1 hour and this effect lasts 3-6 hours. The proteins increase the metabolism with 30%, glucides with 6 % and lipids with 4%. SDA of proteins is due to a great extent to the deamination of amino acids, which takes place especially in liver. The additional energy liberated after the ingestion of glucides is necessary for the synthesis of glycogen.

Lipids have a SDA due to the stimulating effects of fatty acids on the cellular metabolism.

It is supposed that SDA could be the result of the more frequently sympathetic discharges after the ingestion of foods, with a higher release of epinephrine and norepinephrine and consecutive intensification of metabolism.

Only the isolated ingestion of proteins, lipids and glucides increases the metabolism in such proportions. A mixed diet does not lead to the summation of SDA of each nutritive substance / foodstuffs ingested. Thus after the alimentation with glucides and proteins, the SDA is with 12, 5% lower than the sum of individual effects. Glucides, proteins and lipids ingested together have a SDA with 22% lower than by addition of effects of each foodstuff.

Therefore in the calculation of daily energetic expenditure an extra 10% of energy needs for SDA is added.

Measuring the metabolism of a man or an animal at different temperature of environment, it has been found that it does not remain constant. Below the zone of thermal comfort (18- 20°C), for a dressing person and 20 -25 °C for an undressing person, the metabolism is intensified, reaching the maximum value during the thermal shiver.

Displaying /exposing the organism at the heat also increase the metabolism, as the organism fights against the overheating by: vasodilation, acceleration of circulation, hyperventilation, increase of sweat, phenomena which need extra energy expenditure.