THE IMPORTANCE OF THE LIVER IN CARBOHYDRATE METABOLISM

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Abstract. *The liver is the main organ in the cells of which biochemical transformations of the products of the digestive hydrolysis of carbohydrates occur and their conversion into glucose — a form available to the cells of the body. The liver is a depot of carbohydrates, since part of the glucose is stored here in the form of glycogen. The liver maintains blood glucose at a constant level — this is the glucostatic function of the liver. With an excess of glucose in the liver, glycogen synthesis from glucose occurs — glycogenesis. After eating a carbohydrate-rich meal, the glycogen content can be up to 8% of the liver weight.*
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With an increase in the body's need for glucose, the breakdown of liver glycogen occurs — glycogenolysis, which is sufficient to meet the needs of the body in the first 12-24 hours after eating. The liver is one of the main organs where the process of enzymatic synthesis of glucose from carbohydrate and non—carbohydrate products occur — gluconeogenesis. Moreover, liver cells are able to respond to the need for glucose in the cells of other organs. During fasting, after the depletion of glycogen reserves, the processes of gluconeogenesis proceed with maximum intensity, maintaining the "sugar" of the blood at a constant level. Glycolysis also occurs in the liver — the enzymatic breakdown of glucose with the release of energy contained in its molecule and its transfer to a form accessible to the body — i.e., into adenosine triphosphate (ATP). Biosynthesis and splitting of various carbohydrates take place in the liver. First of all, the liver maintains a certain amount of glucose in the body, which comes here from the small intestine with the blood flow. Only about 80% of lactic acid formed during the anaerobic breakdown of carbohydrates goes to glycogen resynthesis. On average, 3% of glucose is converted into glycogen. The glycogen content in the liver ranges from 1.5-20% of the total mass of the organ, it serves as a source of energy for the whole body. These processes are regulated by neurohumoral pathways and the liver tissue itself through activation and inhibition of the corresponding enzyme systems. With a lack of glucose in the blood and liver tissues, glyconeogenesis occurs. The blood sugar level is influenced by sodium and potassium. K^+ ions contribute to the synthesis of glycogen, Na^+ ions - decay. Their content in the blood is regulated by the hormone aldosterone. The chemical energy of carbohydrates is released during anaerobic glycogenolysis or glycolysis, in the tricarboxylic acid cycle and the pentose phosphate pathway. Carbohydrates are the primary products of photosynthesis and the main starting products of the biosynthesis of other substances in plants. They make up an essential part of the food ration. Carbohydrate metabolism is a set of processes of carbohydrate transformations in the body. Carbohydrates entering the body with food products are mainly represented by starch and cane sugar. Starch is a polysaccharide of plants, it consists of a chain of interconnected simpler molecules — monosaccharides, the main of which is glucose. Starch is similar in structure to glycogen. Cane sugar is a carbohydrate that predominates in our diet. Structurally, it is a disaccharide, i.e. it consists of two monosaccharide molecules — glucose and fructose. Glucose and fructose can be found in different foods and in free form, for example, in honey and fruits. Dairy products contain mainly a carbohydrate such as lactose. The body has a "depot" of carbohydrates — glycogen, formed from glucose molecules. Carbohydrates are primarily a source of energy, to a lesser extent they perform a plastic function. The human body does not need certain carbohydrates. The only "irreplaceable" carbohydrate derivative that must necessarily come with food is ascorbic acid or vitamin C, since a person lacks one of the enzymes necessary for its synthesis. In a balanced diet, about 50% of the energy a person needs should come from carbohydrates. The process of converting carbohydrates begins with their digestion in the oral cavity under the influence of saliva, then continues for some time in the stomach and ends in the small intestine — the main place of hydrolysis of carbohydrates under the influence of enzymes contained in the digestive juice of the pancreas and small intestine. Hydrolysis products — monosaccharides — are absorbed in the intestine and enter the blood of the portal vein, through which monosaccharides of food enter the liver, where they are converted into glucose. Glucose then enters the bloodstream and can enter into processes occurring in cells or passes into liver glycogen.

The liver is a depot of carbohydrates, since part of the glucose is stored here in the form of glycogen. The liver maintains blood glucose at a constant level — this is the glucostatic function of the liver. With an excess of glucose in the liver, glycogen synthesis from glucose occurs — glycogenesis. After eating a carbohydrate-rich meal, the glycogen content can be up to 8% of the liver weight. On average, glycogen stores account for about 5% of the liver weight, which in an adult is equivalent to about 90 g of glucose. With an increase in the body's need for glucose, the breakdown of liver glycogen occurs — glycogenolysis, which is sufficient to meet the needs of the body in the first 12-24 hours after eating. The liver is one of the main organs where the process of enzymatic synthesis of glucose from carbohydrate and non—carbohydrate products occurs — gluconeogenesis. Moreover, liver cells are able to respond to the need for glucose in the cells of other organs. During fasting, after the depletion of glycogen reserves, the processes of gluconeogenesis proceed with maximum intensity, maintaining the "sugar" of the blood at a constant level. Glycolysis also occurs in the liver — the enzymatic breakdown of glucose with the release of energy contained in its molecule and its transfer to a form accessible to the body — i.e., into adenosine triphosphate (ATP). In cells, glucose can be broken down both anaerobically (without oxygen) and aerobically (with oxygen). Under anaerobic conditions of glycolysis, 2 molecules of adenosine triphosphate (ATP) and 2 molecules of lactic acid are formed from each molecule of split glucose. During aerobic glycolysis, intermediate products of carbohydrate metabolism formed during the anaerobic breakdown of carbohydrates (pyruvic acid) are not reduced to lactic acid, but are oxidized in mitochondria in the tricarboxylic acid cycle to carbon dioxide and water with energy accumulation in the form of ATP. In addition, glycolysis intermediates are the material for the synthesis of many important compounds and are used by the body as another source of material for assimilation processes. The state of carbohydrate metabolism can be judged by the content of sugar in the blood. In a healthy person, a constant glucose concentration of 70-120 mg% is maintained in the blood. After eating a meal containing carbohydrates, the concentration of glucose in the blood increases to about 150 mg% and remains at this level for about 2 hours, and then returns to normal. The glucose content in the blood is one of the most important constants of the liquid internal environment of the body. The leading role in maintaining this constant at a constant level due to the processes of glycogenesis and glycogenolysis going on there belongs to the liver. Prolonged increase in blood glucose — hyperglycemia stimulates the release of insulin into the blood. Insulin decreases the glucose content in the blood after increasing its concentration (hyperglycemia). In a healthy person, in the period between meals, the normal glucose content in the blood is maintained by the breakdown of glycogen in the liver with the formation of free glucose — the process of glycogenolysis. With a decrease in blood sugar — hypoglycemia, which lasts for a longer time, glucagon, a hormone secreted by the pancreas, enters the blood. Insulin, a hormone of the pancreas, stimulates the processes of glycogen synthesis in the liver — glycogenesis, glucose uptake by cells of other tissues of the body, suppresses the formation of glucose, i.e. the processes of gluconeogenesis. Insulin is the main hormone. This hormone has a specific effect: it acts exclusively on the processes of glycogenolysis, accelerating the formation of glucose. All living organisms breathe, i.e. they absorb oxygen and emit carbon dioxide and water. In this case, the decomposition of organic substances and the release of energy necessary for the life of each cell, the whole plant. In fact, this process is multi-step. It consists of a number of successive redox-regenerative reactions. Carbohydrates, proteins and fats are mainly used as organic substances necessary for respiration. A typical compound oxidized during respiration is glucose. Energetically, the most beneficial substance for respiration is fat. 1 g of fat, when oxidized to CO2 and H2O, gives 9.2 kcal, proteins — 5.7 kcal, carbohydrates - 4 kcal. The process of converting the initial organic matter to simpler ones and then to CO2 and H2O requires a large number of different enzymes. In the process of photosynthesis, plants synthesize carbohydrates, which are transported from the leaves to other organs. In the light and in the dark, plant cells "breathe", oxidizing carbohydrates with molecular oxygen to form CO2 and water. At the same time, a large amount of free energy is released: C6H12O6 + 6O2 = 6CO2 + 6H2O + energy; ΔG = -2882 kJ/mol (-686 kcal/mol) This formula generally reflects an extremely complex, and most importantly, controlled process, which can be conditionally divided into three stages: glycolysis, the tricarboxylic acid cycle and oxidative phosphorylation in the respiratory chain. Glycolysis and the tricarboxylic acid cycle are biochemical pathways of glucose oxidation, occurring respectively in the cytosol and mitochondrial matrix. In biochemical reactions, a small amount of ATP is synthesized, and their main result is the formation of compounds with high reducing potential — NADH and FADN2. At the final stage, the reducing equivalents are oxidized in the electron transport chain localized in the inner membrane of the mitochondria. The electron transfer in the circuit is completed by the reduction of oxygen to water. In the process of electron transport, an electrochemical proton gradient δμ'H is formed on the membrane, the energy of which is used for the synthesis of ATP from ADP and Fn. The process in which the work of the respiratory chain is associated with the synthesis of ATP is called oxidative phosphorylation. It is in this process that the bulk of ATP formed during respiration is synthesized. In both plants and animals, respiration performs three main functions. Firstly, the energy released during the oxidation of carbohydrates is converted into convertible forms of cellular energy of ATP. The second, no less important function is the supply of cells with metabolites that are formed during the oxidation of glucose and are used in a variety of biosyntheses. The third function is related to thermogenesis, i.e. by dissipating energy in the form of heat. The process of respiration is fundamentally similar in animals and plants, but the latter has its own characteristics. Together, they reflect the plasticity of plant metabolism and are associated with the functioning, along with the main ones, of alternative enzymes and reactions. The presence of alternative pathways expands the adaptive capabilities of plants, but complicates (from the researcher's point of view) the system of regulation of metabolic processes.

In the future, many researchers have studied in detail the enzymatic nature and mechanism of alcoholic fermentation (see diagram). The first reaction of glucose conversion during alcoholic fermentation is the addition of phosphoric acid residue from adenosine triphosphoric acid (ATP, see Adenosine phosphoric acids) to glucose under the influence of the enzyme glucokinase. In this case, adenosine diphosphoric acid (ADP) and glucose-6-phosphoric acid are formed. The latter, under the action of the enzyme glucosophosphate-somerase, turns into fructose-6-phosphoric acid, which, receiving from a new ATP molecule (with the participation of the enzyme phosphofructokinase) another phosphoric acid residue is converted into fructose-1,6-diphosphoric acid. (This and the following reactions, indicated by the counter arrows, are reversible, i.e. their direction depends on the conditions — enzyme concentration, pH, etc.) Under the influence of the enzyme ketose-1-phosphataldolase, fructose-1,6-diphosphoric acid is cleaved into glycerol dehydrophosphoric and dioxyacetone phosphoric acids, which can be converted into each other under the action of the enzyme triose phosphatizomerase. Glycerinaldehyde phosphoric acid, attaching a molecule of inorganic phosphoric acid and oxidizing under the action of the enzyme phosphoglycerinaldehyde dehydrogenase, the active group of which in yeast is nicotinamide adenine dinucleotide (NAD), turns into 1,3-diphosphoglyceric acid. The liver plays a leading role in maintaining the physiological concentration of glucose in the blood. Of the total amount of glucose coming from the intestine, the liver extracts most of it and spends: 10-15% of this amount on glycogen synthesis, 60% on oxidative decomposition, 30% on fatty acid synthesis. With physiological hypoglycemia, glycogen breakdown is activated in the liver. The first stage of this process is the cleavage of the glucose molecule and its phosphorylation (enzyme phosphorylase). Further, Glu-5-F can be spent in three directions:

1. along the path of gltcolysis with the formation of pyruvic acid and lactate;
2. by the pentose phosphate pathway;
3. split under the action of phosphotase into glucose and phosphorus.

The latter pathway prevails, which leads to the release of free glucose into the general bloodstream.

Gluconeogenesis is active in the liver, in which glucose precursors are pyruvate and alanine (coming from muscles), glycerol - from adipose tissue and a number of glucogenic substances with food. Excessive intake of glucose from food increases the intensity of all the ways of its transformation in the hepatocyte. This activates its oxidation with the formation of a large amount of pyruvate. For its further oxidation, a large amount of CoA is also needed, which is also used for the oxidation of fatty acids. As a result, the oxidation of fatty acids and the breakdown of lipids in fat depots slows down.

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