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ГОМЕОСТАЗ И ПИТАНИЕ ЧЕЛОВЕКА

HOMEOSTASIS AND HUMAN NUTRITION

Учебное пособие

МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ
РОССИЙСКОЙ ФЕДЕРАЦИИ

УРАЛЬСКИЙ ФЕДЕРАЛЬНЫЙ УНИВЕРСИТЕТ
ИМЕНИ ПЕРВОГО ПРЕЗИДЕНТА РОССИИ Б. Н. ЕЛЬЦИНА

И. С. Селезнева, Т. В. Глухарева

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Рекомендовано методическим советом
Уральского федерального университета
в качестве учебного пособия для студентов вуза, обучающихся
по направлению подготовки 19.04.01 «Биотехнология»

Екатеринбург
Издательство Уральского университета
2021

УДК 574.3:612.39(075.8)
ББК 28.701.25я73-1
С29

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С29 Гомеостаз и питание человека = Homeostasis and human nutrition : учеб. пособие / И. С. Селезнева, Т. В. Глухарева ; М-во науки и высш. образования Рос. Федерации, Урал. федер. ун-т. – Екатеринбург : Изд-во Урал. ун-та, 2021. – 116 с. : ил. – Загл. парал. рус., англ. – Текст англ. – Библиогр.: с. 111–113. – 30 экз. – ISBN 978-5-7996-3314-1. – Текст : непосредственный.

ISBN 978-5-7996-3314-1

Учебное пособие составлено в соответствии с действующим Государственным образовательным стандартом высшего профессионального образования и магистерской программой по направлению «Биотехнология». В краткой форме в учебном пособии изложены основные сведения о строении и свойствах химических веществ продуктов питания, приведены особенности их превращений в организме человека и указаны важнейшие пищевые источники. Рассмотрены принципы здорового и качественного питания и вопросы, связанные с решением проблемы обеспечения людей биологически полноценным питанием для поддержания гомеостаза.

Предназначено студентам вуза, осваивающим дисциплину «Физиология питания», для подготовки к занятиям и сдачи итогового теста.

Educational medium is a textbook on «Nutrition Physiology» discipline, compiled in accordance with the existing State educational standard of higher education and master's curriculum for the direction «Biotechnology». Structure fundamentals, properties of chemical food components, their transformations and food sources are stated in a short and laconic form. Issues, connected with the requirements to high quality nutrition in solving a problem of providing people with biologically adequate food and keeping homeostasis, are considered.

Systematic material stating, disclosing main notions and principal scientific points of the course, allows using this medium to prepare for classes and for passing end-of-term test in the discipline.

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ББК 28.701.25я73-1

ISBN 978-5-7996-3314-1

CONTENT

1. INTRODUCTION

1.1. «Homeostasis and human nutrition» discipline aims

Process of studying this discipline is aimed to get the following results of education:

– RE 6 – to organize and to implement educational process using modern information, educational and multimedia technologies;

– RE 7 – to organize independent and collective scientific research for solving fundamental, technological and project tasks.

To know

K.3.4. The knowledge of biochemistry and human physiology, as well as physiology of microorganisms and other biological objects.

K.3.10. The knowledge of the composition and main functions of basic classes of biologically active compounds.

To be able to

A.2.2. To be able to process information, to carry out library and patent search.

A.7.2. To be able to demonstrate the skills in dealing with scientific literature.

To handle

H. 8.1. To handle the proficiency in historical and methodological analysis of scientific research and its results.

1.2. The place of discipline in module structure and in the main educational program

Discipline «Nutrition physiology» refers to general scientific cycle of the variation part and refers to Biotechnology preparation direction.

The discipline is based on bachelor's program courses «Organic chemistry», «Analytic chemistry and physic-chemical methods of analysis», «Fundamentals of biochemistry and molecular biology» and precedes the study of the disciplines «Food chemistry», «Modern biotechnology problems», «Microbiological aspects of biotechnological production» and «Biotechnology based on raw materials of plant origin».

1.3. Laboriousness of discipline mastering

Kinds of study work, control forms	Total, h	Study terms, number
		1
Auditorium classes, hrs	54	54
Lectures, hrs	18	18
Practical classes, hrs	18	18
Laboratory works, hrs	18	18
Independent students work, hrs	54	54
Kind of progress control	–	Credit test
Total laboriousness, hrs	108	108
Total laboriousness according to the study plan, credits	3	3

1.4. Brief discipline description

Discipline «Nutrition physiology» is dedicated to the study of the scientific foundations of rational nutrition, digestion processes and digestive system, chemical structure studying, biological activity of the main nutrients – proteins, fats, carbohydrates, mineral substances, vitamins, as well as enzymes and hormones. Studying the discipline students must obtain knowledge about their chemical and spacious structure, physicochemical properties and biological functions. Furthermore, requirements to high quality nutrition are considered in solving the problem of providing people with biologically wholesome food and maintaining homeostasis. Practical skills of working with food products and biologically active compounds are acquired in laboratory classes, methods of analysis of raw materials and final products are mastered.

1.5. Discipline content

Section 1. Introduction

Brief discipline characteristics, its aims, tasks, volume, content. The order of material studying forms of independent work control. Characteristics of recommended books are given.

Section 2. Nutrition as the main component of healthy life-style formation process

History and evolution of human's nutrition. Modern definition of «health, homeostasis». Factors, determining modern human's average life duration. Role

of nutrition in health sustaining and in civilization diseases emerging. Russia's state policy concept in organizing and providing population's healthy nutrition.

Section 3. Theoretical bases of homeostasis and nutrition. General notions about physiology and biochemistry of nutrition

Modern definition of the following concepts: homeostasis, digestion, food products, appetite. Human's digestive system. Structure and functions of gastrointestinal tract. Types of digestion. Processes of absorption and fixation of nutrients. Brief characteristics of structure and functioning of primary (microelement and microecological systems) and complex secondary (immune, endocrine and nervous systems) regulatory mechanisms of human's homeostasis sustaining. The role of gastrointestinal tract micro flora in the main nutrient's metabolism.

Section 4. Concept of food quality, nutritional, biological and energy value

The list of the main food products groups, containing essential and regulatory food substances. Brief characteristics of composition and nutritional value of products made of grain, meat and its substitutes, milk and dairy products, vegetables and fruit, oils, fats and different sweets. Biological value of food. Definition of the concept «recommended food components daily consumption rates». Energy exchange (metabolism) of the organism. Energy value of food. Caloric coefficient of proteins, fats and carbohydrates. Human's daily requirement for the main nutrients.

Section 5. Medical-biological significance and functions of the main food components

A list of main macro- and micronutrients. Physiological role of proteins, fats carbohydrates, vitamins and mineral substances. Protein-calorie deficiency. Significance of unsaturated fatty acids in human's nutrition. Cholesterol and its role in human's organism. Hyper-, hypo- and avitaminosis. Physiological functions of the main macro and microelements.

Section 6. Modern notions about rational nutrition

Theories and concepts of nutrition. Fundamentals of rational nutrition. Ecological, medical-biological, socio-economical problems of rational nutrition. Modern pyramid of healthy nutrition and principles of its construction. Combination of products is the basis of healthy nutrition structure. Food substances and energy recommended consumption rates. Modern human's dietary intake. The main groups of food. Concept of healthy nutrition. Analysis of alternative notions about human's nutrition. Separate nutrition. Fasting. Diets. Vegetarianism.

Section 7. Products creation principle for alimentary correction of homeostasis disorder

Definition of food additive notion, probiotics, functional nutrition products. Differences between clinical, dietary and functional nutrition. Medioprophylactic nutrition.

1.6. What is nutrition physiology?

The science of nutrition physiology is an old science. Hippocrates (fig. 1), the ancient Greek physician, was aware of the food effects on the body. Nutrition physiology is the study of food's effect on the human body's ability to sustain the chemical and physical processes that are necessary for biological life functions.

Figure 1. Portrait of Greek physician Hippocrates [1]

Nutrition physiology concerned with different types of food and their effects on the metabolism. The importance of nutrition during growth, development, and ageing is appreciated both in human medicine. Moreover, it has become increasingly apparent that the body health depends on a healthy and functional intestine and that many of today's common diseases, such as heart failure, cancer and diabetes, are related to intestine function and to the diet.

Nutrition physiology deals with:

1) how the body extracts the nutrients from the food;
2) how we obtain the needed energy;
3) how we utilize nutrients;
4) how all this is related to health and diseases.

2. NUTRITION AS A PART OF HEALTHY WAY OF LIFE FORMATION

2.1. What means nutrition?

Nutrition is defined as the process whereby living organisms take in and transform extraneous solid and liquid substances necessary for the maintenance of life, growth, the normal functioning of organs and the energy production. In general terms, the consumption of food serves a twofold purpose for the human body: first, it provides the source for energy, which is measured in calories; secondly, food assists the multitude of chemical functions required to sustain life.

One of the most important and complex problems which humanity faces is providing world's population with food products. From the one hand nutrition is one of the most important environmental factors, but from the other hand it influences human's organism during all his life. Chemical components of food products get into human's organism from the environment with food, during metabolism they turn into cells structure elements, provide organism with energy and plastic material, determine health and human's organism duration of life. In connection with this, nutrition condition along with the other factors determines both nation's and everybody's health.

Food products should satisfy human's requirements in main nutritives as well as perform preventive and medicinal functions effectively.

In Russian Federation great attention is paid to these issues on the state level, so RF Government order on the 25 of October 2010 № 1873-p passed «Fundamentals of the RF state policy in healthy nutrition till 2020», «Doctrine of food safety of the Russian Federation» has been approved. State policy in healthy nutrition means complex of measures for creating conditions ensuring satisfaction of RF population needs in rational healthy nutrition, however it is essential to take into consideration its traditions, habits, economic condition.

Russian population's health has worsened during recent decades – children, teenagers and elderly people in particular. Furthermore, average lifespan has been reducing (58 years for men, 73 – for women, 65.5 years on average), because general disease incidence has been increasing. These rates are considerably lower than in most of the highly developed countries. Cardio-vascular and oncological diseases rank the first among reasons for mortality. It is believed that their development relates to poor nutrition to some extent.

It is necessary to note that Russian population nutrition is not rational and (according to the data of Nutrition Institute of RAS) the main food status disturbances are:

– excess consumption of animal fats,

– deficit of polyunsaturated fatty acids,
– deficit of animal proteins,
– deficit of vitamins (C, B_2, B_1, A, β-carotene, folic acid, tocopherol),
– deficit of mineral substances (Ca, Fe),
– deficit of dietary fibres.

Malnutrition is caused by underconsumption of the both main food nutrients (tab. 1), and vitamins and minerals.

Table 1

Annual consumption of the main food products in RF per capita (according to the data of Rosstat, 31.12.2019 [2])

Products	Rational norm, kg	Annual consumption in 2018	
		Per capita, kg	% of rational norm
Meat	81	75	92.6
Milk	392	229	58.4
Eggs, pieces	298	280	94.0
Fish and seafood	23.7	20.2	85.2
Sugar	40	39	97.5
Vegetable oil	13.6	14.0	102.9
Potatoes	120	89	74.2
Vegetables	145	107	73.8
Fruit and berries	76	61	80.3
Bakery products	107	116	108.4

Furthermore, consuming sub-quality, falsified and dangerous for the human's health products exerts negative influence. RF law № 29-ФЗ «About food products quality and safety» adopted on January 2, 2000 favours the elimination of these drawbacks.

All this requires technology of traditional products obtaining to be improved and new food products generation to be created.

2.2. What does the motion give?

First, the physical exercises reduce the appetite. This phenomenon is explained by the peculiarities of our thermoregulation: to avoid the overheat after training, the organism needs to transport much bigger blood volume through the vessels

at the same period. However, when human eats, blood rushes to the stomach to make the digestion easier. Thus, in order to avoid blood usage «not as intended» at the moment the organism should switch off a sense of hunger for a while. As a result, a person drinks more water or juices, eats fruit and vegetables and avoids heavy food. It is known that this effect lasts about 1 hour. After that the organism seeking to fill in energy reserves will send intensive signals of hunger.

Secondly, we help our organism stay healthy and be in a good shape by constantly moving and practicing sport or physical training. Physical exercise improves muscle tone, fatty tissue becomes denser. As a result, cardiac muscle tone improves, blood vessels load reduces, and the body looks more fit and slim as well.

2.3. Factors determining the lifespan of a modern person

A person in the course of his life is under the constant influence of several external factors – from environmental to social. They all have a direct impact on the vital functions, health and lifespan. It should be noted that the role of various factors in the population health is assessed as follows: lifestyle (49–53 %), human genetics (18–22 %), environment (17–20 %), public health (8–10 %). The modern scientists believe that life expectancy directly depends on social conditions of life: daily life, working conditions and severity, nutrition, recreation and lifestyle.

Let's discuss a nutrition role in maintaining health and initiating diseases of the civilization. Healthy human nutrition study is carried out considering age, profession, physical and neuropsychic activity, and national and climate peculiarities. One of the most important and complex problems which humanity faces is providing world's population with food products. The population faces an acute problem of protein nutrition provision; especially there is a shortage of animal proteins. In different countries and regions of the Earth the average quantity of protein in human ration varies a lot. So, in Australia and New Zealand daily ration contains 106 g of proteins, in which animal protein is about 70 %, while in a few Eastern countries the total protein amount is only 50 g and animal protein are hardly 6–10 g. By 2050, the World's population will approach to 9 billion people. We can assume that due to lack of food in the next 40 years, humanity will become completely vegetarian (fig. 2).

Cardio-vascular and oncological diseases rank the first among reasons for mortality. It is believed that their development relates to poor nutrition to some extent. Obesity is a serious disease of the century 21, which has come from the West along with potato chips and hamburgers.

Nowadays in Russia there is also a problem of excess weight. In Sverdlovsk region over 55 % of adult population suffer from overweight and obesity.

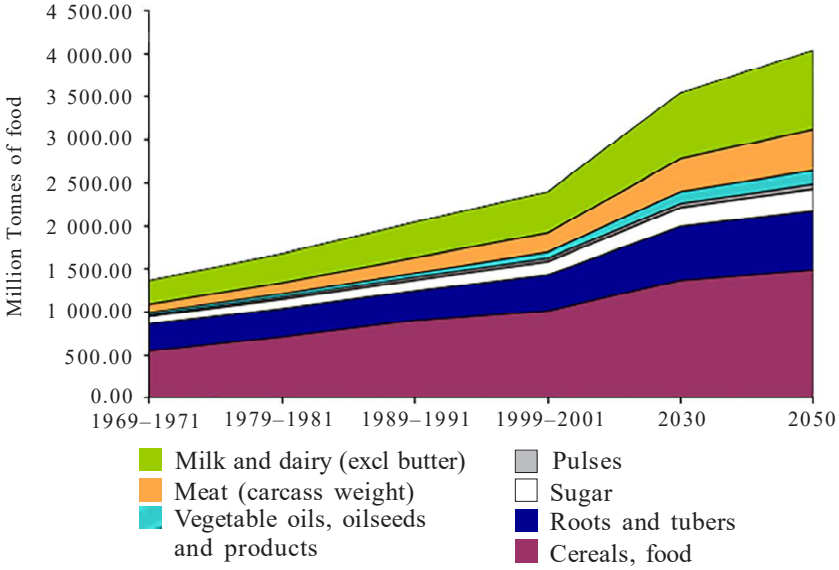
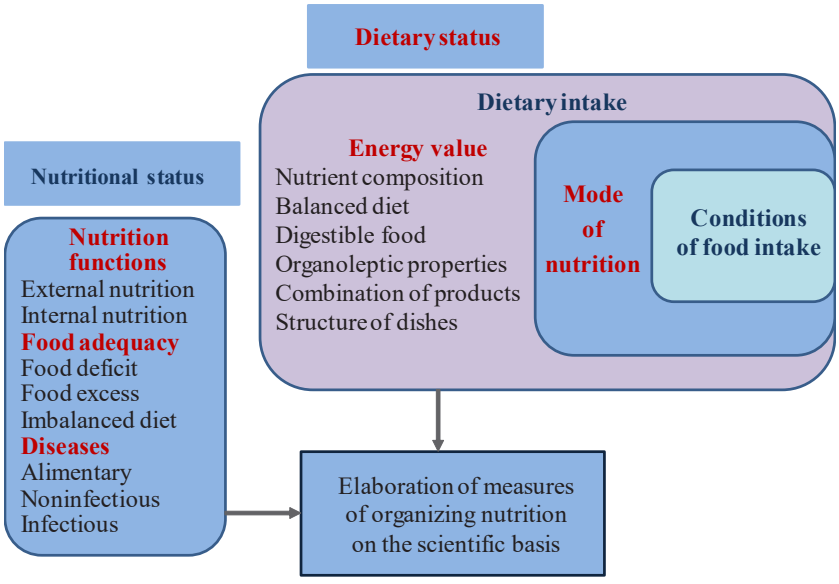


Figure 2. Global demand for the food products till the year 2050 (FAO UN) [3]

Russian population's health has worsened during recent decades, in particular children, teenagers and elderly people, general disease incidence has been increasing. Furthermore, average life span has been reducing: 58 years for men, 73 – for women, 65.5 years on average.

Human nutrition is a basis of his health (fig. 3). Healthy food includes proteins, fats, carbohydrates, vitamins, minerals, biological active compounds.



Fugure 3. Nutritional and dietary status

3. THEORETICAL BASES OF HOMEOSTASIS AND NUTRITION. GENERAL NOTIONS ABOUT PHYSIOLOGY AND BIOCHEMISTRY OF NUTRITION

3.1. Definition of the «Homeostasis» concept

In 1878 Claude Bernard (fig. 4) put forward an assumption about organism's internal environment constancy.

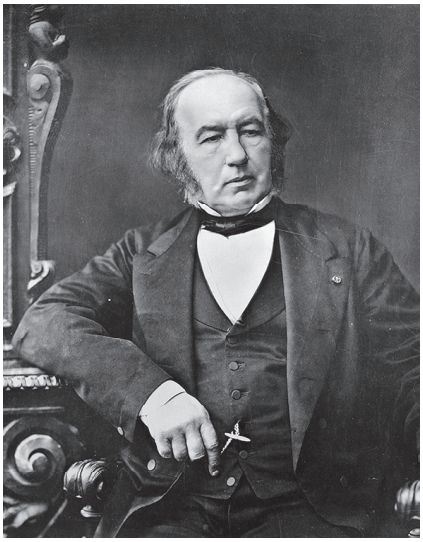


Figure 4. French scientist Claude Bernard (12.07.1813 – 10.02.1878) [4]

In 1932 an American physiologist Walter Cannon (fig. 5) in his book «The Wisdom of the body» suggested the term «*homeostasis*» to call «coordinated physiological processes, which support the majority of sustainable conditions of the organism».

Thus, one can say that *homeostasis* – is an ability of living organisms to keep dynamic constancy of composition and properties of internal environment and stability of the main physiological functions in changing external environmental conditions.

Nowadays this term is used to characterize dynamic constancy of internal condition of any open system.

By means of neurohumoral regulation (interaction of nervous system and internal secretion glands, fig. 6) homeostasis provides constancy of human's body temperature (thermal regulation), blood pressure, volume of tissue liquid and lymph, cellular and humoral composition of blood.

Figure 5. American physiologist
Walter Cannon (19.10.1871 – 01.10.1945) [5]

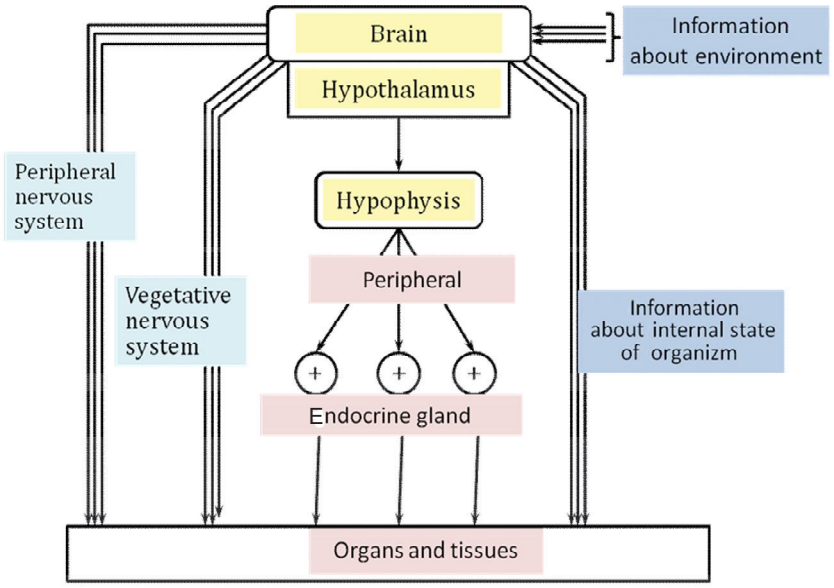


Figure 6. The neurohumoral regulation

The most important role is performed by cortex of the brain, hypothalamus (fig. 7), hypophysis (pituitary gland, fig. 8) and endocrine glands.

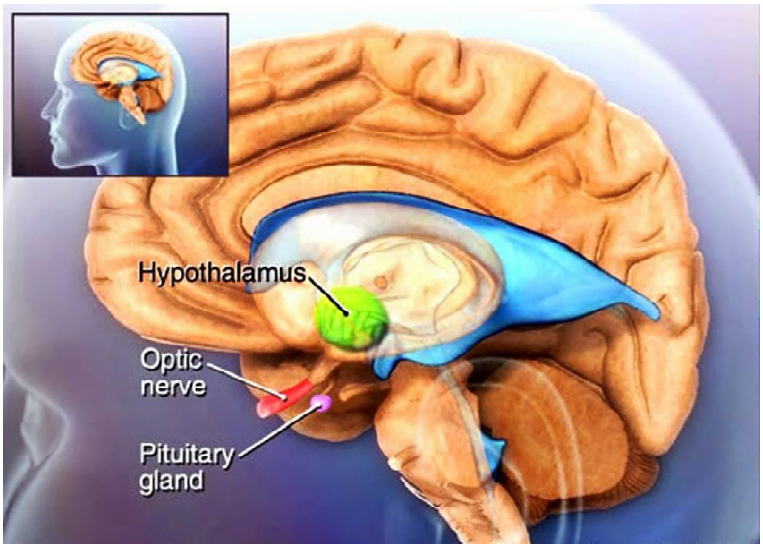


Figure 7. The hypothalamus in relation to other parts of the brain [6]

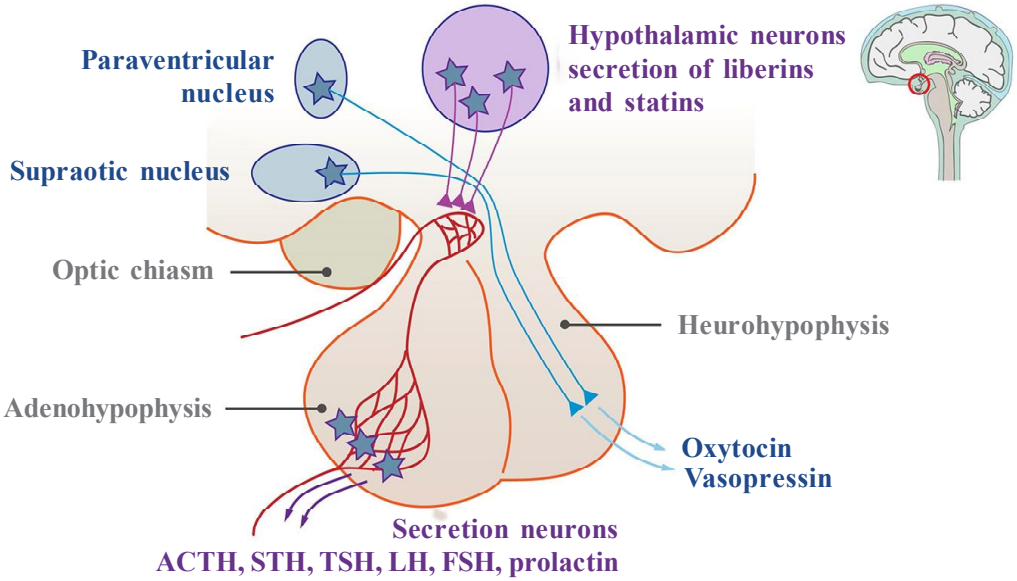


Figure 8. The hypophysis (pituitary gland) [7]

3.2. Homeostasis regulation

Nervous system. It consists from Autonomic nervous system and Somatic nervous system. Autonomic nervous system is the section of the vertebrate nervous system that controls the involuntary actions of the smooth muscles, heart, and glands. It has 2 divisions; they are sympathetic and parasympathetic.

Somatic nervous system is the section of the nervous system responsible for sensation and control of the skeletal muscles.

The nervous system composed of three main parts: sensitive (afferent), central (integrative), including brain and spinal cord, and movement (motor). Receptors of sensitive centre (skin receptors, eye and ear) perceive signals concerning organism condition or external environment. Brain stores information, generates ideas, sets objectives and determines variants of organism reaction in response to changing of external environment condition or internal parameters of organism. Then backward signals are transmitted to motor centre to perform planned action.

Vegetative nervous system comprises a considerable part of nervous system and directs the work of internal organs – regulates cardiac output, motility of digestive tract, secretion of organism's glands.

Endocrine system. It complements nervous mechanisms of regulation. Eight endocrine glands of the organism discharge hormones, which enter blood, then intercellular fluid and are transported to all the organs and tissues of the organism to regulate cellular functions. For example, insulin regulates glucose exchange, adrenocorticotrophic hormone – the content of Na^+, parathyroid hormone – the content of Ca^{2+} and phosphates in bones.

The fig. 9 shows the relationship between the nervous, endocrine and immune systems and their interconnection with psychological and somatic health problems.

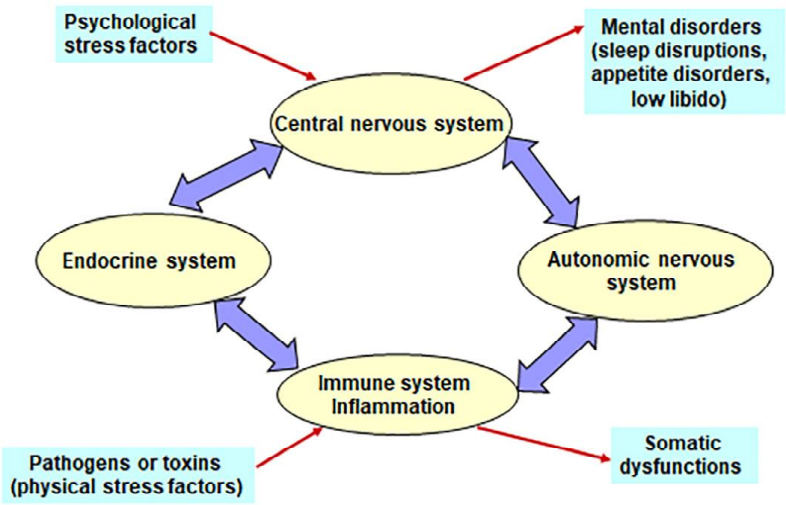


Figure 9. Interaction between the immune and neuroendocrine systems

Psychological stress signs are relationship conflicts at home; new or increasing work responsibilities; increasing demands; financial strain; loss of a loved one; health problems; moving to a new location.

Disturbance of mechanisms, providing constancy of human's organism internal environment parameters, are characterized as «homeostasis diseases».

3.3. Characteristics of digestion and digestive system

Digestion is a combination of processes, ensuring the breakdown of food substances into simple soluble compounds able to be absorbed, easily assimilated by organism cells. Digestion is the mechanical and chemical food processing in digestive tract. The main physical process is food disintegration. It occurs when chewing food and as a result of rhythmic contractions of the intestine and stomach.

During digestion food macromolecules (biopolymers) are broken into smaller molecules (monomers). The main chemical reaction is enzymatic hydrolysis (disintegration of proteins, fats and carbohydrates). Proteins, fats and carbohydrates are broken into small, water-soluble molecules by hydrolysis, which are assimilating by organism. After that food is absorbed through the intestinal wall and gets into the body fluids (blood, lymph). So, digestion is digesting and assimilating food substances by organism.

The process of digestion is carried out with the help of the digestive (hydrolytic) enzymes. Enzymes are proteins that initiate specific chemical reactions. Digestive enzymes are produced in the pancreas and released throughout the digestive tract. Protease digests protein. Lipase and amylase are responsible for digestion of fat and carbohydrates respectively.

Assimilation of food substances goes successively according to the scheme, based on different types of digestion:

1) abdominal (cavitary);

2) membrane (parietal);

3) intracellular (absorption).

Abdominal digestion takes place in digestive cavities (mouth cavity, stomach and intestinal canal), remote from secretory cells. It provides intensive initial digestion.

Membrane (parietal) digestion is carried out under enzymes action, localized on microvilli of small intestine. Thus, there is a hydrolysis of food substances and conjugation of final stages of digestion and initial stages of assimilation.

Absorption digestion is a physiological process of transporting substances from all the segments of digestive tract into blood and lymph.

During digestion there occur mechanic, physicochemical and chemical changes of food substances in special connected with each other organs forming digestive system. Digestion involves 3 main stages:

1) mechanic grinding food (chewing food);

2) hydration and swelling of the food (physicochemical processes occurring under the influence saliva and digestive juices);

3) enzymatic hydrolysis of food compounds.

Human's digestive system (fig. 10) represents a digestive (alimentary) canal (gastrointestinal tract) with a length of 8–12 m, which includes mouth cavity, gullet (esophagus), alimentary canal, stomach, small bowel (its upper part is called dodecatactylon), large intestine, straight intestine and also digestive glands (salivary,

pancreatic, liver, intestinal). Organs of digestive system are tongue, teeth, salivary glands, gullet, alimentary canal, stomach, small and large intestine, liver, gallbladder and pancreatic gland (fig. 11, 12).

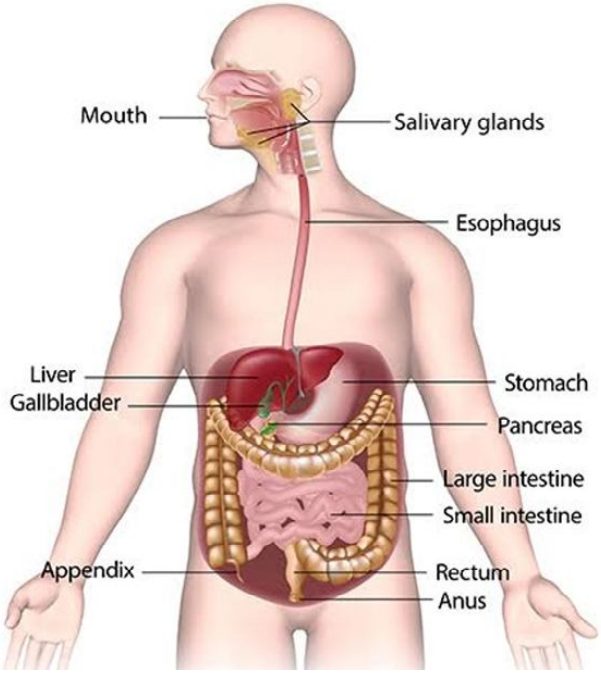


Figure 10. The digestive system [8]

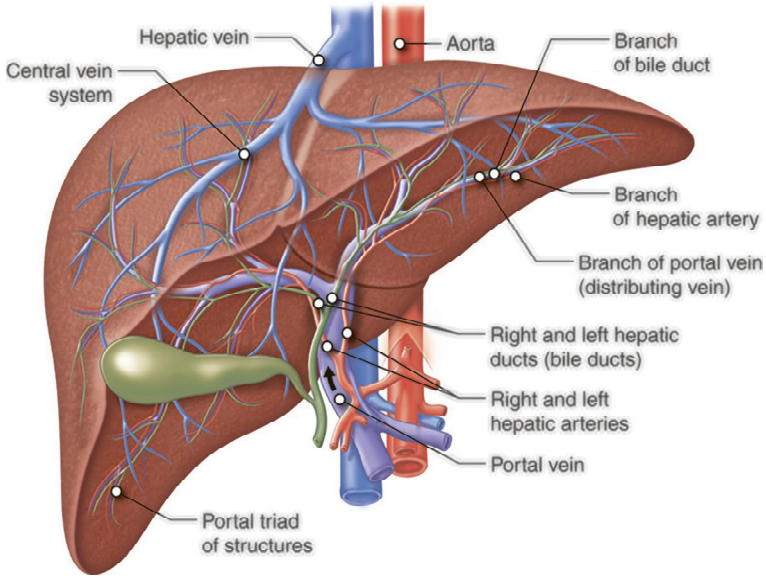


Figure 11. Liver [9]

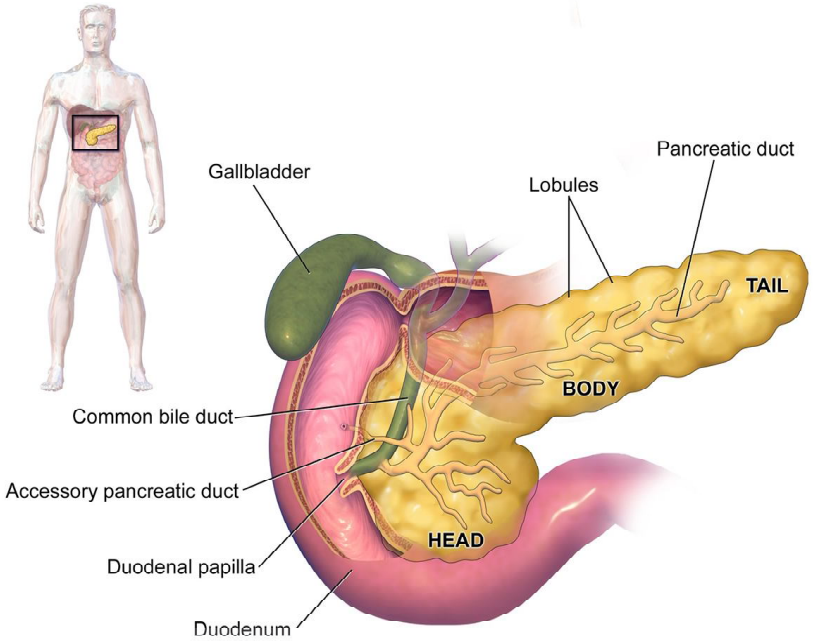


Figure 12. Pancreas [10]

Liver and pancreas releases chemicals that help digestion of carbohydrates, fats and proteins. Liver produces bile which is required for digestion fat. Pancreas releases a fluid that contains enzymes that breakdown food. Besides them pancreas releases bicarbonates that neutralize the acidity present in food.

Small intestine plays vital role in digestion and absorption process of food. It has specialized structures to help this process. Before being absorbed, complex molecules such as protein, fat and carbohydrate are broken down to simpler molecules by enzymes present in the small intestine.

Gastrointestinal tract performs digestive, excretory and regulatory functions (fig. 13).

Digestive function of gastrointestinal tract combines following processes: motility, secretion, hydrolysis, absorption and excretion:

– mouth – bite, chew, swallow;
– pharynx and esophagus – transport;
– stomach – mechanical disruption, absorption of water and alcohol;
– small intestine – chemical and mechanical digestion and absorbtion;
– large intestine – absorb electrolytes and vitamins (B and K);
– rectum and anus – defecation.

The main designation of digestive system is to provide organism with energy and plastic substances. Furthermore, it carries out disintoxication (neutralization) of toxic substances entered with food or formed during its splitting in the organism as well as synthesis of biologically active substances (hormones, vitamins, enzymes).

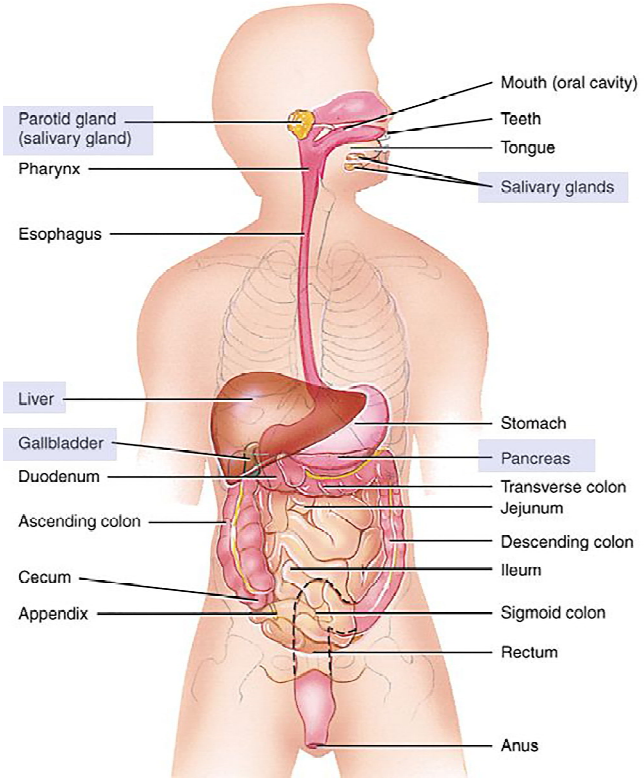
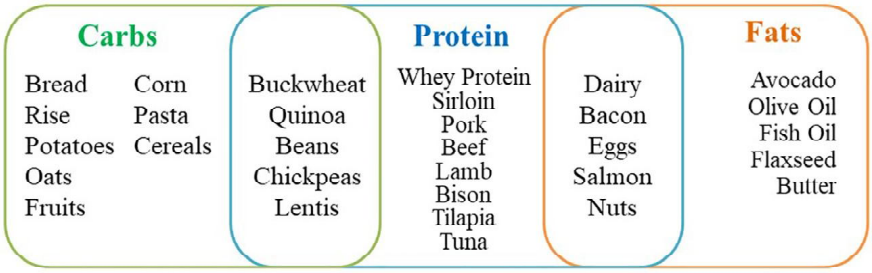


Figure 13. Gastrointestinal tract functions [11]

Topic «*Digestive system*», do and check tests using this link [12]: http://www.bbc.co.uk/education/guides/z9pv34j/test.

3.4. Schemes of macronutrients digestion processes

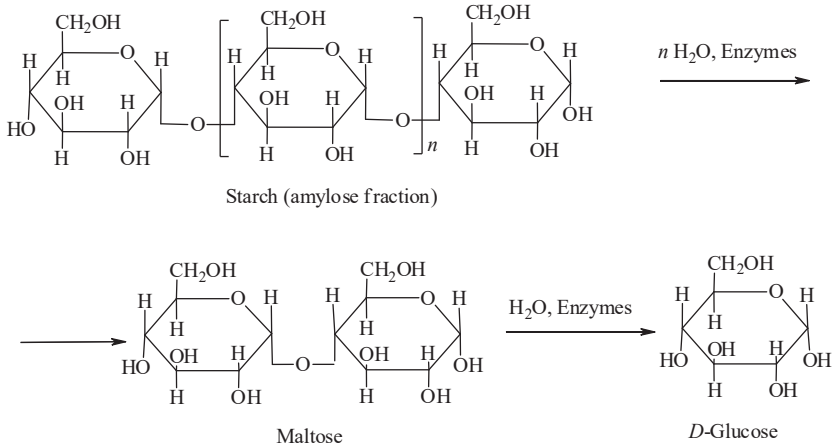
The 3 molecules – carbohydrates, proteins, and lipids (fats) are important molecules in food that need to be physically and chemically digested by the digestive system. Bellow you can see food products containing the biggest amount of proteins, fats, carbohydrates:



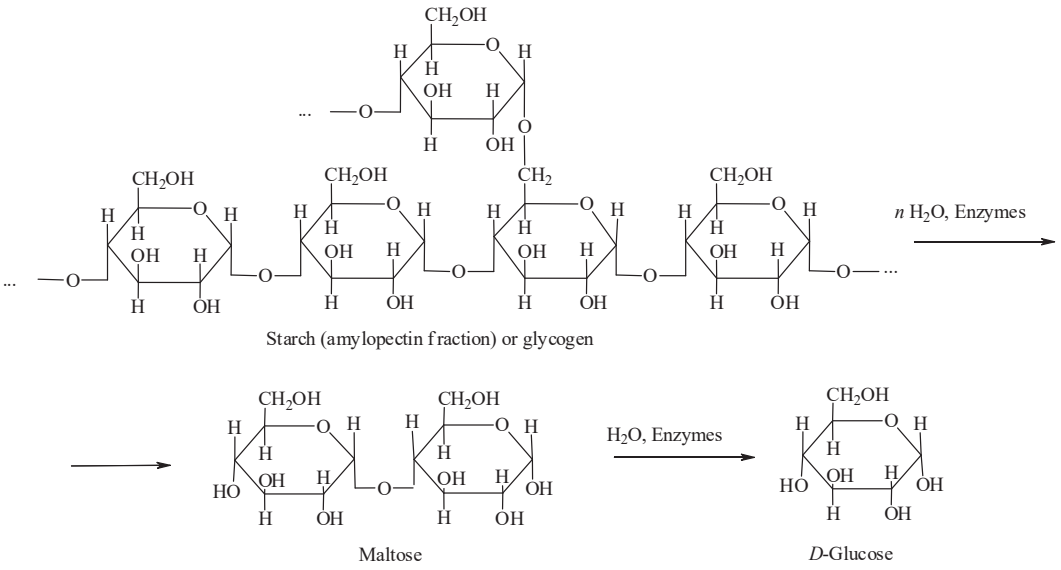
Hydrolysis of high-molecular-weight food substances (proteins, fats, carbohydrates) result in the formation of low-molecular weight monomers. Every macronutrient has its scheme of digestion.

Digestion of carbohydrates

In the human organism polysaccharides (starch, glycogen, fig. 14) and disaccharides (sucrose, maltose, lactose, fig. 15) are digested to form monosaccharides molecules (*D*-glucose, *D*-fructose, *D*-galactose) as final products.

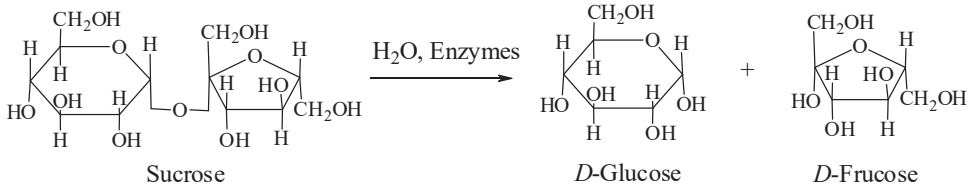


Hydrolysis of amylase (linear fraction of starch)

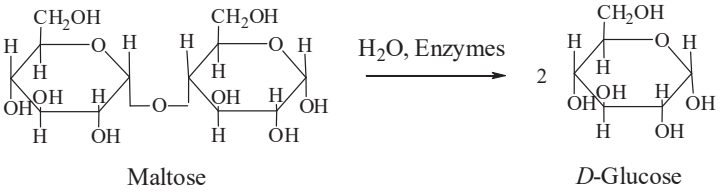


Hydrolysis of glycogenor amylopectin (highly branched fraction of starch)

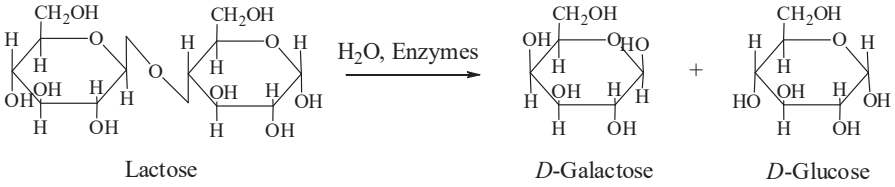
Figure 14. Hydrolysis of polysaccharides (starch and glycogen)



Hydrolysis of sucrose



Hydrolysis of maltose



Hydrolysis of lactose

Figure 15. Hydrolysis of disaccharides

Carbohydrate digestion starts in the oral cavity under the action of amylase produced by salivary glands and continues and finishes in small intestine under the action of pancreatic amylase. α-Amylase attacks the α-glycosidic bonds in starch $(C_6H_{10}O_5)_n$, the main carbohydrate ingested by human. Cleavage of glycosidic bonds leads to the formation of dextrins, maltose and glucose mixture. Maltose is broken down into 2 glucose molecules by maltase (fig. 16).

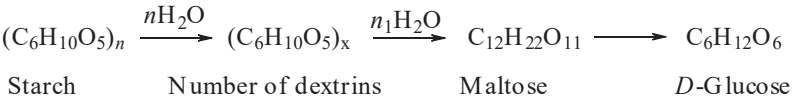


Figure 16. Hydrolysis of starch

The α-amylase mixed into the food remains active as the food passes through the esophagus, but it is rapidly inactivated in the acidic environment of the stomach. Digestion of starch mainly occurs in the duodenum as a result of the action of pancreatic amylase. This enzyme cleaves the straight chains of starch, as well as the dextrins, to produce the disaccharide maltose and the trisaccharide maltriose (fig. 17).

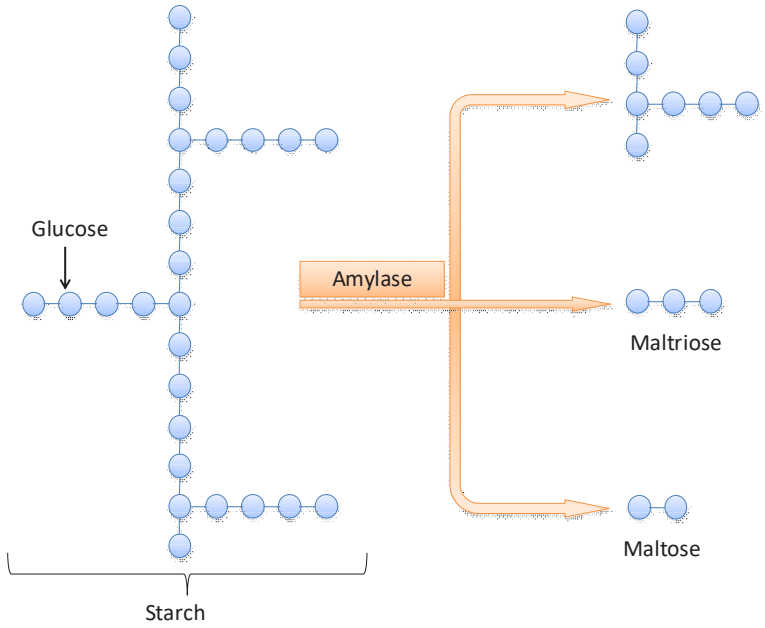


Figure 17. Starch hydrolysis

Maltose, maltriose, and oligosaccharides are hydrolyzed to monosaccharides by brush border enzymes (fig. 18). They are located on the microvilli of epithelial cells in the small intestine.

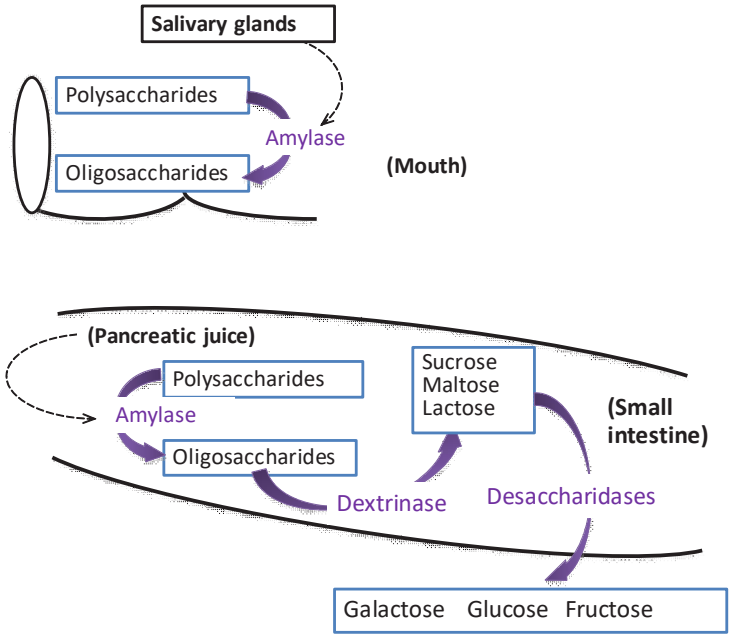


Figure 18. Carbohydrate digestion

Disaccharides such as sucrose and lactose are not digested until they reach the small intestine, where they are acted on by sucrase and lactase, respectively (fig. 19).

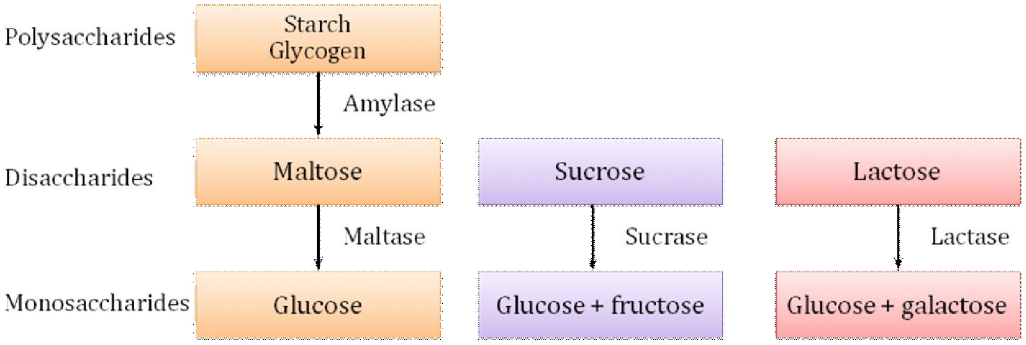


Figure 19. Scheme various carbohydrates hydrolysis

Glucose, fructose, and galactose are absorbed through the wall of the small intestine into the bloodstream. It should be note that monosaccharides are absorbed through the cell wall into the bloodstream with different rates: let glucose rate equal – 100, then galactose rate equal – 110, fructose – 43 and mannose – 19.

Glycemic index (GI) is an index indicating the effects of various foods on blood sugar. Fast-releasing foods that raise blood sugar levels quickly have high index, while slow-releasing foods, at the bottom of the index, give a slow but sustained release of sugar. For example, the glycemic index of a ripe banana is 50; the glycemic index of an avocado is 10 and for French fries – 95.

Glycemic Load (GL) is an index indicating the amount of carbohydrate contained in a specified serving of a particular food.

It is calculated by multiplying the food's glycemic index by its carbohydrate content in grams and then dividing by 100. There are 8.53 g of carbohydrates per 100 g banana, so its GL = 50 × 23/100 = 11.5.

There are 23 g of carbohydrates per 100 g avocado, so its GL = 10 × 8.53/100 = = 0.853.

There are 29 g of carbohydrates per 100 g French fries, so its GL = 95 × 29/100 = = 27.55.

Digestion of fats

It proceeds in small intestine under the action of lipase of pancreatic gland with the presence of bile acids. The final products of hydrolysis are glycerin (glycerine, glicerol) and higher fatty acids (fig. 20).

Fat digestion begins in the upper portion of the small intestine. A hormone secreted in this region stimulates the gallbladder to discharge bile into the duodenum.

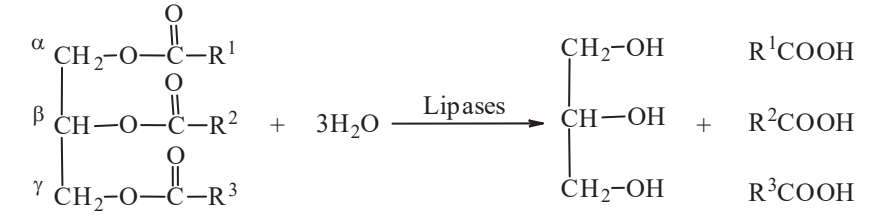


Figure 20. Scheme various carbohydrates hydrolysis

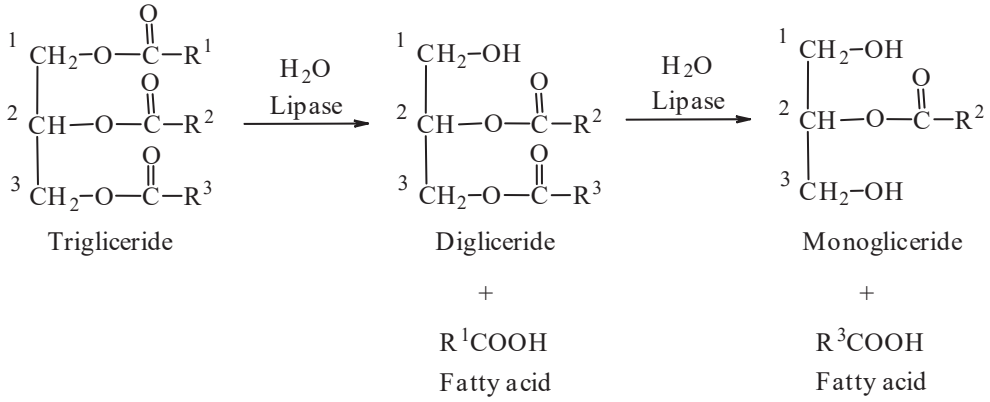


Figure 21. Scheme fat hydrolysis

The free fatty acids, monoglycerides derived from the digested fats are more polar than the undigested fats. Therefore, the monoglycerides and fatty acids cross the intestinal lining into the bloodstream, where they are resynthesized into human triglycerides and transported as lipoprotein complexes known as chylomicrons (fig. 22).

Phospholipids and cholesterol esters undergo similar hydrolysis (fig. 23–25) in the small intestine, and their component molecules are also absorbed through the intestinal lining.

Cholesterol esters hydrolysis occurs in the small intestine under the influence of choline esterase, which is formed in pancreas (see fig. 25).

In the human body cholesterol is synthesized by the liver (endogenous cholesterol) and we consumed it from meat, eggs and dairy products (exogenous cholesterol) (fig. 26).

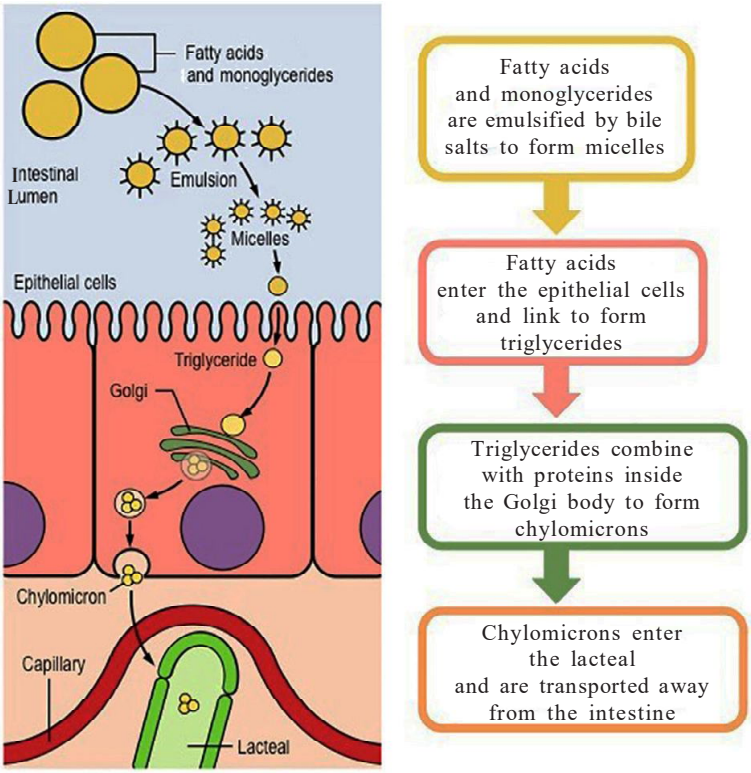


Figure 22. Fats absorption [13]

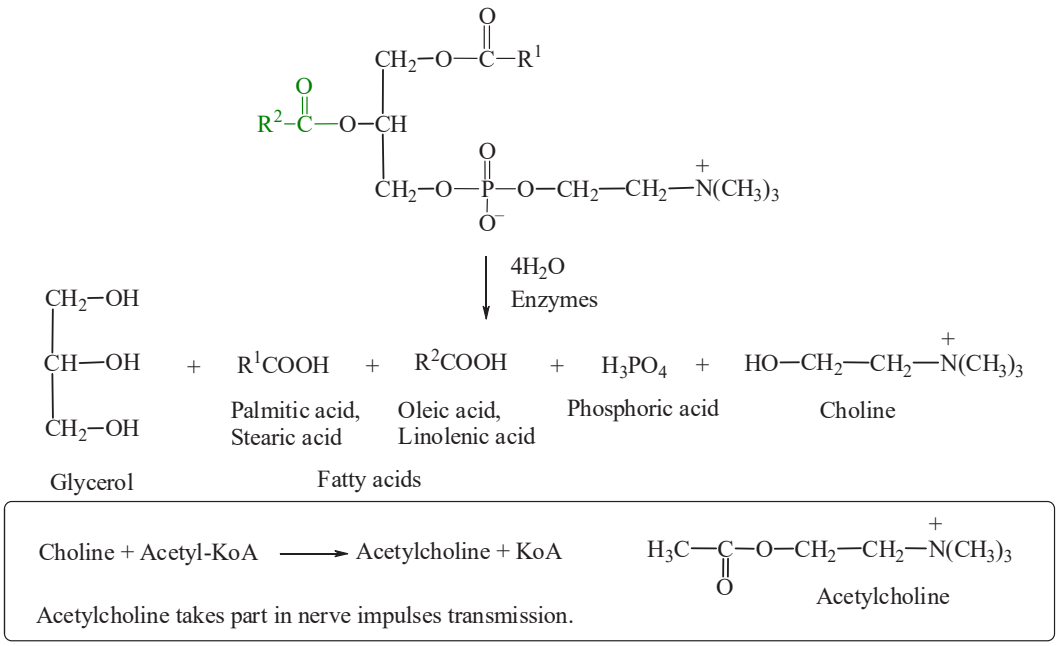
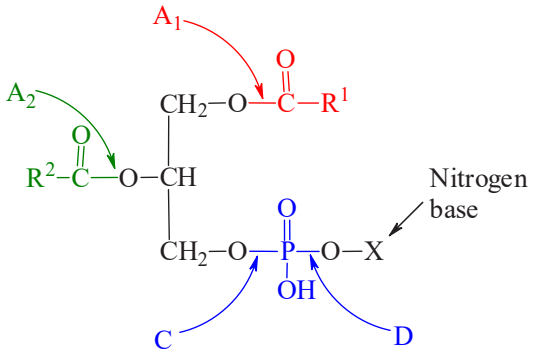


Figure 23. Lecithin hydrolysis



A_1, A_2, C, D – Specific phospholipases

Figure 24. Phospholipid hydrolysis

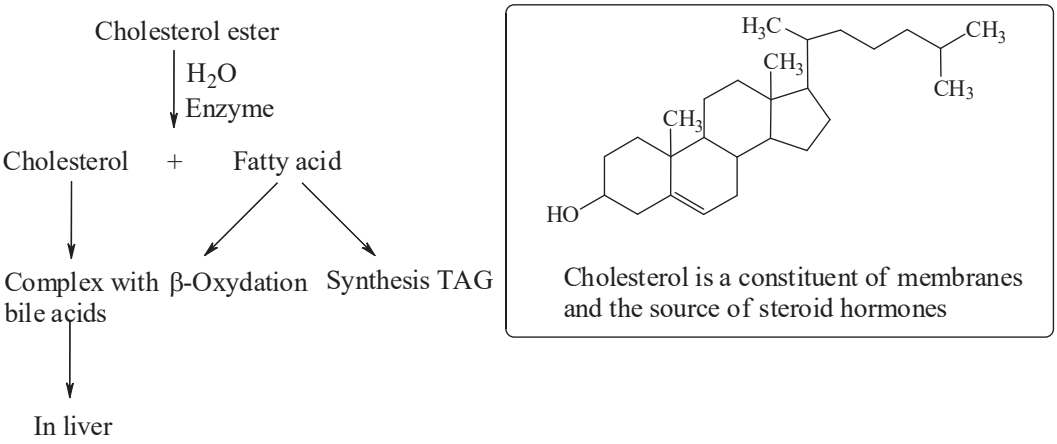


Figure 25. Cholesterol ester hydrolysis

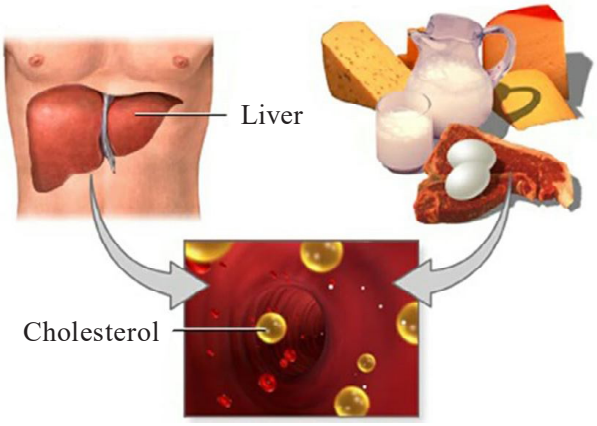


Figure 26. Endogenous and exogenous cholesterol [14]

Cholesterol has many biological uses (fig. 27), such as its being in the cell membranes, and its role in forming the sheath of some neurons.

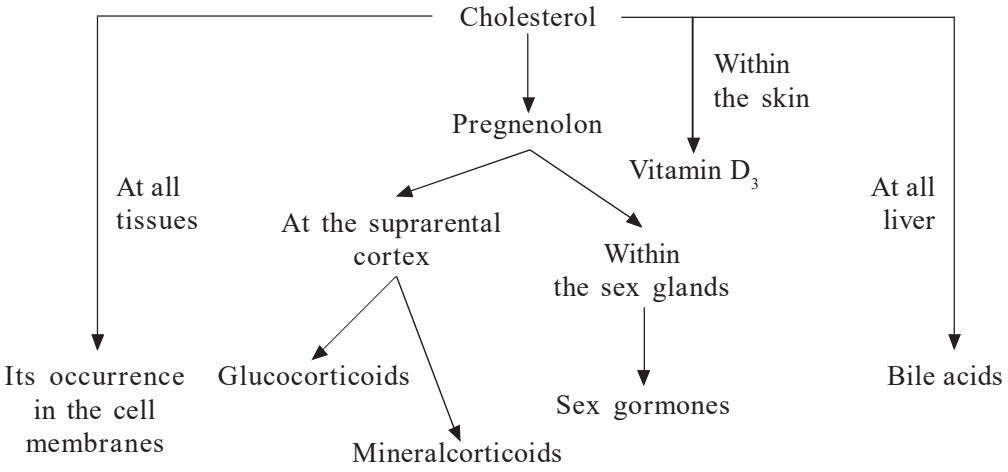


Figure 27. The cholesterol using in the biosynthesis of biological active compounds

Cholesterol is carried through the bloodstream by lipoproteins. There are two types of lipoproteins: the first is high-density lipoproteins (HDL) «Good cholesterol» and the second – low-density lipoproteins (LDL) «Bad cholesterol». «Good cholesterol» is stable and carries «bad cholesterol» away from the arteries. «Bad cholesterol» sticks to artery walls and contributes to plaque build-up. Excess cholesterol in the blood has been linked to atherosclerosis, hardening of the arteries (fig. 28).

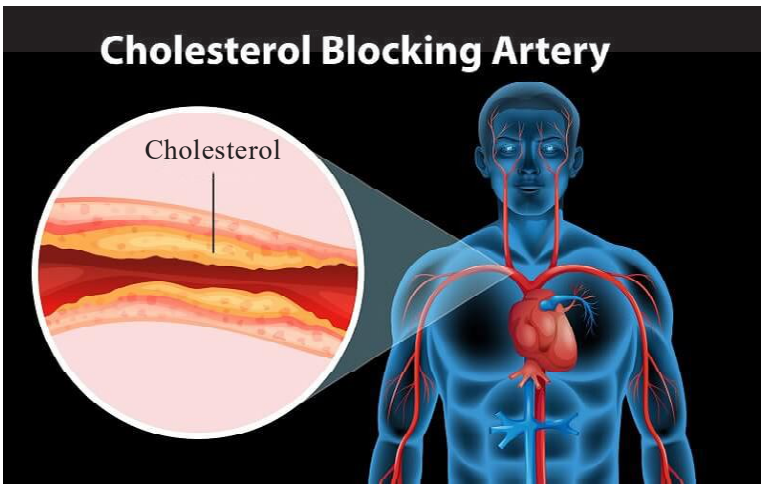


Figure 28. The cholesterol plaque in the artery [15]

In the fig. 29 you can see the full scheme of fats digestion and metabolism.

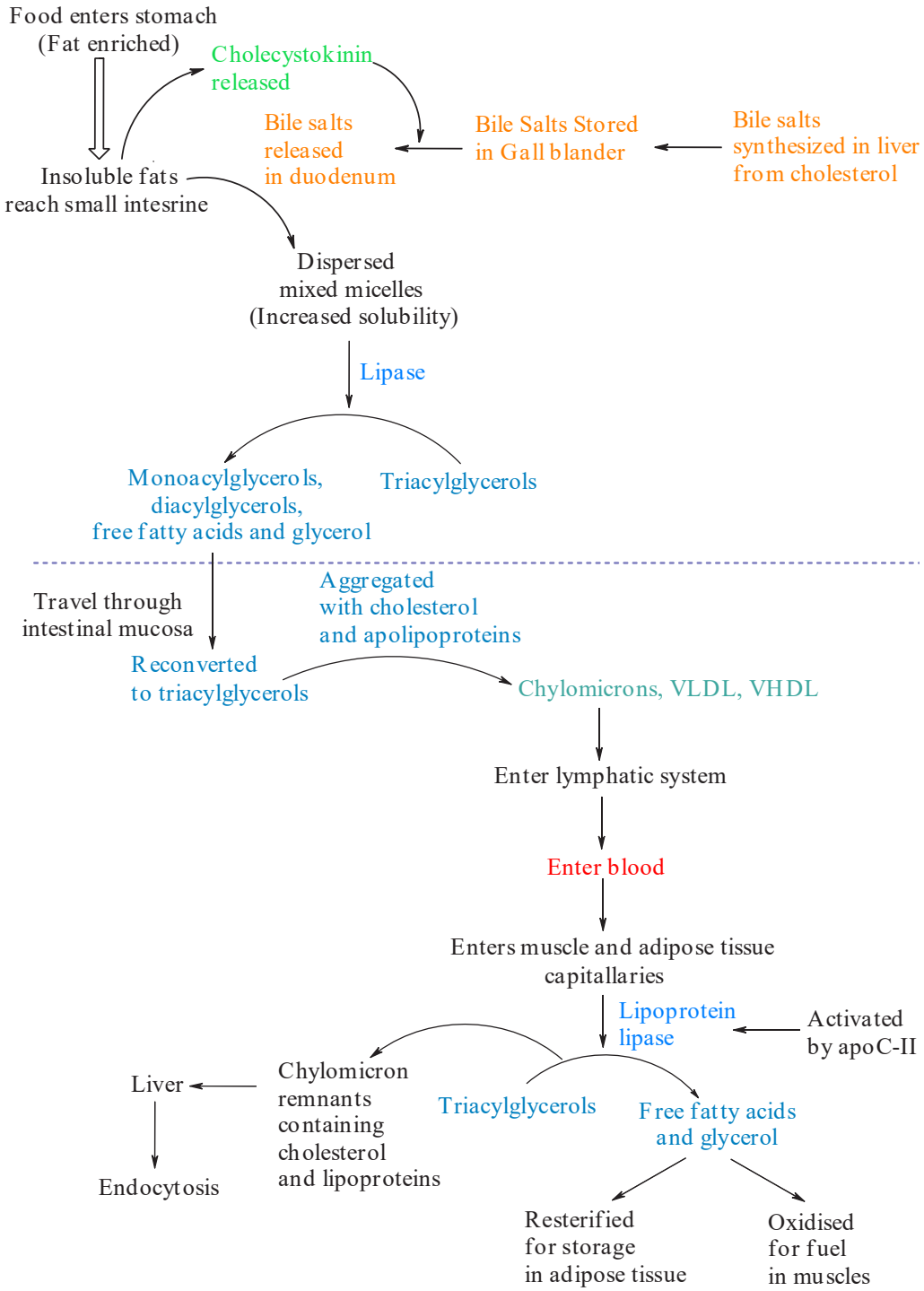


Figure 29. Fat digestion and metabolism

Topic «*Fat Digestion»,* answer questions after studying the figure 29.

1. Write chemical equations of fats hydrolysis and fats synthesis.

2. Choose two organs of the digestive system. Explain how the structure of these organs contributes to the function of these organs – the fats digestion.

3. What steps of fat digestion do you know?

Digestion of proteins

Proteins digestion is carried out by proteolytic enzymes of gastric, pancreatic and intestine juices. In the organism enzymes of gastric and pancreatic juices are produced in an inactive form (as proenzymes) and activated in the cavity of gastrointestinal tract in the process of food digestion (fig. 30). This prevents unwanted effect of these enzymes on the proteins of digestive tract cells.

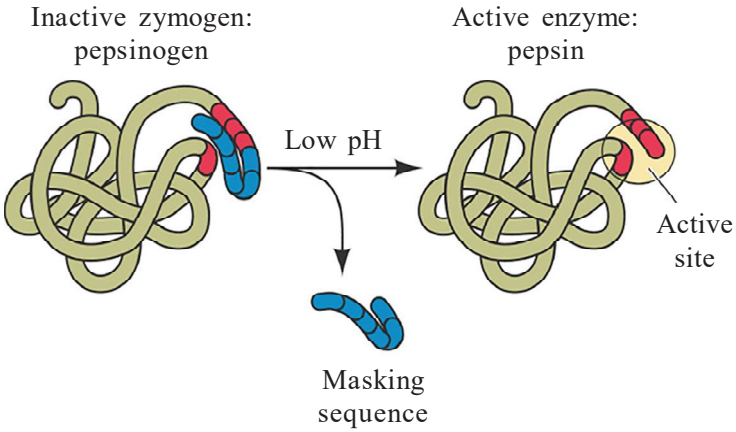


Figure 30. Activation of pepsinogen [16]

Pepsin catalyzes the hydrolysis of peptide bonds within protein molecules. It has a fairly broad specificity but acts preferentially on bonds involving the aromatic amino acids: tryptophan (trp), tyrosine (tyr), phenylalanine (phe), as well as methionine (met) and leucine (leu).

Protein digestion begins in the stomach where the action of gastric juice hydrolyzes about 10 % of the peptide bonds. Gastric juice is a mixture of water (more than 99 %), inorganic ions, hydrochloric acid (helps to denature food proteins) and various enzymes and other proteins. Protein digestion is completed in the small intestine. Pancreatic juice, carried from the pancreas via the pancreatic duct, contains inactive enzymes such as trypsinogen and chymotrypsinogen. They are activated in the small intestine as follows (fig. 31).

Chymotrypsin catalyzes the hydrolysis of peptide bonds following aromatic amino acids. Trypsin catalyzes the hydrolysis of peptide bonds following lysine and arginine (fig. 32).

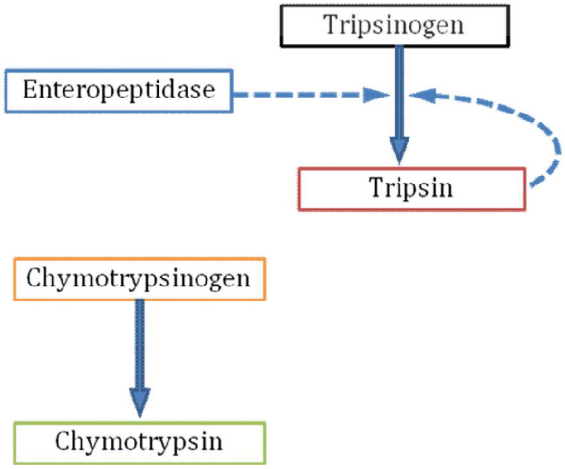


Figure 31. Activation of trypsinogen and chymotrypsinogen

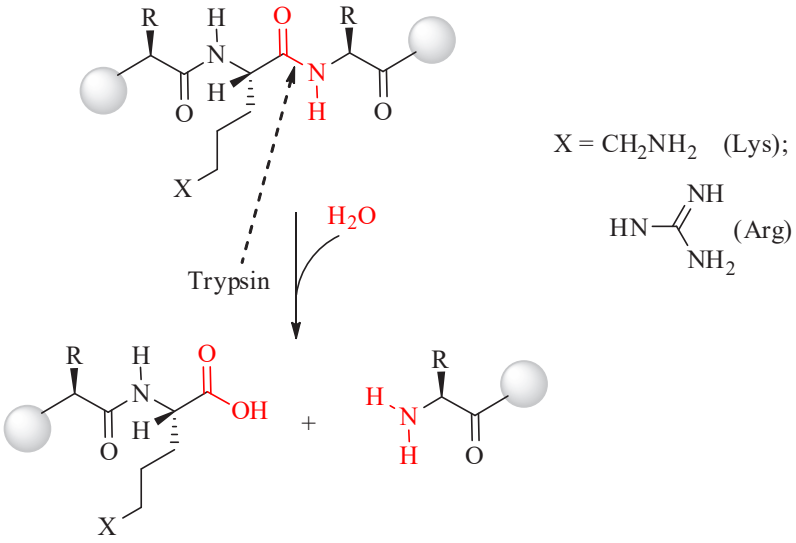


Figure 32. Trypsin catalysis of peptide hydrolysis

Aminopeptidases in the intestinal juice remove amino acids from the N-terminal end of peptides and proteins possessing a free amino group. The words peptide and protein actually refer to the same structure; however, peptide is generally used for shorter chains of amino acids and protein for longer chains.

This diagram illustrates where in a peptide the different peptidases would catalyze hydrolysis the peptide bonds (fig. 33).

Under the action of proteolytic enzymes peptide bonds in the molecules of food proteins are broken up, i. e. proteolysis proceeds and food proteins are turned into amino acids (fig. 34).

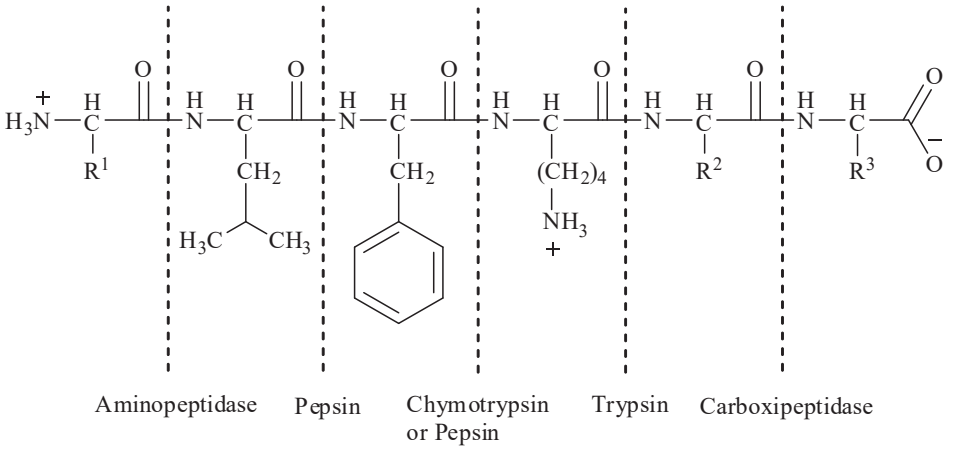


Figure 33. Enzyme hydrolysis the peptide bonds

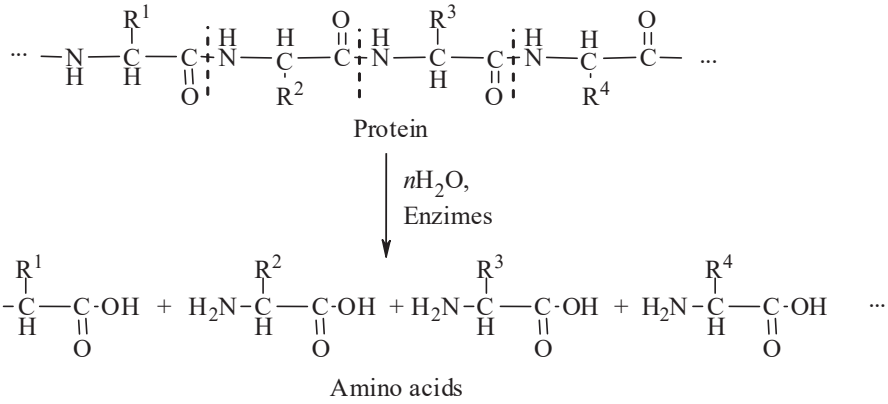


Figure 34. Hydrolysis the peptide bonds

About 100 g of amino acids are formed from the food proteins per day. Absorption of amino acids takes place by the system of portal vein. The free amino acids are absorbed by cotransport with Na^+ into the epithelial cells and secreted into blood capillaries (fig. 35).

A constant exchange and renewal occur between the fund of free amino acids, formed in the process of food digestion as well as a result of disintegration of cell proteins and entering blood, and tissue proteins (fig. 36).

Key takeaways

During digestion:

1) carbohydrates are broken down into monosaccharides;
2) triglycerides are broken down into glycerol and fatty acids;
3) and proteins are broken down into amino acids.

Most of the digestion reactions occur in the small intestine.

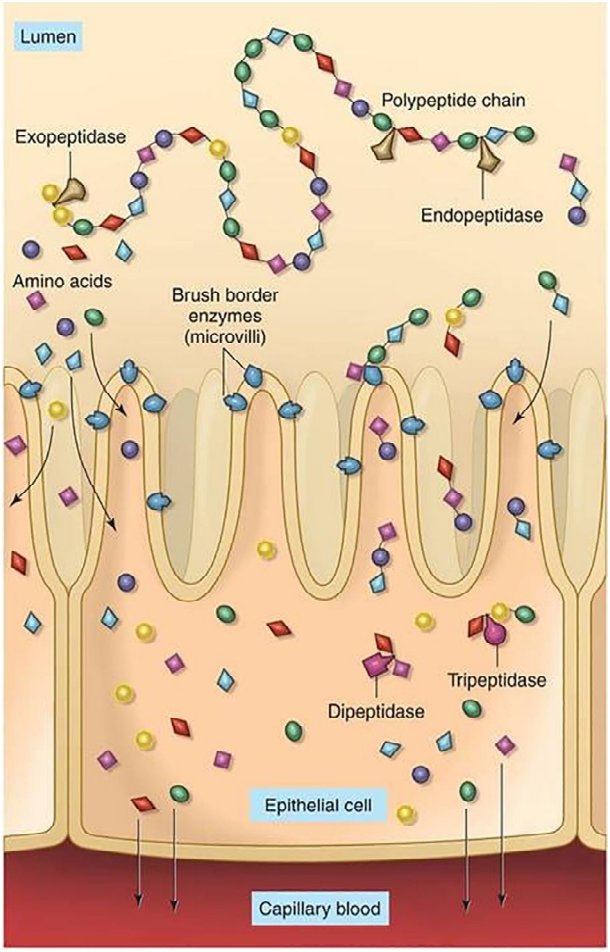


Figure 35. Proteins hydrolysis and amino acids absorption [17]

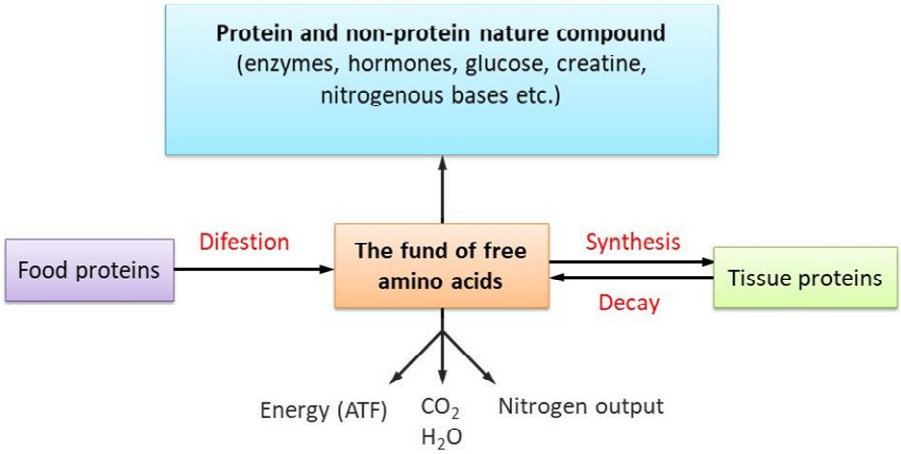


Figure 36. Metabolism of proteins

Answer the question

1. What are the expected products from the enzymatic action of chymotrypsin on each amino acid segment?

a) Gly-Ala-Phe-Thr-Leu.

b) Ala-Ile-Tyr-Ser-Arg.

c) Val-Trp-Arg-Leu-Cys.

2. What is the difference between each pair of compounds?

a) Pepsin and pepsinogen.

b) Chymotrypsin and trypsin.

c) Aminopeptidase and carboxypeptidase.

3. What are the main end products of each form of digestion?

a) Carbohydrates digestion.

b) Fats digestion.

c) Proteins digestion.

4. In what section of the digestive tract do most of the carbohydrates, fats, and proteins digestion take place?

3.5. Regulatory mechanisms of digestion

Neural and endocrine regulatory mechanisms work to maintain the optimal conditions in the gastrointestinal tract needed for digestion and absorption. These regulatory mechanisms, which stimulate digestive activity through mechanical and chemical activity, are controlled both extrinsically and intrinsically.

Neural Controls. The alimentary canal walls contain a variety of sensors that help regulate digestive functions. These include various receptors, such as mechanoreceptors, chemoreceptors, and osmoreceptors, which are capable of detecting mechanical, chemical, and osmotic stimuli, respectively. Stimulation of these receptors provokes an appropriate reflex that furthers the process of digestion. This may entail sending a message that activates the glands that secrete digestive juices into the lumen, or it may mean the stimulation of muscles within the alimentary canal, thereby activating peristalsis and segmentation that move food along the intestinal tract.

The extrinsic (outside), nerves connect the digestive organs to the brain and spinal cord. These nerves release chemicals that cause the muscle layer of the GI tract to either contract or relax, depending on whether food needs digesting.

The intrinsic (inside) nerves within the GI tract are triggered when food stretches the walls of the hollow organs. The nerves release many different compounds that speed up or delay the movement of food and the production of digestive juices.

Hormonal Controls. A variety of hormones are involved in the digestive process. The main digestive hormone of the stomach is gastrin, which is secreted

in response to the presence of food. Gastrin stimulates the secretion of gastric acid by the parietal cells of the stomach mucosa.

Hormones produced by the duodenum include:

1) secretin, which stimulates a watery secretion of bicarbonate by the pancreas;

2) cholecystokinin (CCK), which stimulates the secretion of pancreatic enzymes and bile from the liver and release of bile from the gallbladder;

3) gastric inhibitory peptide, which inhibits gastric secretion and slows gastric emptying and motility.

These GI hormones are secreted by specialized epithelial cells, called endocrinocytes, located in the mucosal epithelium of the stomach and small intestine. Then these hormones enter the bloodstream, through which they can reach their target organs.

Role of enzymes in digestion food. Enzymes are proteins that initiate specific chemical reactions. Digestive enzymes are produced in the pancreas and released throughout the digestive tract. Protease digests protein. Lipase and amylase are responsible for digestion of fat and carbohydrates, respectively.

3.6. Gastrointestinal tract micro flora

In the bowels of a healthy human's organism there inhabit more than 500 kinds of microorganisms, the majority of which (35–50 %) are localized in the large intestine. Total mass of micro flora is 1–3 kg. Approximately 90 % of all microorganisms are anaerobic bacteria and they are main (residential) micro flora, about 10 % are aerobic bacteria, this is facultative (concomitant) micro flora and 0.01–0.02 % – are incidental (residual) microorganisms (staphylococcus, clostridium, proteus and fungi). Moreover, there are about 10 enteric viruses in large intestine and some nonpathogenic protozoa. Among anaerobic bacteria the share of bifid bacteria is about 60 %.

Bifidobacteria are slightly curved gram-positive bacillus (fig. 37). There are plenty of bifidobacteria in the intestine of breastfeeding babies. Bifid bacteria percentage significantly reduces in adult's intestine.

Lactobacillus (fig. 38) take the place of bifid bacteria. Lactobacillus mainly represent microbial community of gastrointestinal tract (GIT). They participate in digestive process and help full food digestion and assimilation. Lactobacillus take part in metabolic process and synthesize different enzymes.

It should be noted that, all the microorganisms and human's macro organism compose symbiosis, where each organism accrues benefits for its existence, and it influences the partner.

Gastrointestinal tract micro flora performs the following functions:

1) morphokinetic and energy effects (regulation of intestinal motility, differentiation, regeneration and energy supply of epithelium);

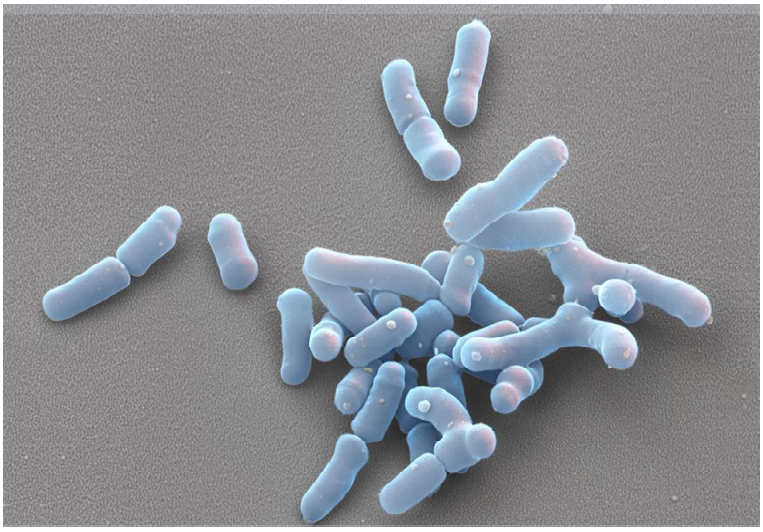


Figure 37. Bifidobacteria [18]

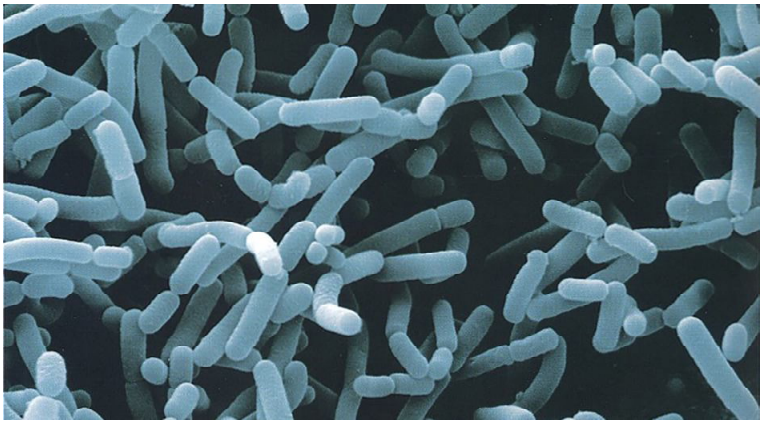


Figure 38. Lactobacillus [19]

2) immunogenic effects (immune system stimulation and immunoglobulins production);

3) forming protective barrier of bowels mucous coat and suppression of pathogenic micro flora growth;

4) detoxification of exogenous and endogenous toxic compounds;

5) synthesis of biologically active compounds, activation of some medicinal preparations;

6) mutagenic/antimutagenic activity;

7) regulation of gaseous composition;

8) storage of genetic material of microorganisms;

9) participation in etiopathogenesis of diseases;

10) sustaining ion homeostasis of organism, participation in salt-water exchange;

11) forming immunological tolerance to food and microbe antigens;

12) participation in metabolism of proteins, fats, carbohydrates, regulation of macromolecules (bile acids, steroids). Microorganisms of bowels produce various enzymes (protease, amylase, lipase) and thanks to it they activate hydrolysis of proteins, attenuate hydrocarbons, saponification fats, interfere cholesterol metabolism, prevent bacterial decarboxylation of food histidine and increasing the amount of histamine.

Causes of pathogenic changes in the intestinal microflora. An imbalance that has occurred in the gastrointestinal tract can be caused by the following reasons:

1) use of antibiotics;
2) treatment with radiation and chemotherapy;
3) infectious pathology;
4) heavy physical activity and severe stress;
5) improper nutrition;
6) early transition of infants to artificial feeding.

Especially severe violations occur as a result of a combination of several factors.

A balanced diet plays a huge role in maintaining the normal state of the intestinal microflora. In the diet of each person should be present fermented milk products that are sources of *bifidobacteria* and *lactobacilli* (fig. 39).

Figure 39. Fermented milk products [20]

It is useful to eat fruits and vegetables.

Among the food products, there are also natural prebiotics that promote the growth of beneficial microorganisms. These include potatoes, leeks, asparagus, and components containing starch, such as viscous rice.

4. CONCEPT OF QUALITY, NUTRITIONAL, BIOLOGICAL AND ENERGY VALUE OF FOOD PRODUCTS

4.1. Nutritional value of proteins. Protein-calorie deficiency and its consequences

Proteins refer to essential substances without which life, organism growth and development are impossible. Proteins are not formed from the other food substances (fats, carbohydrates) and are not stored as reserves (which is typical of fats).

If the quantity of proteins entering with food is smaller than the recommended norms, proteins of tissues in the organism (liver, blood plasm, etc.) start decomposing, and the amino acids formed as a result are expended for the synthesis of enzymes, hormones and other biologically active substances necessary for the survival of the organism (fig. 40).

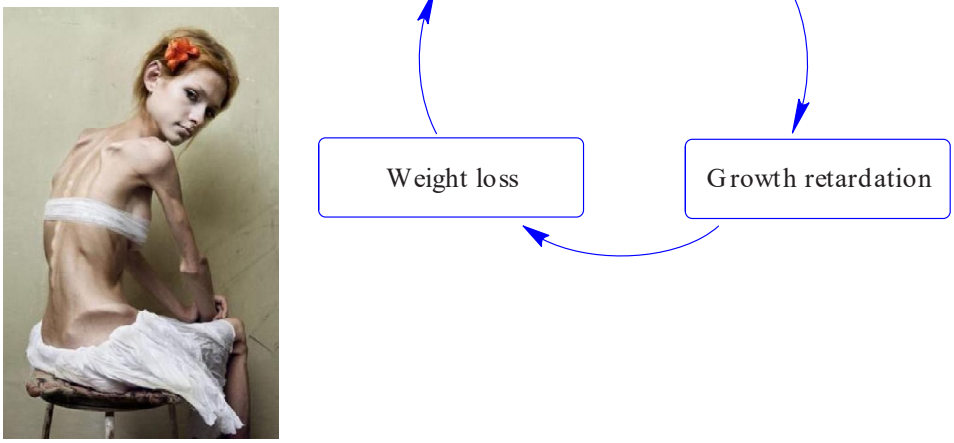


Figure 40. Consequences of an amino acids lack

Increased amount of proteins in the food ration doesn't influence metabolism in the organism considerably.

Protein turnover depends to a greater extent on the shortage or lack of essential amino acids. Human's organism cells can't synthesize necessary proteins, if even one essential amino acid (tab. 2) is missing from the food.

Table 2

Essential and nonessential amino acids

Essential	Nonessential
Isoleucine	Alanine
Leucine	Asparagine
Lysine	Aspartic Acid
Methionine	Cysteine*
Phenylalanine	Glutamic Acid
Threonine	Glutamine*
Tryptophan	Glycine*
Valine	Proline*
	Selenocysteine*
	Serine*
	Tyrosine*
	Arginine*
	Histidine*

* Essential only in certain cases.

Synthesis of proteins is also disturbed in the cases when some part of amino acids is destroyed by pathogenic micro flora in the bowels, amino acids are poorly absorbed or proteolytic enzymes of the gastro-intestinal tract are low active.

4.1.1. Main characteristics of proteins nutritional value

The rate of breakdown and renewal of body proteins varies. The half-life of peptide hormones is minutes or hours, plasma and liver proteins are about 10 days, and muscle proteins are about 180 days. On average, all proteins in the human body are updated in 80 days.

The total amount of protein that has undergone decomposition per day is indicated by the amount of nitrogen removed from the human body. The protein contains

about 16 % nitrogen (i. e. in 100 g of protein – 16 g of nitrogen). Thus, the release of 1 g of nitrogen by the body corresponds to the breakdown of 6.25 g of protein. During the day, about 3.7 g of nitrogen is released from the body of an adult. From these data, it follows that the mass of protein subjected to complete destruction per day is $3.7 \times 6.25 = 23$ (g), or 0.028–0.075 g of nitrogen per 1 kg of body weight per day (Rubner wear coefficient).

Nitrogen balance is a balance between the amount of proteins entering and of decomposition products being excreted.

There are several types of nitrogen balance.

1. *Nitrogen equilibrium* – in this case the amount of nitrogen entering with food is equal to the amount of nitrogen being excreted (fig. 41). Nitrogen equilibrium is typical for a mature organism.

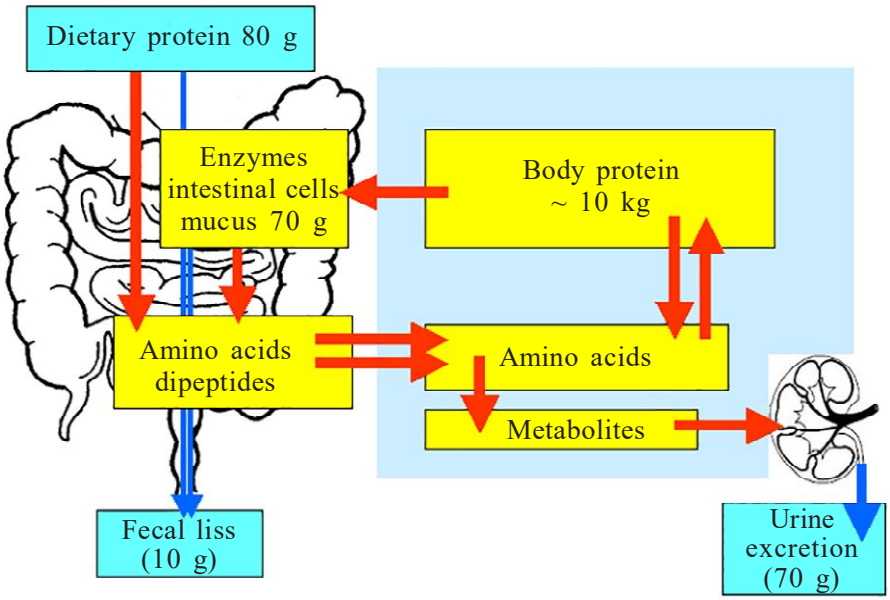


Figure 41. Nitrogen equilibrium [21]

2. *Positive nitrogen balance* – the amount of nitrogen entering with food is higher than the amount being excreted from the organism. It's typical for a young organism when protein mass is being accumulated, a several of necessary compounds for the organism are being formed.

3. *Negative nitrogen balance* – the amount of nitrogen entering with food is less than the amount being excreted. It's typical for the elderly people when there aren't enough proteins, essential amino acids, vitamins, mineral substances in the food ration, with protein starvation or complete starvation and in case of some diseases. Continuous negative nitrogen balance leads to the death of organism.

Biological value and the amount of protein entering with food also influence protein turnover.

4.1.2. Biological value

Biological value of proteins is determined by the balance of amino acid composition and proteins susceptibility to attacks by enzymes of the gastro-intestinal tract.

Main function of protein in nutrition is providing organism with the necessary amount of amino acids. In food protein not only the amino acid content must be balanced, but also a particular ratio of essential and nonessential amino acids is necessary, otherwise a part of essential amino acids will be expended purposelessly.

Biological value of protein can be assessed by comparing its amino acid composition with the composition of an «ideal protein».

Amino acid score (AAS) is calculated according by the formula:

$$AAS = \frac{\text{AA content (mg) in 1 g of the protein tested}}{\text{Same AA content (mg) in 1 g of the ideal protein}} \times 100\ \%,$$

where AA – amino acid.

Amino acid content in protein is identified by amino acid scale. After calculating a limiting acid with the lowest score is identified in the tested protein.

World Health Organization / Food and Agriculture Organization (WHO/FAO) recommends (tab. 3).

Table 3

The recommended daily human requirement for essential amino acids and the content of essential amino acids in an ideal protein

Essential amino acids	WHO / FAO information, mass, mg/g of protein				Mass, mg/kg body weight	Content, mg/g of ideal protein
	Children 2 … 5 years	Children 10 … 12 years	Teenagers	Adults		
Ile	40	28	28	13	10	40
Leu	70	66	44	19	14	70
Lys	55	58	44	16	12	55
Met + Cys	35	25	22	17	13	35
Phe + Tyr	60	63	22	19	14	60
Tre	40	34	28	9	7	40
Trp	10	11	9	5	3.5	10
Val	50	35	25	13	10	50

The right column is amino acid scale, which is used for calculation of amino acid score (see tab. 3).

Animal proteins are the closest by their composition to an «essential» protein. Most vegetable proteins contain an insufficient amount of essential amino acids. For example, proteins of grain varieties are inadequate by the amount of lysine, methionine, threonine. Potato protein and some leguminous plants protein lack methionine and cysteine (only 60–70 % of the optimal amount).

Biological value of proteins can be raised by adding limiting amino acid or introducing a component with its increased content.

Animal and vegetable proteins are not assimilated by organism in the same way. Proteins of milk, dairy products and eggs are digested only by 96 %, the ones of meat and fish – by 93–95, the ones of bread – by 62–86, the ones of vegetables – by 80, the ones of potato and some leguminous plants – by 70 %.

At the same time, it should be remembered that during heat treatment and long storing some amino acids can form compounds nondigestible by organism, i. e. they become «inaccessible». It reduces the value of protein.

Main sources of food protein are caviar, meat, fish, cheese, nuts, eggs, legumes (peas, soy, beans), milk, cottage cheese, mushrooms, grain derivative products.

Food protein plays an important role in forming hemoglobin and erythrocytes, in the synthesis of enzymes, hormones, antibodies providing immunity. The most important function of protein is to provide organism with the necessary amount of essential and nonessential amino acids. Most proteins of vegetable origin lack certain essential amino acids. For example, buckwheat lacks leucine, rice and millet lack lysine. One product can supplement another with the content of essential amino acids; therefore, it's reasonable to use various combinations of products. Animal proteins are referred to the most adequate ones by their amino acid composition.

Insufficient amount of protein entering with food as well as continuous consuming proteins of low biological value lead to protein deficiency – an unhealthy process, caused by the disruption of balance between the formation and decomposition of protein in adults and its insufficient accumulation in growing organism. At the same time nutrition can satisfy organism needs in energy by using fats and carbohydrates. Protein deficiency declares itself through:

– reducing body mass;
– slowing down children's growth and psychic development;
– decreasing in immunity;
– liver, pancreatic gland, blood-forming organs function abnormality;
– anaemia.

Mild and not so serious cases of protein deficiency can occur in strict vegetarians consuming only vegetable food of limited assortment, in children and teenagers having irrational nutrition, in dissatisfying increased organism need in proteins during pregnancy, in breast-feeding, in self-treatment by physiologically unreasonable diets. Continuous protein deficiency leads to a serious disease – *Kwashiorkor*, which is observed in children aged 1–5, especially after breast-

feeding cessation (fig. 42). The disease is accompanied by a violation of intestinal function, since the pancreatic enzymes are not synthesized at the proper speed and the cells of its mucous membrane are not updated. A vicious circle of Kwashiorkor occurs, and it characterizes by the termination of the process food protein assimilation.

Figure 42. Kwashiorkor [22, 23]

The body develops a negative nitrogen balance, water-salt metabolism is disrupted, muscle atony appears and growth stops. Food dystrophy is especially dangerous for infants. Kwashiorkor can be accompanied by their death from diarrhea, acute infections, liver diseases and lagging in physical and mental development.

A significant and quickly decrease in protein synthesis in the liver against the background of insufficient intake of it into the body reduces the amount of serum albumin, low-density lipoproteins (LDL) and hemoglobin in the blood (fig. 43).

4.2. Nutritional value of fats and oils

Lipids are an essential component of food – energy (37.66 kJ or 9 kcal are released after fat oxidizing) and structure-plastic material for human, supplier of several necessary substances for him. Recommended amount of fats in human's ration is 90–100 g in caloric value and 30–33 % in weight percentage on average per day.

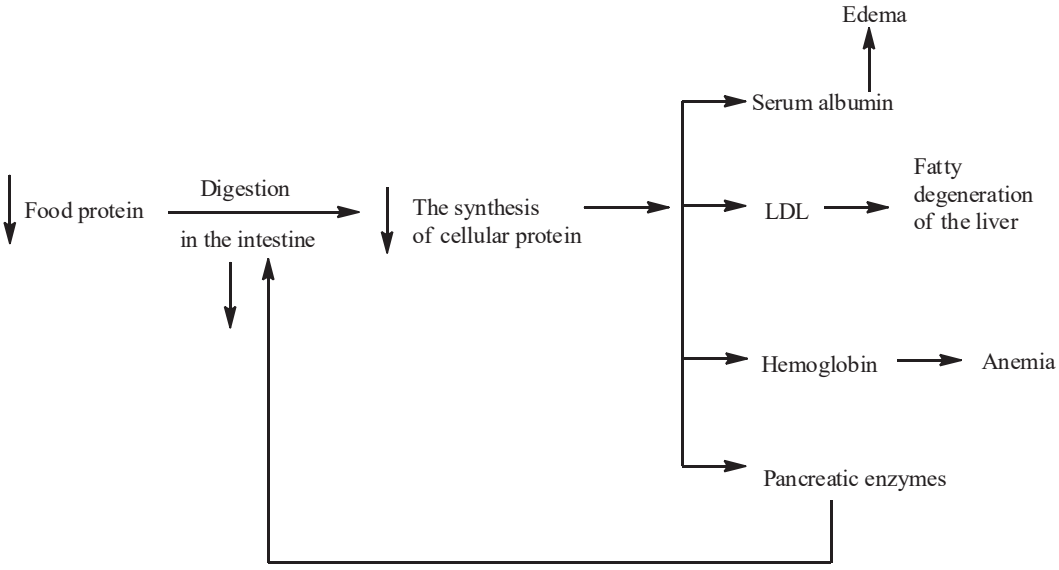


Figure 43. A vicious circle of Kwashiorkor [24]

Continuous limiting fats in nutrition leads to irregularities in physiological state of the organism: central nervous system activity is disturbed, immunoresistance decreases, lifetime reduces. Excess consumption of fats is either undesirable, it leads to obesity, cardio-vascular diseases and other adverse phenomena.

The most important sources of fats in nutrition are:

– vegetable oils (in refined oils – 99.7–99.8 %),
– butter (61.6–82.5 %),
– margarine (up to 82.0 %),
– dairy products (3.5–30 %),
– chocolate (35–40 %),
– cereals-buckwheat (3.3 %), oatmeal (6.1 %),
– cheeses (25–50 %),
– pork products, sausages (10–23 %).

In nutrition it is not only quantity that is significant, but also chemical composition of lipids, especially presence of polyunsaturated fatty acids in their content. One should note that linoleic and linolenic acids are not synthesized in human's organism and arachidonic acid is synthesized from linoleic one involving vitamin B_6. For this reason, they are called key or essential acids.

Vegetable oils, especially corn, sunflower and soy ones are rich with polyunsaturated acids, animal fats contain extremely low amount of them.

Arachidonic acid is contained in trace amounts food products and vegetable oils practically do not contain it at all. Eggs contain its greatest amount – 0.5 %, byproducts – 0.2–0.3 %, and brains – 0.5 %.

It is important that vegetable fats are a source of vitamin E and β-carotene, and animal fats – of vitamins A and D.

4.3. Nutritional value of carbohydrates

Human's daily requirement in carbohydrates is 400–500 g (35 % – monosaccharides and disaccharides, 65 % – polysaccharides). Proportion of carbohydrates in food is 50–60 % and more (by caloric value). Main sources of carbohydrates are products of vegetable origin.

From the point of view of nutritional value carbohydrates are divided into assimilable and inassimilable.

Assimilable carbohydrates are mono- (glucose, fructose, galactose), oligo- (saccharose, maltose, lactose), polysaccharides (glycogen, starch). Fructose and glucose are the easiest to digest and then saccharose, maltose and lactose follow. Starch and dextrins are digested more slowly as they must be depolymerized to glucose before (tab. 4). Therefore, their consumption doesn't lead to a sharp increase of glucose level in blood unlike mono- and disaccharides.

Table 4

Fast and slow carbohydrates

Digestible simple carbohydrates, fast carbohydrates (5–10 min)		**Digestible complex carbohydrates, slow carbohydrates (20–25 min)**	
Monosaccharides	Examples	Polysaccharides	Examples
Glucose	Fruit, honey, corn syrup	Glycogen	Meat
Fructose	Fruit, honey, juices, corn syrup	Starch and dextrins	Cereals, legumes, vegetables
Galactose	Milk		
Disaccharides	Examples	Partially digestible complex carbohydrates	Examples
Sucrose (table sugar)	Sugar cane, sugar beet	Inulin	Onion, garlic
Lactose	Milk		
Maltose	Beer		
Carbohydrate derivatives	Examples	Indigestible complex carbohydrates (dietary fibre)	Examples
Ethyl alcohol	Fermented cereals	Cellulose	Vegetables and seeds
Lactic acid	Milk products	Hemicellulose	Vegetables and seeds
		Pectins	Citrus fruit
		Gum solution	Oats, barley, seeds

Excess of carbohydrates brings about obesity, nervous system disturbances, especially in children, organism allergization. Norm of carbohydrates must be reduced for people suffering from diabetes, allergies and inflammatory processes as well as for those not involved in physical labour and for elderly people.

Inassimilable carbohydrates (ballast substances) – cellulose, hemicellulose, pectine substances are not utilized by human's organism, but they are extremely important for digestion and make up (together with lignin) the so-called food fibres. Human doesn't have enzymes able to split these polysaccharides. Partial splitting takes place under the action of enzymes secreted by bowels microorganisms.

Food fibres perform the following functions in human's organism:

– stimulate bowels motor function;

– prevent cholesterol resorption;

– play a positive role in normalizing content of the microflora of the intestine, in inhibiting putrefactive processes;

– exert influence on lipid exchange, disturbance of which leads to obesity;

– adsorb bile acids;

– reduce toxic substances of microorganisms' activity and promote excreting toxic products from the organism.

Insufficient content of inassimilable carbohydrates in food means increase of cardio-vascular diseases and malignant tumors in straight intestine. Daily rate of food fibres is about 20–25 g. Main sources of ballast substances are rye and wheat bran, vegetables (potatoes, cabbage, carrots), fruit. Whole-wheat bread is much more valuable from the point of view of food fibres content than top-grade flour bread.

4.4. Caloric value of daily ration

Energy coming with food must correspond to the energy expenses of the organism.

Energy equivalent of food can be measured quantitatively in kilo joules or in kilocalories (1 kJ = 0.24 kcal). Kilocalories are used more often in measurements, that is why food energy value is called caloric value.

Caloric value can be determined knowing the content of proteins, fats and carbohydrates in a food product. One should proceed from the energy coefficients of the main nutrients: oxidizing 1 g of proteins and 1 g of carbohydrates releases 4 kcal respectively in organism and 1 g of fats – 9 kcal. According to the formula of balanced nutrition the proportion of proteins : fats : carbohydrates = 14 : 30 : 56. One can calculate the amount (in gram) of main nutrient materials for daily ration. For example, if caloric value of ration is 4 000 kcal, then proteins must account for 140 g (560 kcal), fats – 133 g (1 200 kcal), carbohydrates – 560 g (2 240 kcal). The calculation was made for the man weighing 70 kg and woman weighing 60 kg.

In the case when the exact content of dishes is unknown, the following data could be used.

Energy value is:

a) soups (portion of 500 g):

– shchi (Russian cabbage soup), borsch (beet-root soup), rassolnik (pickle soup) – 200–300 kcal;

– milk, cereals soups, solyanka (a thick soup of vegetables and meat) – 400 kcal;

b) second courses:

– meat dishes with garnish – 500–600 kcal;

– fish – about 500 kcal;

– vegetable – 200–400 kcal;

c) third courses – 100–150 kcal.

Thus, knowing the content of daily food ration one can identify how much energy was obtained during the day, i. e. caloric value of daily ration.

Daily caloric value of food for a human in a condition of bed rest must be 1 300–1 800 kcal. For a person leading a usual life, but not involved in physical labor or going in for sport, it must be 3 000 kcal, and for working people and training sportsmen – 3 500, 4 000 and even 5 000–5 500 kcal (depending on load intensity and type).

If the caloric value of nutrition is lower than the factual energy expenditure and the amount of proteins in food is smaller than need in them (energy and plastic requirements of organism will not be satisfied), then it can lead to disorder in normal state of the organism, reducing work capacity and even developing ill conditions.

Body mass reduction is observed in continuous use of lowered caloric value ration and body mass increases in excessive intake of energy sources mainly through lipid storage.

Calculation of total daily energy expenses and caloric value of daily food ration allows identifying energy balance of the organism. Energy balance – the ratio between the consumption of energy by the human body and its intake from food. Stability of body mass and outside form of the organism testifies to the realization of the law of energy adequacy.

There are 3 types of energy balance:

1) energy equilibrium;

2) positive energy balance;

3) negative energy balance.

Energy equilibrium (fig. 44, *a*) is observed in a healthy adult. Amount of energy coming with the food equal to energy consumption. The result is constant body weight and high efficiency.

Positive energy balance is observed when energy input is more than energy output (fig. 44, *b*). Human body stores excess energy as fat, this results in weight gain.

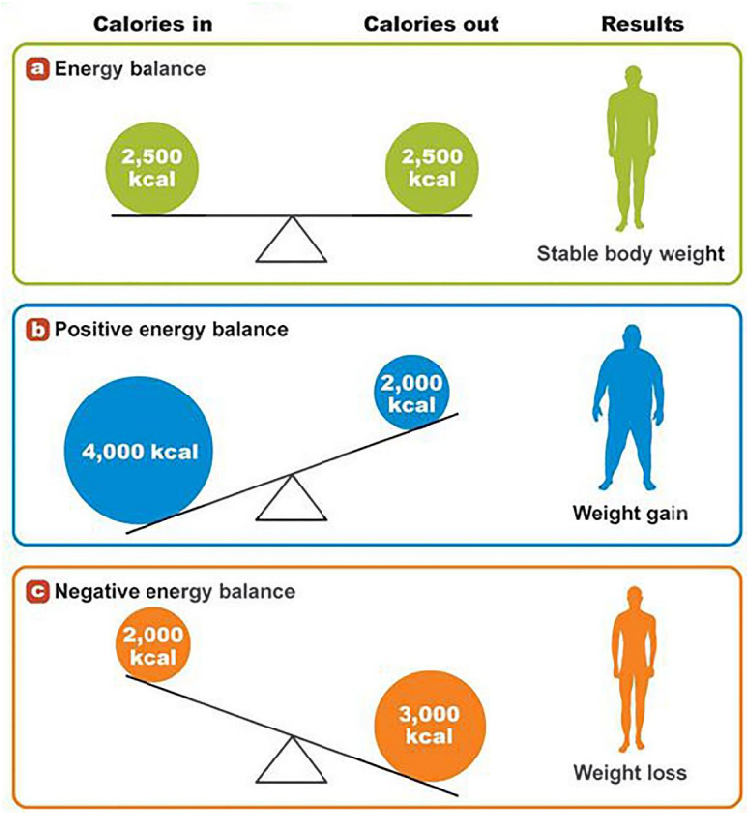


Figure 44. The concept of energy balance [25]

Negative energy balance (fig. 44, *c*) occurred when less energy from food is taken in than is consumed by a person. The human's body mobilizes its energy reserves to meet the energy deficit. As a result, there is a decrease in body weight.

5. MEDICAL-BIOLOGICAL VALUE AND FUNCTIONS OF THE MAIN FOOD COMPONENTS

5.1. Main chemical components of food (nutrients)

Food consumed by human contains various chemical substances having both organic and inorganic nature. According to the classification by A. A. Pokrovskiy, leading nutrition physiologist, food substances are divided into two groups – firstly, nutrients (they must be contained in food) and secondly, non-edible components.

Nutrients provide organism with energy, substances and biochemical processes regulators, without which normal human's life activity is impossible (fig. 45).

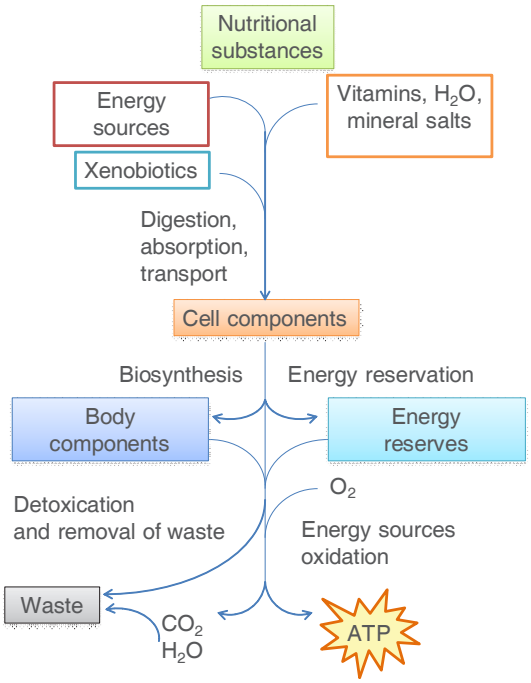


Figure 45. Metabolism of nutritional substances

There are primary nutrients, which get into human's organism from the environment and secondary nutrients formed in the organism during digestion and biosynthesis processes. It should be noted that at present considering the peculiarities of growing and technological processing of food raw materials, methods of transporting and storing, usage of different additives modern food covers organism's needs in nutrients insufficiently (by 20–40 %).

Nutrients include (fig. 46):
1) proteins – complete and incomplete; animal origin and vegetable origin;
2) fats – animal based and vegetable based; lipoids;
3) carbohydrates – simple sugars; polysaccharides;
4) vitamins – watersoluble; liposoluble;
5) mineral substances – macro- and microelements;
6) water.

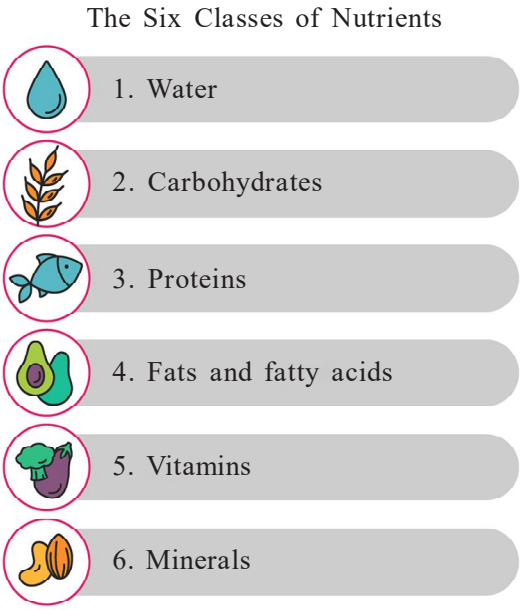


Figure 46. Six groups of essential nutrients [26]

Three groups of nutrients can be differentiated by their quantative content in organism (tab. 5).

Table 5

Classification of nutrients

Nutrients		
Macronutrients	Micronutrients	Nanonutrients
Proteins, fats Carbohydrates Neuropeptides Macro elements	Ferments, vitamins Nucleic acids Microelements (K, Na, Mg, Ca, P and others)	Selenium, chromium, vanadium, germanium and others

Non-edible components include ballast substances (cellulose, pectines), protective components, flavour and aromatic substances, food components, exerting negative influence on human organism.

So, proteins, fats, carbohydrates are the main nutrients. They are usable as energy sources in human body and as raw products in biosynthesis of body components (fig. 47).

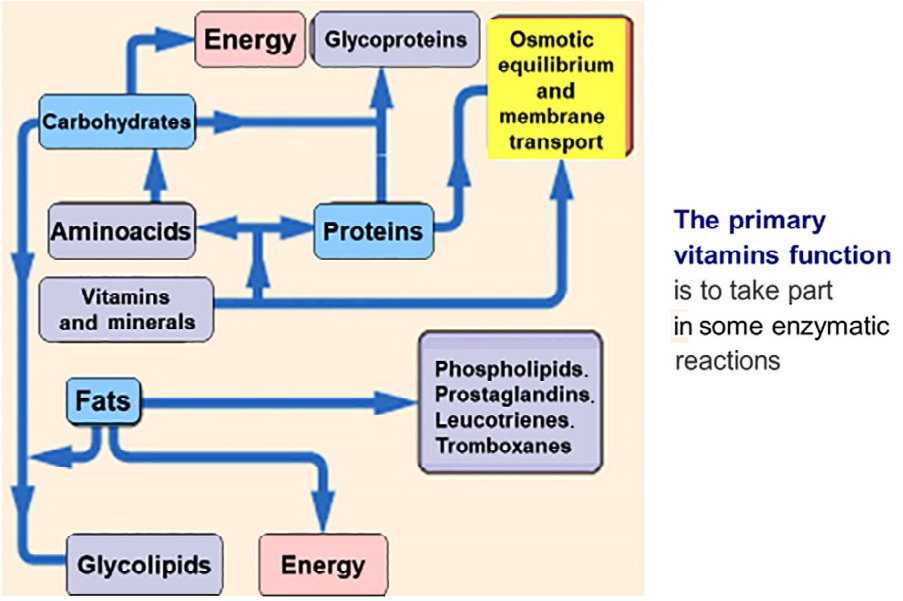


Figure 47. Nutrients functions

5.2. Metabolism

The term metabolism is used to describe all chemical reactions involved in maintaining the living state of the cells and the organism. Metabolism can be conveniently divided into 2 categories:

1) catabolism – splitting of molecules to produce energy;

2) anabolism – synthesis of all necessary compounds for cells.

The following mnemonic «A B C D» may help in remembering the difference:

Anabolism = Biosynthesis;

Catabolism = Degradation.

Anabolism refers to those metabolic processes that utilize energy to biosynthesize complex molecules and to generate growth. The reverse process is catabolism, whereby nutrients are broken down to release energy (fig. 48).

Catabolic processes provide intermediates for synthetic or further catabolic pathways and release energy, usually as the energy carrier molecules NADPH and ATP (fig. 49).

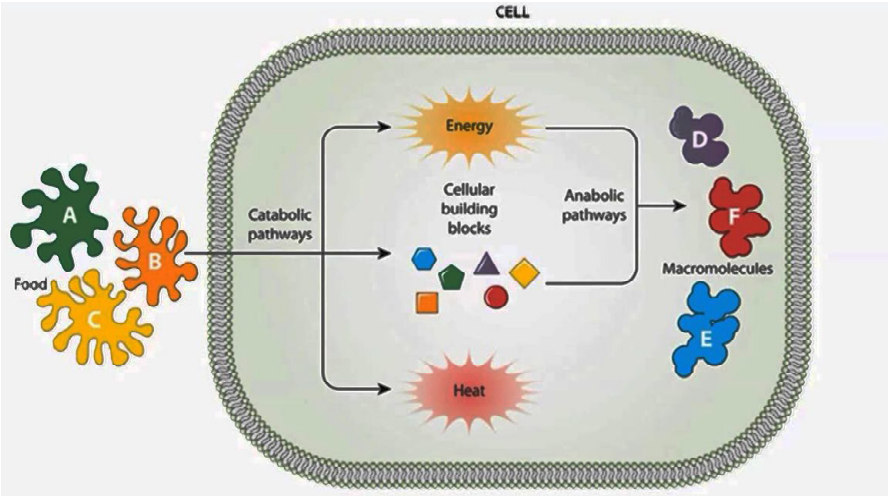
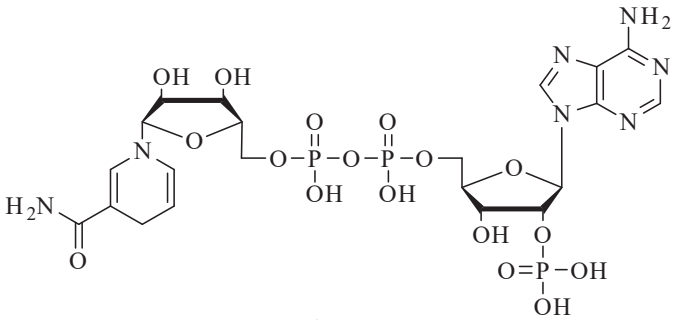
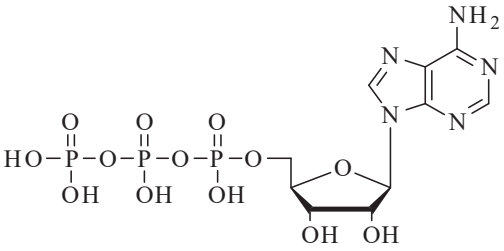


Figure 48. Catabolic and anabolic pathways in cell metabolism [27]



NADPH

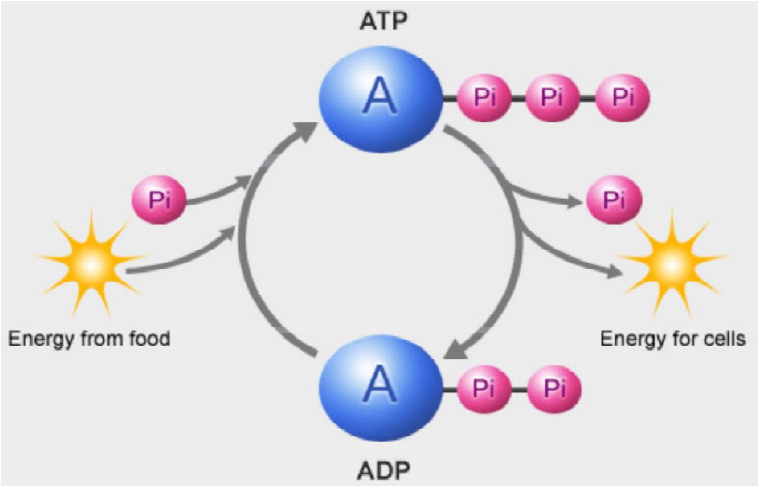


ATP

Figure 49. Structure of NADPH and ATP

The energy is stored in the form of energy-rich ATP, which powers the reactions of anabolism. The useful energy of ATP is stored in the form of a high-energy bond between the second and third phosphate groups of ATP and released by ATP hydrolysis (fig. 50).

ATP – 100 % renewable energy



All living cells rely on one source of energy to do everything from building molecules to flexing muscles ATP (adenosine triphosphate). Breaking down ATP releases energy, and cells constantly replace their ATP by wacking a spare phosphate onto ADP (adenosine diphosphate). The energy for that comes from food we eat (in animals) or make (in plants). Enzymes control the breaking and making of ATP

Figure 50. Energy and ATP [28]

Anabolism uses energy stored in the form of adenosine triphosphate (ATP) to build larger molecules from smaller molecules. Catabolic reactions degrade larger molecules in order to produce ATP and raw materials for anabolic reactions.

There are four stages of catabolism (fig. 51).

In the first stage the storage forms of proteins, triacylglycerols and polysaccharides are broken down in the cell's cytoplasm into amino acids, fatty acids and glucose, respectively (1). Within the mitochondrion, the intermediates generated by catabolism of proteins, fats, and sugars (2) are delivered to the Krebs cycle (3).

The Krebs cycle also known as citric acid cycle (CAC) or the tricarboxylic acid cycle (TCA cycle) is a series of chemical reactions used by all aerobic organisms to release stored energy through the oxidation of acetyl-CoA derived from proteins, carbohydrates and fats.

The catabolism of proteins delivers pyruvate, acetyl-CoA and oxaloacetate to the Krebs cycle. Beta-oxidation of fatty acids ultimately delivers acetyl-CoA. Glycolysis generates acetyl-CoA via pyruvate. Products of the Krebs cycle are then processed by oxidative phosphorylation (4).

Anabolism and catabolism have 3 major functions:

1) to extract energy from nutrients;

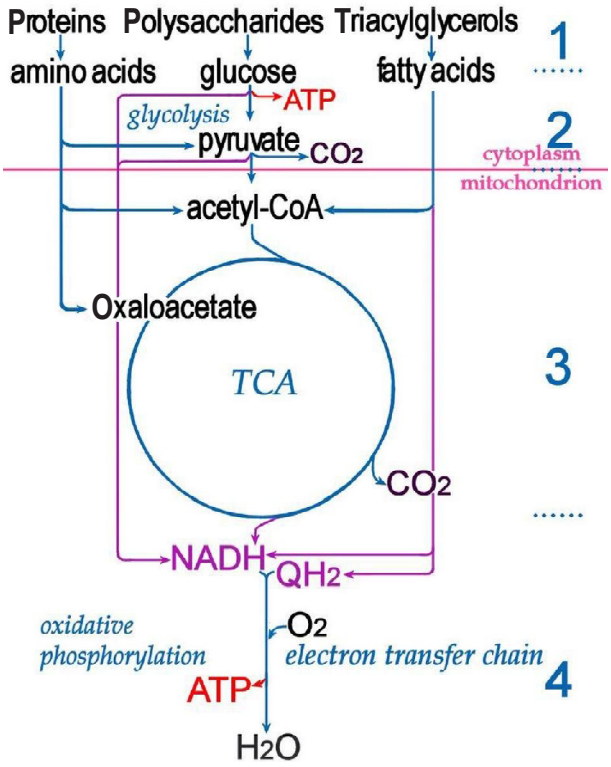


Figure 51. Stages of catabolism

2) to synthesize the building blocks that make up the large molecules of life – proteins, fats, carbohydrates, nucleic acids, and combinations of these substances;

3) to synthesize and degrade molecules required for special functions in the cells.

These reactions are controlled by enzymes. Often, an additional molecule called a coenzyme is required for the enzyme to function. For example, some coenzymes accept an electron that is released from the substrate during the enzymatic reaction. Most of the water-soluble vitamins of the B complex serve as coenzymes, riboflavin (vitamin B_2) for example is a precursor of the coenzyme flavin adenine dinucleotide (FAD), while pantothenate is a component of coenzyme A, an important intermediate metabolite.

A knowledge of normal metabolism is essential for an understanding of abnormalities underlying disease. Normal metabolism includes adaptation to periods of starvation, exercise, pregnancy, and lactation. Abnormal metabolism may result from nutritional deficiency, enzyme deficiency, abnormal secretion of hormones, or the actions of medicines and toxins. An important example of a metabolic disease is diabetes mellitus.

5.3. Proteins

Proteins are the organism's main plastic material and compose about 17 % of body mass. They are necessary to form new muscle fibres, to restore injured and to replace died off tissues of all organs. Cellular membranes are protein-lipid complex. All the enzymes, antibodies and some hormones have protein nature. Proteins functions are shown at fig. 52.

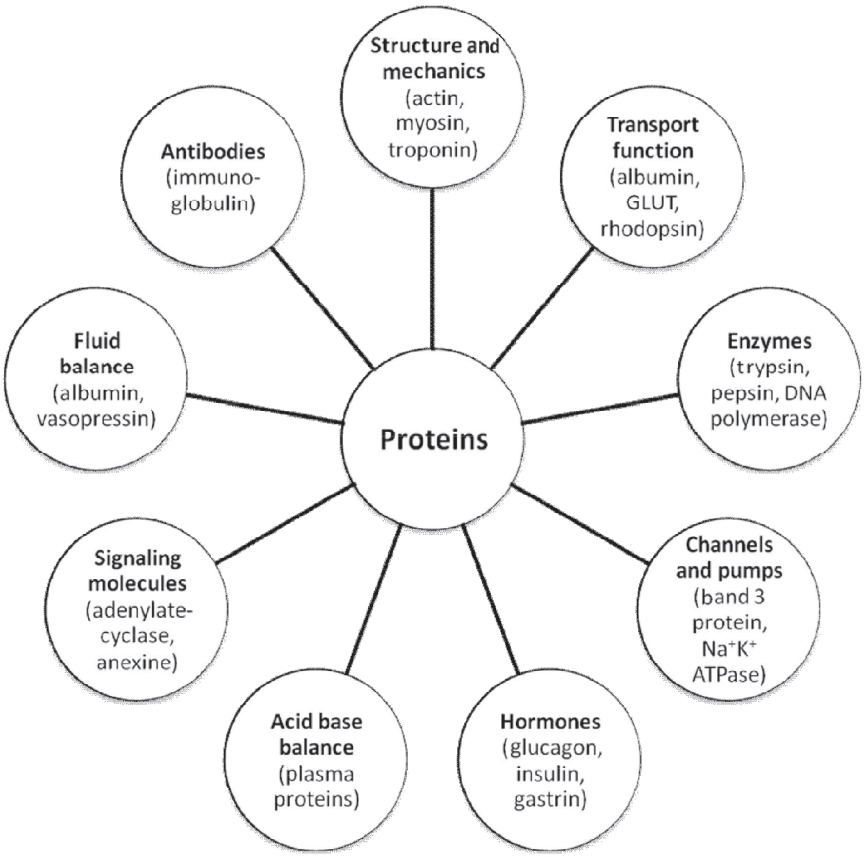


Figure 52. Proteins functions

In the organism proteins are formed by consuming proteins of food. Sources of protein are products of animal (meat, fish, milk, eggs) and vegetable (leguminous plants, soya, nuts) origin (tab. 6).

Daily need in proteins depends on body mass, age, job, climate conditions, motion activity. For an adult it is 100–120 g (1.6–2.3 g per 1 kg of body weight). One should take into account that in introducing more than 3 g of protein per 1 kg of body weight its digestion deteriorates, ammonia and urea (protein decomposition products) excretion with urine accelerates. The liver and kidneys burden rises.

Table 6

Proteins content in food products

Products of animal origin	Proteins content per 100 g of product, g	Products of vegetable origin	Proteins content per 100 g of product, g
Meat	20.2	Bread	8.1
Fish	16.0	Rice	7.3
Cheese	26.8	Beans	22.3
Curd	14.0	Potato	2.0
Milk	3.0	Cabbage	1.8
Eggs (2 pieces)	12.7	Walnuts	15.0

Furthermore, the content of toxic substances increases (indole, skatole, phenol, cresol), which are neutralized in the liver.

In consuming less than 2 g of protein per 1 kg of body weight during intensive physical training a negative nitrogen balance is observed, potassium loss and calcium retention increase sharply. Excretion of some vitamins with urine accelerates, such as ascorbic acid, thiamine, riboflavin, pyridoxine, niacin. Therefore, unbalanced protein ration can lead to the lack of vitamins in the organism.

Biological value of proteins depends on their amino-acid composition. Food proteins must contain all the essential amino acids. These amino acids must regularly enter with the food as they are not accumulated in the organism. It should be noted with a lack of tryptophan, the synthesis of nicotinic acid decreases and xanthurenic acid accumulates, which inhibits the p-cells of the Islands of the pancreatic Langerhans, thereby provoking the occurrence of diabetes.

In this case, it is important not only the amount of each amino acid, but also the ratio between them. It must be as close as possible to their correlation in the proteins in human body. Balance disorder of amino acid composition of food proteins can lead to synthesis disorder of the organism's own proteins and their decomposition acceleration. Typical violations of proteins metabolism are:

– mismatch of proteins intake in the body to its needs;
– violation of proteolysis in the gastrointestinal tract;
– violation of the protein content in the blood plasma;
– disorder final stages of protein catabolism;
– disorders of amino acid metabolism;
– violation of the transmembrane transport of amino acids.

The use of complete animal protein or balanced plant protein mixtures in the diet is necessary to avoid irreversible deviations in human health.

Along with the biological value, amount and intake schedule of protein its assimilability also has a big significance. It relates to the speed and degree of digestion, presence of digestive enzymes inhibitors (for example in leguminous plants) and thermal decomposition of proteins in culinary processing. Daily amount of protein should be better distributed evenly for 46 meals, as smaller amounts of product are better digested and used by the organism more effectively.

Proteins of egg, milk, meat and fish possess high biological value. Based on decreasing the speed of their digesting, proteins can be arranged in the following order: egg and milk, fish and meat, vegetable ones.

Culinary processing simplifies digestion and assimilation of proteins (the only exception is proteins in boiled milk).

Control questions

1. What is the role of proteins in human nutrition?
2. What is the nitrogen balance and what types of it can be observed in the body?
3. What is the recommended amount of protein in the diet and what factors they depend?
4. What is Kwashiorkor syndrome and what are its ensuing consequences?
5. How can you describe the main functional properties of proteins?

5.4. Carbohydrates

First of all, try to answer on these questions.

1. What natural carbohydrates do you know?
2. Which life organisms contain them?
3. What carbohydrates functions do you know?
4. How does the term «carbohydrate» relate to the structure of carbohydrate molecules?

Carbohydrates sources are bread, cereals, vegetables, fruits. Carbohydrates are 2/3 all used food nutrients. Carbohydrates are a common source of energy in living organisms. Carbohydrates give 75 % energy necessary for a human. However, no carbohydrate is an essential nutrient in humans.

Pasta and whole-grain bread contain complex carbohydrates, which are long chains of glucose molecules. Nutritionists recommend that 55–60 % of calories come from carbohydrates, and especially complex carbohydrates.

Glucose is monosaccharide formed in the body in digesting complex saccharides of food and it is a nearly universal and accessible source of calories. Glucose metabolism is shown on the fig. 53.

In decreasing glucose level in blood activity of nervous and muscle cells are broken, spasms and faintness appear. After a large intake of glucose with food (over 150 g) or with a violation of carbohydrate metabolism, it appears in the urine (glucosuria).

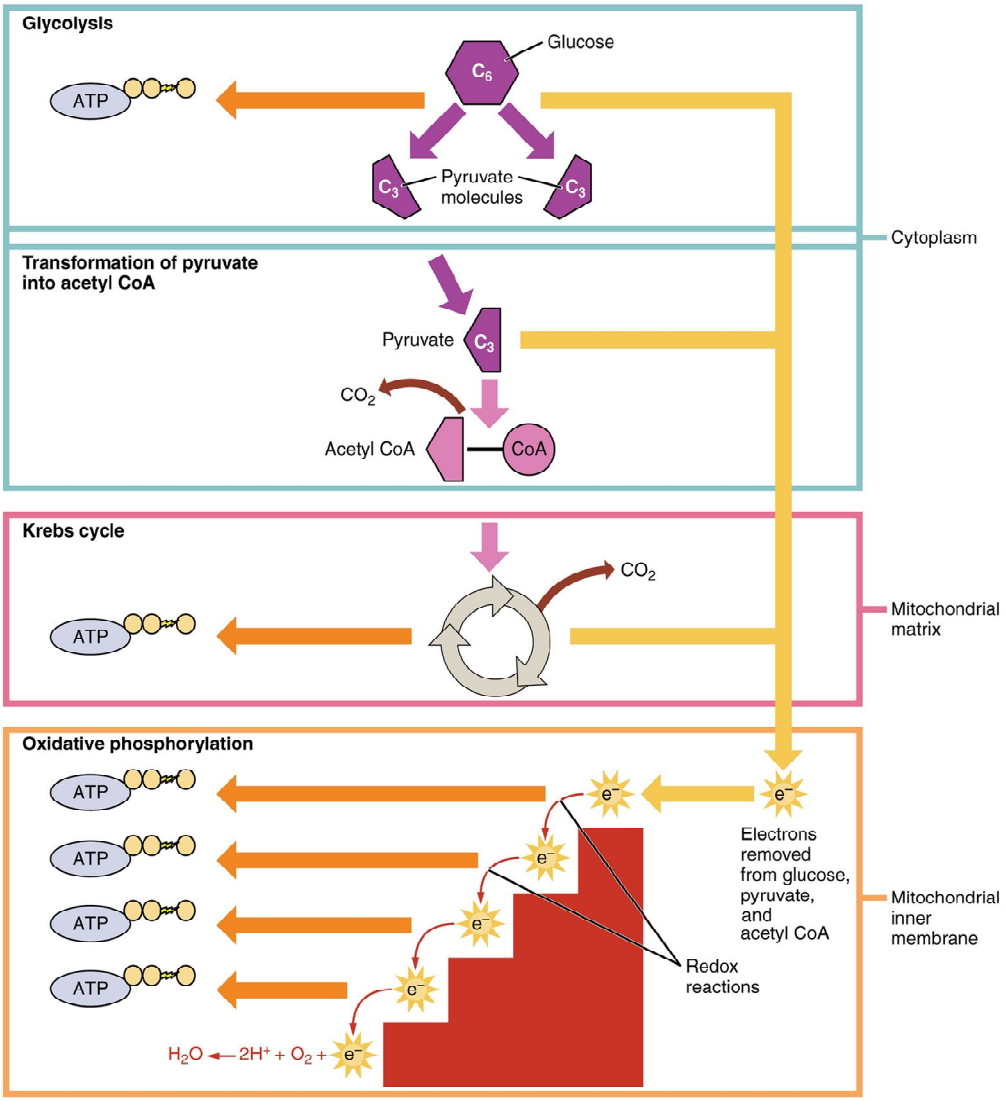


Figure 53. Glucose metabolism [29]

Starch, glycogen and cellulose are polysaccharides (fig. 54).

Starch is used by plants to store energy in their numerous carbon-hydrogen bonds. It is accumulated in seed, tubers (40–78 %). Starch is one of the primary sources of calories for humans.

Glycogen (animal starch) is used by animals to store energy. In human organism glycogen is in the liver (to 5 % her weight), muscles (to 2 %) and heart (0.1–0.3 %).

Most organisms, as well as humans, can't metabolize cellulose or other polysaccharides like chitin and arabinoxylans. Although cellulose is digested and used for energy by herbivores Cellulose acts as rough food. Cellulose stimulates the peristalsis movement and secretion of digestive enzymes.

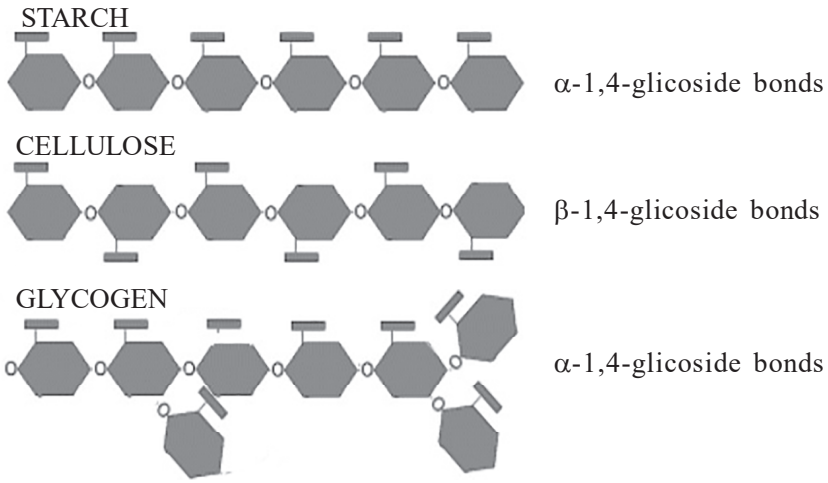


Figure 54. Polysaccharide structures [30]

Carbohydrates are in different forms like the sugars, starch and cellulose in the human's diet. These compounds convert to glucose in the body for energy production by anaerobic and aerobic oxidations or storage in the liver and muscles as glycogen by glycogenesis. Besides they are also used for fats and proteins biosynthesis in the body (fig. 55).

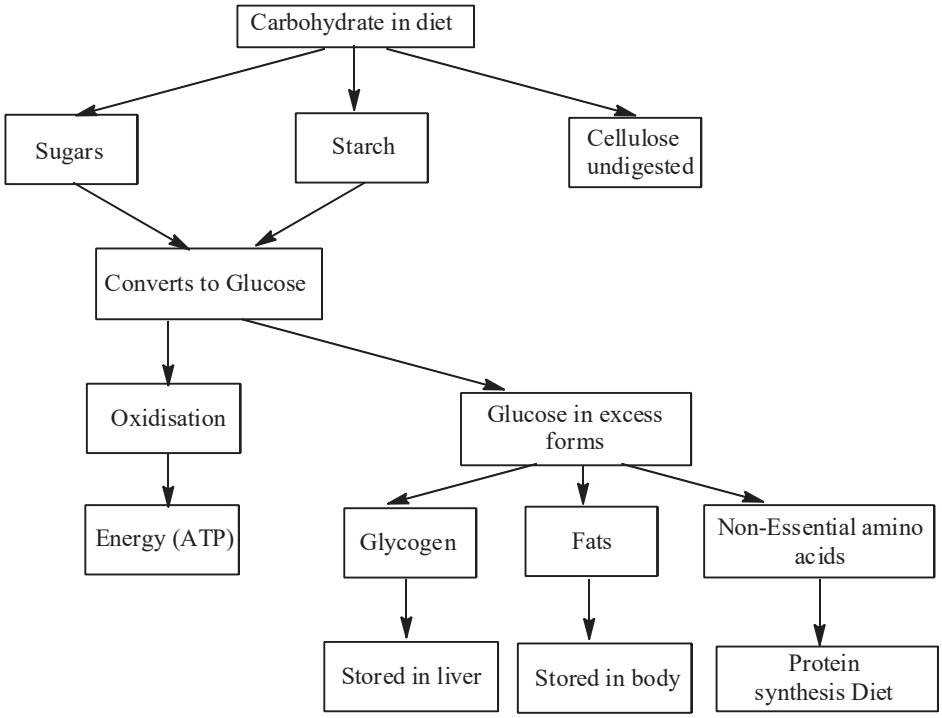


Figure 55. Carbohydrate metabolism

Carbohydrates catabolism is accompanied by the energy release, which accumulates in the macroergic bonds (~) of ATP molecules. It is used for synthesis of a cell components and carrying out work. Amino acids, lipids, nucleotides are formed from metabolites.

Carbohydrates function as biofuel. Polysaccharides (starch and glycogen) are first hydrolyzed by enzymes to glucose. Glucose is transported from one cell to another by blood in case of animals or cell sap in case of plants. Glucose is then oxidized inside the mitochondria to produce carbon dioxide, water and ATP. Energy is released in this process which is used for cells functioning.

In this way, glucose can be oxydized for energy production, stored in form of glycogen or transformed into other compounds (TAG) (fig. 56).

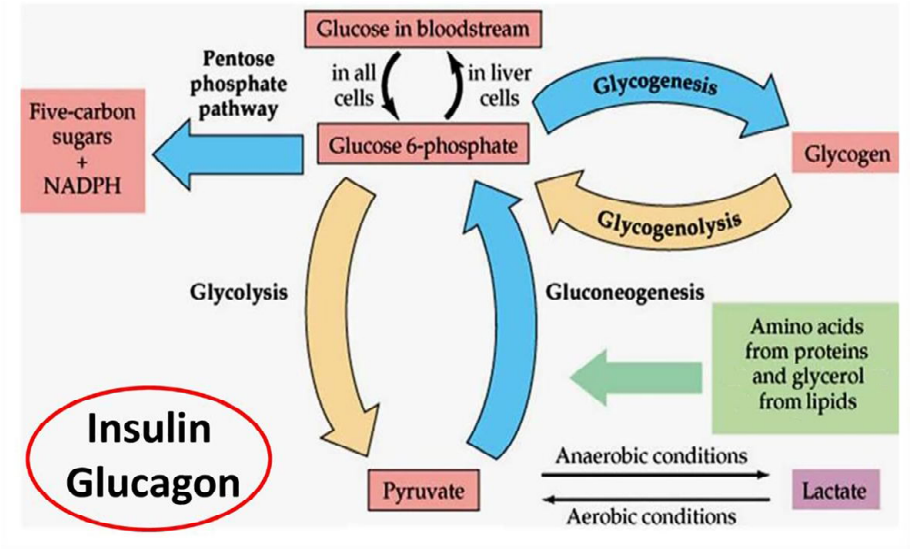


Figure 56. Main pathways of glucose metabolism [31]

When the blood glucose level increases, the pancreas releases a large amount of insulin. The rate of glucose transport to most cells is significantly increased by insulin to ten or more times the rate of transport when insulin is not secreted. Conversely, the amount of glucose that can diffuse into most body cells in the absence of insulin, with the exception of liver and brain cells, is too small to provide the amount of glucose for normal energy metabolism.

Insulin promotes the incorporation of GLUT-4 transporters into the membranes of tissues strictly glucose-dependent (e. g. erythrocytes, cells of the CNS) as well as insulin-sensitive tissues (e. g. skeletal muscle, adipose tissue). In fact, the rate of carbohydrate utilization by most cells is controlled by the rate of insulin secretion by the pancreas.

So we can say, that, the rate of carbohydrate utilization by most body cells is controlled by the rate of insulin secretion by the pancreas (fig. 57).

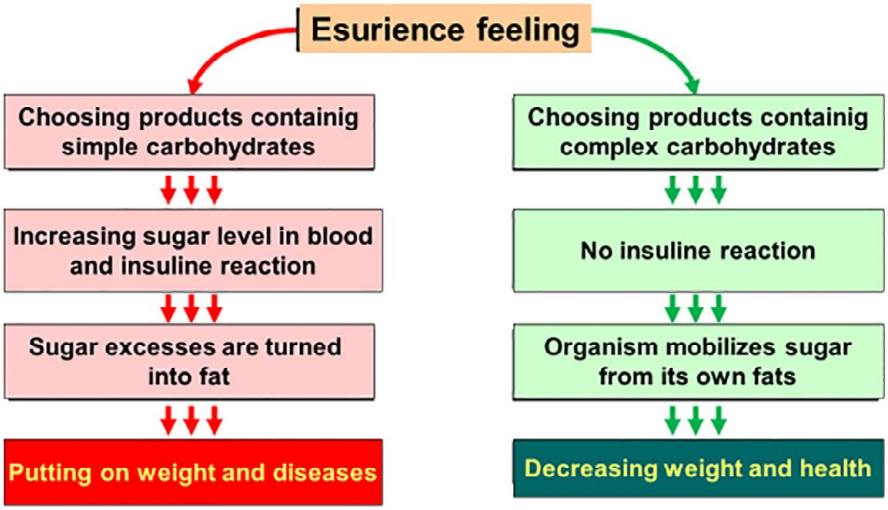


Figure 57. Carbohydrate utilization

When the pancreas stops producing insulin a person develops type 1 diabetes. While with the development of the cell membrane resistance to the action of insulin, type 2 diabetes occurs.

Low blood sugar level is called as hypoglycemia. Meanwhile, high blood sugar level is called as hyperglicemia.

According to the World health organization definition:

– normal blood sugar level in the range of 4–7 mmol/l (72–126 mg/DL);

– hyperglycemia is a condition in which blood glucose levels above 7 mmol/l (126 mg/DL) on an empty stomach and blood glucose levels above 11 mmol/l (200 mg/DL) 2 hours after eating;

– hypoglycemia is a condition in which blood glucose level below 4 mmol/l (72 mg/DL) (fig. 58).

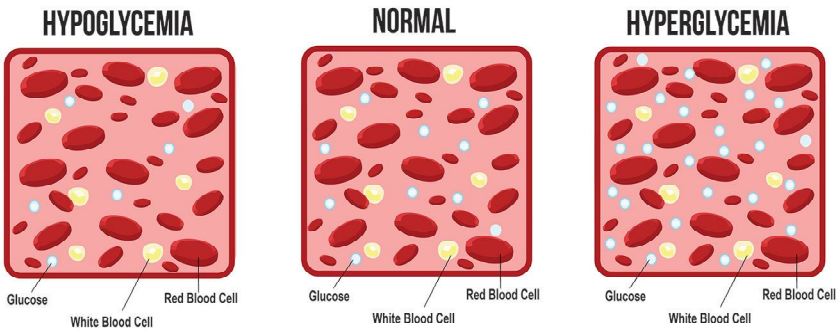


Figure 58. Blood sugar levels [32]

Figure 59 shows symptoms of hypo-and hyperglycemia.

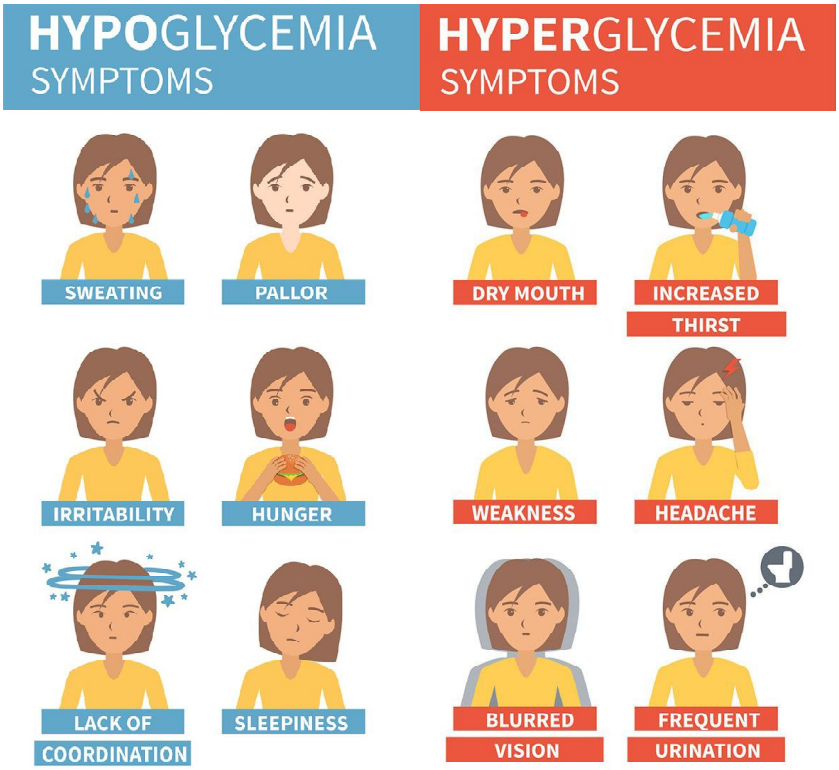


Figure 59. Hypoglycemia and hyperglycemia symptoms [33]

Choose the correct answers

	Question	Answer variants
1	Which cells contain more carbohydrates?	A. Plants. B. Animals. C. The same number in both
2	What qualities do the polysaccharides have?	A. They are easily dissolved in water, are sweet. B. They are badly dissolved in water, are sweet. C. No sweet taste, can be dissolved in water
3	What are the main biological functions of carbohydrates?	A. Protective. B. Energy and building. C. Energy and protective
4	How can you identify starch and glucose?	A. By smell. B. By dissolving in water. C. By colour

Choose the correct answers

The end of the table

	Question	Answer variants
5	What substance is related to monosaccharides?	A. Cellulose. B. Dezoxiribose. C. Sucrose
6	How much energy is released in carbohydrates breaking?	A. 38.9 kJ. B. 17.8 kJ

Control questions

1. What are digestible and non-digestible carbohydrates?
2. What functions do digestible and non-digestible carbohydrates perform in the human body?
3. What functions do polysaccharides perform in food products?

5.5. Lipids and fats

Lipids are widely distributed in nature and together with proteins and carbohydrates make up the bulk of organic substances of all living organisms, being an essential component of every cell. They are widely used in the production of many food products, are important components of food raw materials, intermediates and finished food products, largely determining their nutritional and biological value and taste.

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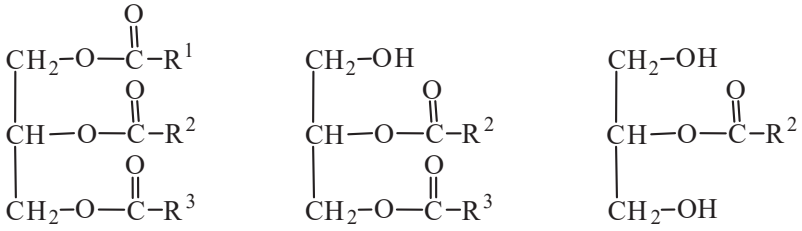
Acylglycerols are the most important and common group of simple, neutral lipids. Acylglyceroles (or glycerides) are esters of glycerol and higher carboxylic acids. They make up the bulk of lipids (sometimes up to 95 %) and, in fact, they are called fats or oils. Fat is composed of mainly triacylglycerides (TAG) and diacylglycerides (DAG) and monoacylglycerides (MAG) (fig. 60).



Triglyceride (TAG) Digliceride (DAG) Monogliceride (MAG)

Figure 60. Structures of TAG, DAG and MAG

TAG, which have unsaturated higher fatty acids in the molecule, are called oils.

Lipids according to their functions in the body are often divided into two groups – spare (reserve) and structural (protoplasmic). Spare lipids, mainly fats (TAG), having a high caloric content, are an energy and building reserve of the body, which is used by it for lack of nutrition and diseases. High caloric content of fat allows the body in extreme situations to exist at the expense of its reserves («fat depots») for several weeks.

Structural lipids (primarily phospholipids) form complexes with proteins (lipoproteins), carbohydrates, from which cell membranes and cellular structures are constructed, and participate in a variety of complex processes occurring in cells.

Vegetable fats and oils are an essential food components, a source of energy and plastic material for a person, a supplier of a number of substances necessary for it (unsaturated fatty acids, phospholipids, fat-soluble vitamins, sterols), that is, they are essential nutrition factors that determine its biological effectiveness. The recommended fat content in the human diet (in terms of calories) is 30–33 %; for the population of the southern zones of Russia it is recommended – 27–28 %, Northern – 38– 40 % or 90–107 g per day, including directly in the form of fat 45–50 g.

The physiological need for fat is from 70 to 154 g/day for men and from 60 to 102 g/day for women. The physiological need for fat for children under one year – 5.5–6.5 g/kg of body weight, for children over one year – from 40 to 97 g/day. Long-term restriction of fat in the diet or systematic use of fats with a reduced content of essential components, including butter, leads to deviations in the physiological state of the body: the Central nervous system is disrupted, the body's resistance to infections (immunity) decreases, and life expectancy is shortened. But excessive fat consumption is also undesirable, it leads to obesity, cardiovascular diseases, and premature aging.

Vegetable and animal fats have a different composition of fatty acids, which determines their physical properties and physiological and biochemical effects. Fatty acids are divided into two main classes – saturated and unsaturated (fig. 61).

Saturated fatty acids. Fatty acids with an average chain length (C8 – C14) can be absorbed in the digestive tract without the participation of bile acids and pancreatic lipase, are not deposited in the liver and undergo β-oxidation. Animal fats contain saturated fatty acids with a chain length of up to twenty or more carbon atoms. Such animal fats include mutton, beef, pork. High consumption of saturated fatty acids is a major risk factor for diabetes, obesity, heart disease. The consumption of saturated fatty acids by adults and children should not exceed 10 % of the caloric content in the daily diet.

Monounsaturated fatty acids. They include palmitoleic acid (fish and marine mammal fats), and oleic acids (olive, sesame, and rapeseed oils). Monounsaturated fatty acids in addition to their intake from food in the body are synthesized from saturated fatty acids and partially from carbohydrates.

The physiological need for monounsaturated fatty acids for adults should be 10 % of the caloric content in the daily diet.

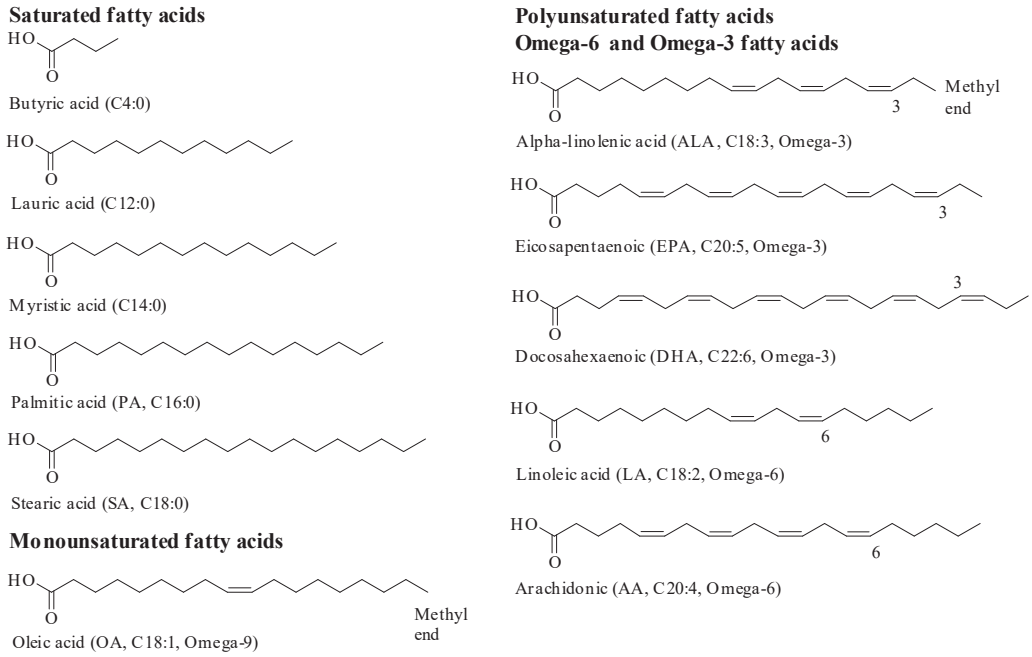


Figure 61. Structures of saturated and unsaturated fatty acids

Polyunsaturated fatty acids. Fatty acids with two or more double bonds between carbon atoms are called polyunsaturated (PUFA). Of great importance for the human body are linoleic and linolenic acids, which are the structural elements of cell membranes and ensure the normal development and adaptation of the human body to adverse environmental factors. PUFAs are precursors of bioregulators formed from them – eicosanoids.

Physiological need for PUFA for adults is 6–10 % of the caloric content in the daily diet. Physiological need for PUFA for children is 5–10 % of the calorie content in the daily diet.

Omega-6 (ω-6) and Omega-3 (ω-3) PUFAs. The two main groups of PUFA are acids of the ω-6 and ω-3 families. Fatty acids ω-6 are contained in almost all vegetable oils and nuts; ω-3 fatty acids are also found in oils (flaxseed, cruciferous seeds, soy). The main food source of ω-3 fatty acids is fatty fish and some seafood.

Of the ω-6 PUFA, a special place is occupied by linoleic acid, which is the precursor of the most physiologically active acid of this family – arachidonic. Arachidonic acid is predominant in the human body.

The physiological requirement for adults is 5–8 % of the caloric content of the daily diet for ω-6 and 1–2 % for ω-3. The optimal ratio in the daily diet of ω-6 to ω-3 fatty acids should be 5–10 : 1. Physiological need for ω-6 and ω-3 fatty acids is 4–9 % and 0.8–1.0 % of the caloric content of the daily diet for children from 1 to 14 years old, 5–8 % and 1–2 % for children from 14 to 18 years old respectively.

5.6. Vitamins

Vitamins are low-molecular organic compounds of various chemical nature, catalysts, bioregulators of processes running in a living organism (tab. 7).

Table 7

The Vitamins

The Vitamins		Functions	Deficiency Disease
Vitamin Lipid-soluble			
A	Retinol, β-carotene	Visual pigments in the retina; regulation of gene expression and cell differentiation (β-carotene is an antioxidant)	Night blindness, xerophthalmia; keratinization of skin
D	Calciferol	Maintenance of calcium balance; enhances intestinal absorption of Ca^{2+} and mobilizes bone mineral; regulation of gene expression and cell differentiation	Rickets = poor mineralization of boneosteomalacia = bone demineralization
E	Tocopherols, tocotrienols	Antioxidant, especially in cell membranes; roles in cell signaling	Extremely rare – serious neurologic dysfunction
K	Phylioquinone: menaquinones	Coenzyme in formation of γ-carboxyglutamate in enzymes of blood clotting and bone matrix	Impaired blood clotting, hemorrhagic disease
Water-soluble			
B_1	Thiamin	Coenzyme in pyruvate and α-ketoglutarate dehydrogenases, and transketolase; regulates Cl^- channel in nerve conduction	Peripheral nerve damage(beriberi) or central nervous system lesions (Wernicke-Korsakoff syndrome)
B_2	Riboflavin	Coenzyme in oxidation and reduction reactions (FAD and FMN); prosthetic group of flavoproteins	Lesions of corner of mouth, lips, tongue, seborrheic dermatitis
Niacin	Nicotinic acid, nicotinamide	Coenzyme in oxidation and reduction reactions, functional part of NAD and NADP; role in intracellular calcium regulation and cell signaling	Pellagra photosensitive dermatitis, depressive psychosis
B_6	Pyridoxine, pyridoxal, pyridoxamine	Coenzyme in transamination and decarboxylation amino acids and glycogen phosphorylase; modulation of steroid hormone action	Disorders of amino acid metabolism, convulsions

The end of the tab. 7

The Vitamins		Functions	Deficiency Disease
	Folic acid	Coenzyme in transfer of one-carbon fragments	Megaloblastic anemia
B_{12}	Cobalamin	Coenzyme in transfer of one-carbon fragments and metabolism of folic acid	Pernicious anemia = megaloblastic anemia with degeneration of the spinal cord
	Pantothenic acid	Functional part of CoA and acyl carrier protein: fatty acid synthesis and metabolism	Peripheral nerve damage (nutritional melalgia or «burning foot syndrome»)
H	Biotin	Coenzyme in carboxylation reactions in gluconeogenesis and fatty acid synthesis; role in regulation of cell cycle	Impaired fat and carbohydrate metabolism, dermatitis
C	Ascorbic acid	Coenzyme in hydroxylation of proline and lysine in collagen synthesis; antioxidant; enhances absorption of iron	Scurvy-impaired wound healing, loss of dental cement, subcutaneous hemorrhage

For normal life activity human needs small amounts of vitamins, but as they are not synthesized in the organism (or they are, but in an insufficient amount), they must be received with food as an essential component. Some vitamins in a limited number are produced by intestine microflora.

Absence or lack of vitamins in the organism causes various pathological (sick) conditions.

The absence or lack of vitamins in the body causes diseases of insufficiency: hypovitaminosis (diseases resulting from long-term deficiency) and avitaminosis (diseases caused by the absence or pronounced deep deficiency of vitamins). The lack of one vitamin relates to monohypovitaminosis, several vitamins – to polyhypovitaminosis.

With hypovitaminosis, fatigue, loss of appetite, irritability, instability to diseases, bleeding gums are observed.

The main reason for the vitamins lack in the human body is their insufficient intake with food (primary, exogenous vitamin deficiencies), however, in some cases, endogenous or secondary vitamin deficiencies are observed, associated with impaired absorption of vitamins in the body.

According to the Nutrition Institute of the Russian Academy of Medical Sciences (V. B. Spirichev), the most important causes of hypo- and vitamin deficiency are the following:

1) insufficient intake of vitamins from food, associated with their low content in the diet, a decrease in the total amount of food consumed, loss of vitamins during the technological process;

2) suppression of the intestinal microflora that produces some vitamins;

3) vitamins assimilation is impaired;

4) increased need for vitamins, associated with the characteristics of the body physiological state or intense physical activity, special climatic conditions;

5) congenital genetically determined disorders of the metabolism and vitamins functions.

When vitamins are taken in quantities significantly exceeding physiological norms, hypervitaminosis may develop. This is especially true for fat-soluble vitamins.

Biological role of vitamins lies in the fact that they form part of coenzymes and prosthetic groups of enzymes and consequently are used by organism as a building material in synthesizing nonprotein parts of enzymes.

Certain food products contain provitamins, compounds capable of turning into vitamins in the organism. For example, β-carotene turns into vitamin A, ergosterols turn into vitamin D in human's organism under the action of ultraviolet rays.

As units of vitamins quantity measurement milligrams are used (1 mg = 10^{-3} g), micrograms (1 mcg = 10^{-6} g) per 1 g of product or mg % (milligrams of vitamins per 100 g of product).

Human's need in vitamins depends on his age, health status, life conditions, kind of activity and presence of main nutritional components in food.

The following questions are proposed for independent study:

1) significance of unsaturated fatty acids in human nutrition;

2) cholesterol and its biological functions;

3) disorder of human organism provision with vitamins – hypo-, hyper-, and avitaminosis;

4) physiological functions of the main macro- and microelements.

Answer the questions

1. How do ATP and ADP differ in structure?
2. Why is ATP referred to as the energy currency of the cell?
3. Why does the hydrolysis of ATP to ADP involve the release of energy?

Choose the correct answer

Identify whether each compound would be classified as a high-energy phosphate compound:

a) ATP;

b) glucose-6-phosphate;

c) creatine phosphate.

Identify whether each compound would be classified as a high-energy phosphate compound:

a) ADP;

b) AMP;

c) glucose-1-phosphate.

6. MODERN NOTIONS ABOUT RATIONAL NUTRITION

6.1. Fundamentals of rational nutrition

Law of energy adequacy

Food products are an energy source for the organism. The amount of energy entering organism with food should correspond with the amount of energy expended by organism.

Energy needs depend on age, gender, body mass and functional activity of an organism. In case of insufficient nutrition functional and adaptive abilities of the organism reduce. To cover energy requirements organism starts using muscle proteins.

Constant energy deficiency leads to body mass reduction, dystrophy, oedemas and marasmus (dementia).

Excessive nutrition leads to the increase of body mass, obesity and different diseases (diabetes 2 type, atherosclerosis, cholecystitis).

Law of plastic adequacy

Food substances must get into organism in balanced quantities, meeting the needs of the organism. Food products must contain proteins, fats, carbohydrates, vitamins, mineral substances and water by all means. They are necessary for constant renewal of organism cells and tissues. Therefore, nutrition should be varied. Ration must contain products of all the main groups – cereals, meat, fish, eggs, vegetables, fruit, dairy products and fats.

Law of enzymatic adequacy

Chemical composition of food must be relevant to enzymatic systems of the organism. For example, if human's activity is very low or he doesn't have β-galactosidase enzyme, he is observed to have milk intolerance because of the lactose hydrolysis process disturbance.

Switching to new diets and nutrition systems can result in unwanted consequences because of rearrangement in the complex of enzymes involved in digesting. One should take into account that fasting or dramatic decrease in the amount of food reduces activity of the digestive system and cuts the production of digestive juices. For that reason, one should move out of such dietary regimes gradually and carefully.

Law of biotic adequacy of nutrition

If some food causes sickly reactions, it must be excluded from the food ration. The reason of sickly reactions can be not only the absence of digestive enzymes, but also the presence of harmful substances in food – heavy metals, nitrites, toxic

chemicals et al. That is why food must be harmless (ecologically pure) and mustn't bring alien substances into internal environment of the organism. Attention must be paid to the content of food products shown on packaging as well as to colour, consistency and smell of food products.

Law of keeping dietary regime

Dietary regime must be relevant to the biological rhythms and social specific features of life.

General fundamentals of rational dietary regime have been formulated:

1) nibbling (not less than 4 times a day);
2) food intake at the same time;
3) duration of time intervals between meals must not exceed 6 hours;
4) dinner must be eaten not later than 2–3 hours before going to bed.

6.2. Some physiological requirements to nutrition

Food is a complex mixture of food products prepared for nutrition. Food ration is the content and the amount of food products used during the day. The following requirements are imposed on food ration:

1) energy value of food ration must cover sportsman organism's energy expenses;
2) optimal quantity of balanced nutrients;
3) good assimilability of food;
4) high organoleptic properties of food (show, consistency, smell, taste, temperature);
5) diversity of food due to broad assortment of products and techniques of their culinary processing;
6) ability of food to bring about the sense of fullness (content, volume, culinary processing);
7) sanitation and epidemic perfection and safety of food.

Assimilation of food starts from digestion in gastro-intestinal tract, continues during absorption of food substances into blood and lymph and finishes with assimilation of food substances by organism's cells and tissues.

Assimilability of food is the degree to which the organism uses the contained nutrients. It depends on the ability of amino acids, glycerin, higher fatty acids and monosaccharides, formed under enzymes action during digestion, to be absorbed from small intestine into blood. Assimilability of food substances depends on the peculiarities of products included into food ration, techniques of culinary processing and condition of digestive system.

Balance nutrition provides organism with all nutrients in definite proportions. So, for example, approximate balance by some indices is:

– proportion between proteins, fats and carbohydrates in daily ration must be 14 : 30 : 56;

– share of proteins with animal origin must be 55 % from the total number of proteins;

– vegetable oils as a source of essential fatty acids must amount to 30 % from the total number of fats;

– starch – 75–80 %, easily digested carbohydrates (glucose, saccharose, fructose) – 15–20 %, fibre and pectin substances – 5 % from the total number of carbohydrates;

– the best for the digestion proportion of Ca, P, Mg = 1 : 1.5 : 0.5;

– vitamin C – 25 mg, B_1 – 0.6 mg, B_2 and B_6 – 0.7 mg, PP – 6.6 mg (per 1000 kcal).

The notion of correct dietary regime includes:

1) food dosage frequency (the number of meals during the day);

2) distribution of daily ration by energy value, chemical composition, product assortment and mass over separate food intakes;

3) time of food intakes during the day;

4) time intervals between food intakes;

5) time spent for the food intake.

Correct dietary regime is necessary for the active and effective work of digestive system and adequate food digestion.

Three-four meals a day are considered to be the most rational nutrition with the intervals between food intakes of 4–5 hours.

Breakfast must be 30 %, lunch – 35–40 %, dinner – 35–30 % of daily caloric value. The number of food intakes depends on the volume and caloric value of daily ration: if volume and caloric value rise, food dosage frequency should be increased too, since digesting and assimilating of food can be incomplete in case of single-step intake of huge amount of food, there arise discomfort (feeling of weight, abdominal distension etc.) and performance decrement.

Everybody has their definite habits and peculiarities formed by the years. Such habits refer to nutrition as well. Some prefer meat, others – fish, still others – dairy-vegetable food. Dramatic sudden change of nutrition system can lead to sport performance decrement.

Habitualness of food assortment has a great significance for identifying the volume of daily food ratio as well. The point is that a sense of fullness is not defined by caloric value of nutrition, but by the degree of stomach filling. Consequently, if people, who are used to low-volume but high-caloric meat food, are moved to high-volume but less caloric vegetable food, they will be sated having taken in the amount of food obviously insufficient in its caloric value. Switching from vegetable to meat food can vice versa lead to overeating, as food giving enough caloric value, due to its small volume will not cause satiety.

For the food to be digested well it must be consumed regularly. Having acquired a habit to eat at a particular time, human always feels appetite at exactly this time and, as I. P. Pavlov showed, appetite is accompanied by intensification of digestive

juices production. If person misses lunch time, then his appetite slackens. Food intake without appetite leads to deterioration of its digesting and assimilating as loss of appetite is accompanied by reduction in digestive juices excretion.

Disorder of dietary regime (eating with no drinks, rare and ample meals, erratic meals) can lead to alimentary organs diseases.

The following questions are suggested for independent study and further discussion:

1) separate nutrition;
2) vegetarianism;
3) fasting;
4) diets.

7. PRODUCTS CREATION PRINCIPLE FOR ALIMENTARY CORRECTION OF HOMEOSTASIS DISORDER

7.1. General principles of making up clinical and prophylactic nutrition rations

Clinical nutrition must meet all the demands of the sick organism in food substances to the full extent and take into account both peculiarities of metabolic processes and the condition of functional systems.

The main task of clinical nutrition is to recover the upset balance in the organism during disease by means of adjusting chemical composition of food ration to the metabolic peculiarities of the sick organism through selecting and combining food products, choosing technique of culinary processing regarding the condition of sick person's organs and systems.

Clinical nutrition is built in accordance with the physiological principles of building food rations in the form of diets. Any diet must be characterized by:

1) chemical composition and caloric value of food products (certain amount of proteins, fats, carbohydrates, vitamins and mineral substances);

2) physical properties of food (consistency, temperature, mass, volume);

3) techniques of food culinary processing;

4) dietary pattern (number of meals, time of food intakes, distribution of daily ration over separate food intakes).

Clinical and prophylactic nutrition must be built taking into account sick person's organism's physiological requirements, that is why any diet must satisfy certain demands:

1) to alter by its energy value based on the organism's energy expenses;

2) to cover organism's balanced requirement in food substances;

3) to lead to an optimal stomach filling, causing a light sense of fullness;

4) to satisfy sick person tastes with consideration of acceptability of food and variety of dietary menu. Unvaried food bores fast, promotes appetite reduction, and insufficient excitation of the digestive system activity worsens assimilation of food;

5) to provide culinary processing of food preserving gustatory qualities of food and valuable properties of original food products;

6) observe the principle of regular nutrition.

Since any therapeutic diet is restrictive, one-sided and inadequate, long-term keeping strict diets can lead to both partial shortage of a number of food substances and detraining of the broken functional mechanisms during the recovering period.

Therefore, diet therapy applies sparing principle, which consists in excluding food products promoting maintaining or advance of pathological process (mechanical, chemical, thermal irritators) and training principle based on broadening of the strict diet and switching to wholesome feeding schedule.

For creating medical and preventive orientation of food rations for people of different age brackets and state of health to provide organism with optimal quantity of biologically and energetically valuable substances, it is necessary to use specialized food products, enriched with vitamins, mineral salts, food vegetable fibres and various food additives.

7.2. Food additives

Three main groups of components are marked out the chemical composition of food products:

1) component parts of alimentary raw materials;
2) food additives;
3) biologically active additives.

Food additives are substances of natural or synthetic origin, they are deliberately introduced into food products during their production to impart definite properties and (or) to preserve their properties. Food additives are not consumed as food; from the technological point of view they are added to food products to solve the following tasks:

– improvement of presentation and organoleptic properties;
– increase of period of storage;
– changing technology of obtaining.

Moreover, food additives have to be harmless and must not have a toxic effect on organism, including such remote effects as carcinogenic, mutagenic, teratogenic and gonadotoxic effects. To determine permissible concentration of food additive «Acceptable daily intake» (ADI) in human organism is used. Acceptable daily intake is such an amount of food additive (in mg per kg of body mass), which a human can get daily throughout all his life without rendering harm to his health.

In food products technology the following groups of food additives are used:

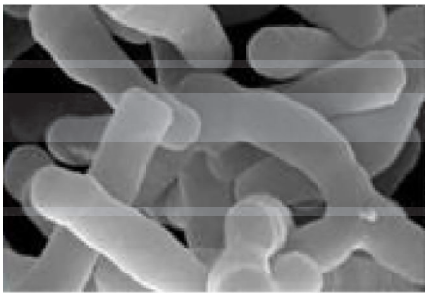
1) colorants;
2) preservatives;
3) antioxidants;
4) consistency stabilisers;
5) emulsifiers;
6) acidity regulators;
7) flavor enhancers;
8) antiflamings.

7.3. Probiotics, prebiotics and synbiotics

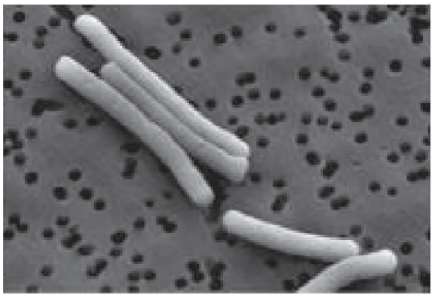
The term «probiotic» (from Greek pro – for and bios – life) was first used by Ferdinand Virgin in his article «Anti- und Probiotika. Hippokrates» in 1954. Probiotics are mixed culture of live bacteria which exert a beneficial effect on the health of organism.

The most important among various types of microorganisms-probiotics are microorganisms of the genera *Bifidobacterium*, *Lactobacillus*, *Propionibacterium*, as well as bacteria of the genus used in associations with them *Lactococcus*, a species of *Streptococcus thermophilus* (fig. 62).

Propionibacterium



Bifidobacterium



Lactobacillus

Figure 62. Probiotic microorganisms

Probiotic bacteria must be resistible when passing through upper gastro-intestinal tract into large bowel where they populate and propagate excreting enzymes and other biologically active substances in the process of their vital functions. Furthermore, they favour propagation of useful bacteria, which suppress growth of pathogenic microflora. Since probiotic bacteria are not included into regular micro flora of human bowels, they have to be taken regularly and durably with food to get a positive effect exerted on man's health. Not only bacteria are used as probiotics, but also yeast fungus.

Probiotics are not considered medicines for the prevention and treatment of diseases but are considered to have a beneficial effect on health or as dietary

supplements. Probiotics can be included in the diet as additives in the form of freeze-dried powders containing *bifidobacteria*, *lactobacteria* and their combinations.

Modern probiotics are divided into two groups depending on their production technology. The first group of probiotics is produced using the method of lyophilic drying of the substrate of living active cells. Drugs are produced in the form of powder, tablets, capsules or candles. These forms have a long shelf life (up to 1 year) and can tolerate short-term changes in storage temperature. Their significant disadvantage is that the lyophilization process puts the bacteria in suspended animation (inactive state). To return to an active physiological state, they need 8–10 hours, and during this time, most of the bacteria is already removed from the human intestine. In addition, during the lyophilization process, bacterial cells lose specific receptors that help them attach to surfaces, so their time in the gut is further reduced.

In the production of the second group liquid probiotics-microbial cells remain active and are able to colonize the gastrointestinal tract for 2 hours after entering the body. Liquid forms of medicines contain an additional therapeutic factor products of the metabolism of active forms of living bacteria. Among them, low-molecular-weight fatty acids, which evaporate during lyophilization, are very important

Prebiotics are indigestible substances, more often oligosaccharides which are contained in plants and enter the composition of all mammals' milk. They are natural environment in which probiotic bacteria live before getting into human organism. Prebiotics are food components (they are contained in dairy products, corn flakes, cereals, bread, vegetables and fruit), they get into the large bowel in an undigested form and serve a source of nutrition for lacto- and bifidus bacteria, as well as human intestinal micro flora. Prebiotics are not medicinal products.

Prebiotics and probiotics cannot be contrasted with each other. The best way is to use them together. In this case, prebiotics enhance the therapeutic effect of probiotics, contributing to the better survival of probiotic strains in the intestine.

Synbiotic is a mixture of probiotics and prebiotics. A synbiotic is defined as a «mixture of probiotics and prebiotics that beneficially affects the host by improving the survival and activity of beneficial microorganisms in the gut» (from: Dietary Interventions in Gastrointestinal Diseases, 2019). Synbiotics are used as additives to functional products. They have a beneficial effect on the health of the host organism, improve the survival in the gut of live bacterial additives, and selectively stimulate the growth and activation of the metabolism of endogenous lacto- and bifidobacteria.

8. METHODOLOGY INSTRAKTIONS FOR PRACTICAL STUDIES

These recommendations are designated for carrying out studies and students' self-preparation for practical studies on «Nutrition physiology» course.

8.1. PRACTICAL STUDY 1. Digestion, metabolism and energy exchange

Questions given to students in advance for discussing at the practical study

1. What role does digestive system play in securing vital functions of the organism?
2. What is the digestive system structure?
3. What physical and chemical transformations of fats, proteins and carbohydrates take place in each gastrointestinal tract segment?

The human body constantly expends energy during its activity (see tab. 7). These energy expenses require compensation by all means, without it life cannot continue. This compensation is done through nutrition.

Simultaneously with energy expenses a continuous turnover of proteins of which tissues and organs are built takes place during life activity. Instead of decaying proteins new tissue proteins, enzymes, immune globulins are created in the organism. Hence, apart from energy sources, plastic material is necessary all the time for building substances inherent for the human organism. Both things are done through nutrition.

So, nutrition performs two functions:

1) *energy function* – to provide organism with substances, which are energy sources (proteins, fats, carbohydrates);

2) *plastic function* – to provide organism with substances, necessary to build tissues and organs (proteins, lipoids).

Apart from proteins, fats and carbohydrates food must contain other substances necessary for the organism – vitamins, mineral salts and water.

Organism needs depend on the age, gender, body weight. Amount of energy coming with the food must correspond with the amount of energy expended by the organism.

In the tab. 8 you can see energy expenditure during various activities for adult.

Table 8

An adult energy expenditure during various activities

Activity	Energy expenses, kcal/h
Sitting	15
Standing	20
Getting dressed, getting undressed	33
Personal hygiene	65
Making the bed	100–144
Doing gymnastics	200–500
Intellectual labour	7–8
Reading	20–35
Singing	37–56
Sewing	10–20
Knitting	31
Washing	130–230
Ironing	59
Washing up	59
Dusting	110
Sweeping the floor	180
Washing the floor	270
Slow walking	115
Medium speed walking	200
Fast walking	535
Going by transport	40–50
Driving a car	80
Riding a bike	130–600
Swimming	200–520
Jogging	485
Running	960
Skiing	485–960

Using the data in table 6 and taking into account the duration of each type of physical activity you can calculate the regulated energy expenditure of a person per day (tab. 9).

Table 9

Regulated energy expenditure

Activity	Time, min	Energy expenses, kcal/h	Calculation of energy expenses, kcal
Sitting	360	15	$15 \times \frac{360}{60} = 90$
Standing	30	20	$20 \times \frac{30}{60} = 10$
Getting dress	3	33	$33 \times \frac{3}{60} = 1.65$
Intellectual labour	180	8	$8 \times \frac{180}{60} = 24$
Doing gym	90	350	$350 \times \frac{90}{60} = 525$
Reading	120	30	$30 \times \frac{120}{60} = 60$
Making the bed	2	120	$120 \times \frac{2}{60} = 4$
Personal hygiene	20	65	$65 \times \frac{20}{60} = 22$
Slow walking	90	115	$115 \times \frac{90}{60} = 172.5$
Jogging	10	485	$485 \times \frac{10}{60} = 80.8$
Total	905	–	990

If the organism gets insufficient nutrition, its functional and adaptive possibilities reduce and to meet energy needs an organism starts using muscle proteins.

The easiest way to control if caloric content of food is adequate to daily energy expenses is changing body weight.

Constant energy deficit leads to body weight reduction, dystrophia, edemata, alimentary marasmus (dementia).

Hyper nutrition leads to growth of body weight, obesity (see tab. 9), and also to different diseases – diabetes, atherosclerosis, cholecystitis.

There are several methods to estimate body weight with the help of different indices.

1. World Health Organization, (WHO) recommends using **Body Mass Index** (BMI) or **Quetelet Index**. BMI devised by Adolphe J. Quetlet (fig. 63) and called it as «Social Physics».

Figure 63. Adolphe Jacques Quetlet (1796–1850) [34]

This index is expressed in units of kg/m^2. BMI is applicable for both men and women aged 20 to 65 (tab. 10).

$$\text{BMI} = m/h^2,$$

where m – person body weight, kg; h – height, m.

Table 10

Obesity classification by BBI

Nutrition (food) status	BBI value depending on the age	
	18–25 years old	26–45 years old
Underweight	less 19.5	less 20.0
Normal weight	19.5–22.9	20.0–25.9
Excessive weight (pre-obesity)	23.0–27.4	26.0–27.9
Obesity 1st degree	27.5–34.9	28.0–35.9
Obesity 2nd degree	35.0–39.9	36.0–40.9
Obesity 3rd degree	40.0 and more	41 and more

BMI chart is shown at the fig. 64. Curved lines show the cutoffs between the BMI categories, as specified by the WHO.

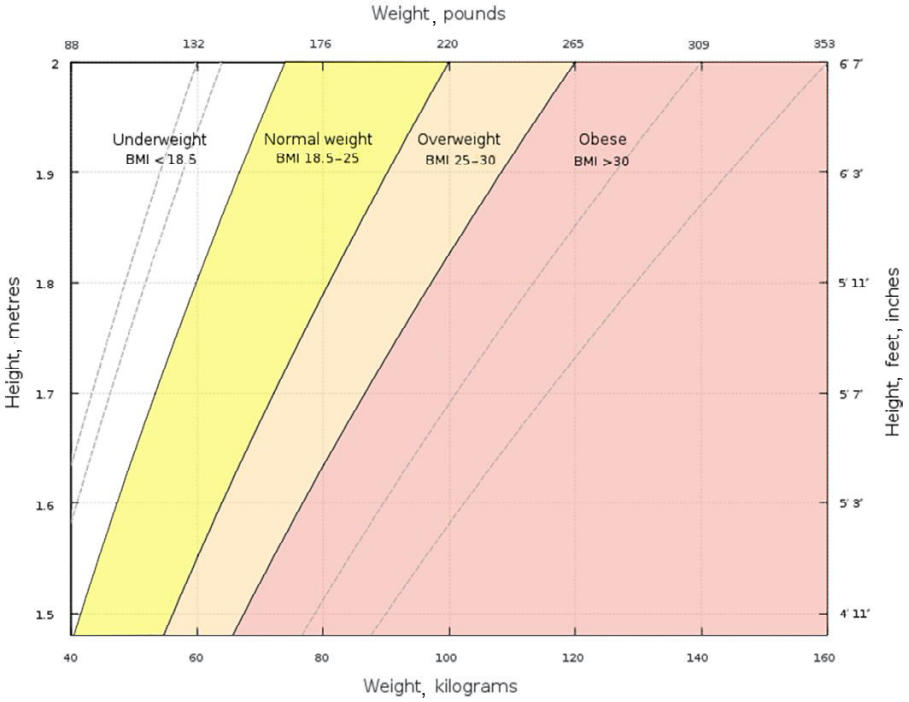


Figure 64. BMI chart

2. **Broca Index**. This index was developed by Paul Broca (fig. 65).

Figure 65. French surgeon and anatomist Paul Broca (1824–1880) [35]

At the height of 155–165 cm deduct (in cm) 100 from height.

At the height 166–175 cm – 105.

At the height more than 175 cm – 110.

3. **Breitman Index (Normal weight formula**).

The Breitman index uses only the height indicator to determine normal weight.

$$\text{Normal weight} = 0.7 \times H - 50 \text{ kg},$$

where H – height, cm.

Example of calculating the normal weight for a woman with a height of 165 cm according to the Breitman index:

$$\text{Normal weight} = 0.7 \times 165 - 50 = 115.5 - 50 = 65.5 \text{ (kg)}.$$

Example of calculating the normal weight for a man with a height of 180 cm according to the Breitman index:

$$\text{Normal weight} = 0.7 \times 180 - 50 = 126 - 50 = 76 \text{ (kg)}.$$

4. **Borngard Index**. The Borngard index was developed in 1886. For his calculations of the ideal weight, Borngard used such a factor as the chest circumference, thereby increasing the accuracy of the commonly accepted formulas at the time.

$$\text{Ideal weight} = H \times C : 240,$$

where H – height, cm; C – chest circumference, cm.

Example of calculating ideal weight according to the index of Bernhardt for women. The ideal weight for a woman with a height of 165 cm, chest circumference of 88 cm, according to the Borngard index:

$$\text{Ideal weight} = 165 \times 88 / 240 = 60.5 \text{ (kg)}.$$

Example of calculating ideal weight according to the Borngard index for men. The ideal weight for a man with a height of 180 cm, chest circumference of 100 cm, according to the Borngard index:

$$\text{Ideal weight} = 180 \times 100 / 240 = 75 \text{ (kg)}.$$

Task for students' self-study at the class

Calculate your body weight by different methods with the help of indices (1–4), make a conclusion.

8.2. PRACTICAL STUDY 2. Energy value of dishes. Modelling the process of human energy expenses compensation

At the beginning of a study a frontal discussion is organized when the following questions are discussed:

1) modern view of human nutrition and its energy reasonability;

2) main nutrients, their energy and biological value;

3) adult daily nutrient and energy requirements;

4) energy needs and organism physiological state – basis of making up a balanced diet;

5) principles of rational nutrition – moderateness, variety, biological value, balance;

6) making up a diet.

Task for students' self-study at the class

Make up a daily menu for your family and calculate energy value and elements content in daily ration products using reference data. Some of them are given below.

Element content (mg) per 100 g of a product

Calcium. Cheese – 1 050, dry milk – 919, lamb 1-st cat. – 270, parsley – 245, chocolate – 187, dried mushrooms – 184, beans – 150, peas – 89, buckwheat – 70, oatmeal – 64, eggs – 55.

Potassium. Cocoa powder – 2 403, beans – 1 100, dry milk – 1 000, peas – 731, potatoes – 568, green peas – 360, garden radish – 357, lamb 1-st cat. – 345, parsley – 340, cod – 338, beetroot – 288, apples – 248, buckwheat – 167.

Magnesium. Oatmeal – 142, dry milk – 139, beans – 103, millet – 101, buckwheat – 98, cocoa powder – 90, peas – 88, parsley, sorrel – 85, wheat flour – 73, eggs – 54, green peas, carrots – 38.

Sodium. Cheese – 1 000, dry milk – 400, green peas – 360, fish – 157, beetroot – 86, eggs – 71, turnip – 58, tomatoes – 40, potatoes – 28, carrots – 21, garden radish – 17, cabbage, oranges – 13.

Iron. Dried mushrooms – 35.0, beans – 12.4, cocoa powder – 11.7, millet – 10.0, buckwheat – 8.0, oatmeal – 7.9, apples – 2.2.

Phosphorus. Dry milk – 790, cocoa powder – 771, dried mushrooms – 606, cheese – 594, beans – 541, oatmeal – 361, buckwheat – 298, chocolate – 235, millet – 233, peas – 226, cottage cheese – 217, green peas – 122, parsley – 95, potatoes – 58, carrots – 55.

Products energy value (kcal/100 g of a product)

Sunflower oil – 899, dry milk – 475, cheese – 400, sugar – 374, cocoa powder – 373, oatmeal – 345, millet – 344, pasta – 332, wheat flour – 329, buckwheat – 326, rice, peas – 323, beans – 309, potato starch – 299, high fat cottage cheese – 226, dried mushrooms – 209, lamb 1-st cat. – 203, eggs – 157, concentrated milk – 135, potatoes – 83, cod – 75, green peas – 72, beetroot – 48, apples – 46, parsley – 45, garden radish – 34, carrots – 33, lemon – 31, turnip, cabbage, sorrel – 28, tomatoes – 19.

Order of calculation

1. Calculate approximate menu content for one person.

For example, soup is cooked for 30 people, 2 kg of carrots, 3 kg of potatoes, 300 g of onion and 200 g of parsley are taken for this. Then there is 30 times less of each product per person and writing in the menu is like that.

«Vegetarian» soup (portion for 1 person): carrots – 66 g, potatoes – 100 g, onions – 10 g, parsley – 6.6 g.

2. Calculate nutritive value of one portion (valuable elements content, g). Use reference data for the calculation, which contain elements content per 100 g of product. To identify these elements content per portion it's necessary to recount mass calculated in item 1.

For example, it's seen from the reference data that carrots contain sodium and phosphorus, potatoes contain sodium and phosphorus, parsley contains calcium, potassium, magnesium and phosphorus. Then total content in one portion of soup of sodium, for example, will be:

– in a carrot weighing 66 g: 13.8 mg · (at 21 mg per 100 g);

– in a potato weighing 100 g: 28.0 mg · (at 28 mg per 100 g).

Total sodium: 13.8 + 28.0 = 41.8 (mg).

3. Calculate energy value of one portion (in kcal), using reference data, similarly to item 2.

8.3. PRACTICAL STUDY 3. Making up a map of food and energy value of nutrients

Energy value of food products characterizes that part of energy that is liberated from the food products during the process of biological oxidation and is used for the physiological functions of human organism. In the food standards people aged from 18 to 60 are divided into groups of labor intensity. The groups differ in energy expenses rates due to professional activity (tab. 11).

In making up daily ration it's necessary to take into account balanced proportion of food substances:

– animal proteins: vegetable proteins = 55 % : 45 %;

– animal fats : vegetable fats = 70 % : 30 %;

– starch : sugars : fibre = 70–75 % : 20–25 % : 5–10 %;

– calcium : magnesium : phosphorus = 1.0 : 0.5 : 1.5.

Basing on the chemical composition of food products on the ready products packaging, energy value is calculated by the following formula:

$$E = 4.0 \cdot P + 9.0 \cdot F + 4.0 \cdot C + \kappa \cdot M_{acid},$$

where E – energy value of a food product, kcal/100 g; P – protein mass per 100 g of a product, g; F – fat mass per 100 g of a product, g; C – carbohydrates mass per 100 g of a product, g; M_{acid} – organic acid mass content per 100 g of a product g; 4.0; 9.0; 4.0; κ – energy value coefficients of correspondingly proteins, fats, carbohydrates, organic acids contained in a food product, kcal/g (tab. 12).

Table 11

Energy value of different population groups daily ration, %

Labor groups	Proteins	Fats	Carbohydrates
I. Intellectual workers, very light physical activity (scientific workers, humanitarian major students, teachers, dispatchers)	13	33	54
II. Light labor workers, light physical activity (tram, trolleybus drivers, conveyor workers, packers, radio-electronic industry workers, agronomist, nurses, hospital cleaners, communications officers, service employees, manufactured goods salesclerks	12	33	56
III. Medium hard physical labor workers, medium physical activity (mechanics, adjusters, tuners, machine operators, drilling technicians, excavators and bulldozers drivers, bus drivers, surgeons, textile workers, workers of the shoemaking industry, railway men, miners drivers, food commodities salesclerks, machinery operators, blast furnace operators, chemical plant workers	12	33	55
IV. Hard physical labor workers, high physical activity (construction workers, drilling technician's assistants, drift miners, farm workers and machine operators, milkmaids, vegetable growers, woodworkers, metallurgists and casters)	11	33	56
V. Especially hard physical labor workers, very high physical activity (machine operators and farm workers in sowing and harvesting campaigns, miners, tree fellers, concrete workers, brick masons, diggers, loaders, reindeer breeders)	11	3	56

Table 12

Energy value coefficients of main food products nutrients

Nutrients	Energy value coefficient, kcal/g
Proteins	4.0
Fats	9.0
Carbohydrates	4.0
Sum of mono- and disaccharides	3.8
Starch, identified experimentally	4.1
Fibre	0.0

The end of the tab. 12

Nutrients	Energy value coefficient, kcal/g
Organic acids:	
acetic	3.5
malic	2.4
lactic	3.6
lemon	2.5

Nutritive value of food products – characterizes organoleptic and useful properties of a food product, including extent to which it covers human physiological needs in main nutrients and energy (tab. 13).

Table 13

Human physiological need in main nutrients and energy

Nutrient	Daily requirement
Proteins	75 g
Fats, including:	83 g
saturated fatty acids	25 g
polyunsaturated fatty acids	11 g
cholesterol	300 mg
Digestible carbohydrates, including:	65 g
saccharose	50 g
food fibers	30 g
organic acids	2 g
Mineral substances: Na	2 400 (not more than 6.15 g of edible salt)
Ca	1 000 mg
P	1 000 mg
K	3 500 mg
Mg	400 mg
Fe	14 mg
Zn	15 mg
I	0.15 mg

The end of the tab. 13

Nutrient	Daily requirement
Vitamins: B_1	1.5 mg
B_2	1.8 mg
PP	20 mg
1	2 mg
B_6	2 mg
C	70 mg
B_{12}	3 mcg
D	5 mcg
A	1 000 mcg
E	10 mcg
Energy value	2 500 kcal/day

Task for students' self-study at the practical class

According to the variant given by the teacher calculate nutritive and energy value of food products, make up a map of nutritive and energy value. It's necessary to enter the obtained results in a table (tab. 14). Make conclusions.

Table 14

Calculation results

Nutrient	Nutrient mass content in a product, %	Product energy value, kcal/100 g	Product nutritive value	
			Daily requirement	Daily requirement coverage, %
Proteins				
Fats				
Carbohydrates				
Organicacids				
Mineral substances, including:				
Ca				

The end of the tab. 14

Nutrient	Nutrient mass content in a product, %	Product energy value, kcal/100 g	Product nutritive value	
			Daily requirement	Daily requirement coverage, %
P				
K				
etc.				
Vitamins				
Total				

8.4. PRACTICAL STUDY 4, 5. Calculating and making up human's daily ration for prophylactic, clinical and special nutrition. Calculating and making up human's daily ration for certain age and professional population groups

Preparing for the study, give characteristics to 15 main clinical diets, filling in tab. 15 according to the example.

Table 15

Main clinical diets characteristics

Diet number	Designated use of a diet	Diet characteristics	Prohibited dishes	Recommended dishes
1	To reduce inflammatory process by normalizing mucous membrane reparation processes, regulating secretory and motor-evacuator stomach function. Cover organism's physiological	Diet with a normal proportion of main nutrients. Common salt is at the lowest border of physiological norm. Chemical and thermal irritants, gastric secretion stimulators are significantly limited	Products, having highly secretogogue action and containing rough fibre: meat and fish broths, vegetable broths, pickles, spicy seasonings, marinades; fried dishes, smoked foods, preserved food, cabbage (except for cauliflower), spinach, sorrel, radish, garden radish, fancy pastry goods, cakes, ice-cream, sparkling and alcohol	Day-old dry white bread, dry sponge cake and lean biscuits. Soups from strained cereals, potatoes and vegetables, milk soups with vermicelli, rice, semolina. Low-fat sorts of meat and fish (beef, veal, chicken, turkey, rabbit, pikeperch, cod, hake, navaga, mackerel icefish). Dishes from minced meat and bird. Boiled

The end of the tab. 15

Diet number	Designated use of a diet	Diet characteristics	Prohibited dishes	Recommended dishes
	requirements during hospital treatment		drinks, brown bread, leguminous plants, coffee	and strained vegetables, purees, steamed, souffle etc.
2				
...				
15				

Task for students' self-study at the practical class

1. According to the teacher's task make up daily ration for people with different diseases, (5 meals a day, %: 1-st breakfast – 25; 2-nd breakfast – 15; lunch – 30; dinner – 20; supper – 10 of daily ration energy value), using data of tab. 16 and literature sources [1–4].

Table 16

Numerical system of the main diets

Diet number	Diseases, for which the diet is recommended
1	Gastro-intestinal tract diseases with excessive secretion of gastric juice (ulcer, gastritis)
2	Digestive system diseases with hyposecretion of gastric juice (ulcer, gastritis, colitis)
3	Bowels chronic diseases with the predominance of constipations
4	Acute and chronic colitis, enterocolitis and gastroenterocolitis during exacerbation period
5	Liver and biliary tracts diseases
6	Uric acid exchange disorder
7	Kidneys diseases
8	Obesity
9	Diabetes
10	Tuberculosis
11	CNS diseases
12	Acute infectious diseases
13	After operations conditions on external organs, bones and soft tissues
14	Urolithiasis and pyelocystitis
15	Diseases which don't require special diets, transition diet to normal nutrition during recovery period

2. Using literature sources data [1–3, 6], make up daily ration (breakfast – 40–45 %, lunch – 30–35 %, dinner – 20–25 %) for students and mental labor people, masons and bus drivers, fill in tab. 14 and calculate total content of proteins, fats, carbohydrates, mineral substances and vitamins in daily ration.

Make a conclusion: show relevance of nutrients proportion to recommended standards.

8.5. PRACTICAL STUDY 6. Nutritive value of raw materials. Technological processing influence on nutritive value of ready product

Nutritive value of ready product depends on both nutritive value of raw material and on technological processes of its processing. As a result of raw material technological processing different physicochemical and biochemical processes take place (hydrolysis, proteins denaturation, carbohydrates caramelization, fermentation, lipids oxidation et al.). Furthermore, a considerable part of vitamins and mineral substances are lost.

As person uses the largest part of food products after they are technologically processed, then choosing technological methods and maintaining production conditions has a great significance for preserving nutritive value of the ready food products.

During practical study the following questions given to students by the professor in advance are discussed

1. How does heat treatment of proteins influence their biological value?
2. What processes happen to fats during their storage? Does their nutritive value change?
3. How does proteins and fats hydrolysis influence their nutritive value?
4. Characterize vitamins losses when technologically processing vegetable raw material in different ways. Give examples.
5. Give examples proving the fact that mineral substances are lost in the ready product after raw material processing.

Conclusion – assess vitamins and mineral substances losses in the ready product caused by raw material technological processing using table of raw material and ready products chemical composition.

9. KNOWLEDGE ASSESSMENT TESTS ON THE «NUTRITION PHYSIOLOGY» DISCIPLINE

1. Choose the correct answer.
Mineral substances are divided into:
a) two groups;
b) three groups;
c) five groups;
d) six groups.

2. Choose the correct answer.
Proteins according to their biological function are:
a) energy source;
b) material for the tissue growth and rejuvenation;
c) metabolism regulators;
d) energy source, material for the tissue growth and rejuvenation, metabolism regulators.

3. Choose the correct answer.
Vitamins are divided into following groups:
a) lipo-soluble and water-soluble;
b) replaceable and irreplaceable;
c) simple and complex;
d) vegetable and animal.

4. Choose the correct answer.
Triacylglycerides are composed of:
a) carbon and oxygen;
b) carbon, hydrogen and oxygen;
c) carbon, hydrogen, oxygen and nitrogen;
d) carbon, hydrogen, oxygen, nitrogen and phosphorus.

5. Choose the correct answer.
This substance refers to simple sugars:
a) glucose;
b) lactose;
c) pectin;
d) starch.

6. Choose the correct answer.

Coefficient of phusiological energy value for carbohydrates is:

a) 2;

b) 4;

c) 5;

d) 9.

7. Choose the correct answer.

They are not digested in the stomach:

a) proteins;

b) fats;

c) carbohydrates.

8. Choose the correct answer.

Their amount must be reduced in human's daily ration:

a) water;

b) sugars;

c) cereals;

d) fruit.

9. Choose the correct answer.

According to their biological function carbohydrates are:

a) energy source;

b) material for the tissue growth and rejuvenation;

c) metabolism regulators;

d) energy source, material for the tissue growth and rejuvenation, metabolism regulators.

10. Choose the correct answer.

According to their origin triacylglycerides are divided into the following groups:

a) simple and complex;

b) vegetable and animal;

c) replaceable and irreplaceable;

d) lipo-soluble and water-soluble.

11. Choose the correct answer.

According to their biological function fats are:

a) energy source;

b) material for the tissue growth and rejuvenation;

c) metabolism regulators;

d) energy source, material for the tissue growth and rejuvenation, metabolism regulators.

12. Choose the correct answer.
How many different L-aminoacids are included in proteins?
a) 40;
b) 20;
c) 128;
d) 34.

13. Choose the correct answer.
Protein L-aminoacids are divided into the following groups:
a) simple and complex;
b) vegetable and animal;
c) replaceable and irreplaceable;
d) lipo-soluble and water-soluble.

14. Choose the correct answer.
Vegetable oils are the source of vitamin:
a) A;
b) D;
c) E;
d) K.

15. Choose the correct answer.
By its chemical nature pectn is:
a) a monosaccharide;
b) polysaccharide;
c) fibre;
d) chondroitin sulfate.

16. Choose the correct answer.
Coefficient of physiological energy value for fats is:
a) 2;
b) 4;
c) 5;
d) 9.

17. Choose the correct answer.
This vitamin refers to lipo-soluble vitamins:
a) vitamin E;
b) vitamin B_{12};
c) vitamin C;
d) vitamin PP.

18. Choose the correct answer.
They start digesting in mouth cavity:
a) proteins;
b) fats;
c) carbohydrates.

19. Choose the correct answer.
Provitamins are:
a) antivitamins;
b) a variety (kind) of vitamins;
c) vitamins precursors;
d) mineral substances.

20. Choose the correct answer.
Carbohydrates are divided into the following groups:
a) simple and complex;
b) vegetable and animal;
c) replaceable and irreplaceable;
d) lipo-soluble and water-soluble.

21. Choose the correct answer.
Food additives are:
a) BAAs;
b) antibiotics;
c) contaminants;
d) natural or synthesized compounds.

22. Choose the correct answer.
Food products contaminants are:
a) antibiotics;
b) food colorants;
c) stabilizers;
d) preservatives.

23. Choose the correct answer.
They are digested in stomach:
a) proteins;
b) fats;
c) carbohydrates.

24. Choose the correct answer.
Meat products in human's nutrition are the source of:
a) starch;
b) food fibres;
c) proteins;
d) ascorbic acid.

10. LABORATORY OPERATIONS MANUAL

Laboratory operations manual is necessary for independent preparation and doing practice in the laboratory for the course «Nutrition physiology». It includes works in the biochemical laboratory for studying fermentation processes, quality methods to find proteins, fats, carbohydrates and vitamins in different food products.

The subject «Nutrition physiology» is devoted to learning chemical composition, spatial structure, physicochemical properties and biological activity of main food components – i. e. proteins, fats, carbohydrates, mineral substances, vitamins, enzymes and hormones. In addition, while studying the subject requirements to high quality nutrition are considered when solving the problem of providing people with biologically adequate food and sustaining homeostasis.

In the Master's programme «Nutritive biotechnology» it is carried out together with studying the theoretical part of the course «Nutrition physiology» subject and is meant to consolidate and deepen the obtained knowledge.

The purpose of laboratory practicum (session) is to form integral knowledge of the «Nutrition physiology» subject and to establish logical coherence between theoretical and practical cycles.

Before work students have safety training. Before doing each work a student has to pass a colloquium for the sections identified by the professor and also for the analysis method. To do this it's necessary:

1) to revise relevant course section;

2) to get familiarized with the work procedure;

3) to be able to compose chemical equation, which is in base of quality analysis being performed;

4) know the peculiarities of the analysis in terms of safety.

In the process of work students make a report, which should include:

– the aim of work;

– structure and main physicochemical properties of the object under research;

– the essence of the analysis method used;

– all the observations made during the experiment (precipitation, decoloration, gas emission etc.);

– practical meaning of work;

– conclusions.

10.1. Identifying food components impact on neurohumoral system

Metabolism regulation is the most important mechanism of organism adaptation to its living conditions. Higher animals and human possess younger and more complex central regulation mechanisms phylogenetically apart from cellular metabolism, which protozoa possess:

1) central and peripheral nervous system through nerve impulses and neurotransmitters;

2) endocrine system through endocrine glands and hormones;

3) paracrine and autocrine systems through different connections, which secrete into intercellular space and interact with cellular membrane receptors;

4) immune system through specific proteins (antibodies, T-receptors etc.).

Neurohumoral regulation provides separate cells metabolism integration for the benefit of the whole organism and is implemented on the nerve and humoral levels.

Hormones are biologically active substances synthesized in endocrine glands (internal secretion glands). They are secreted into blood in small amounts and transferred to other organs. They act as chemical mediators, transferring signals from central nervous system and different organs, and they are regulators of metabolism processes and physiological functions in the organism.

Endocrine glands include pituitary bodies (upper – pineal gland, lower – hypophysis); thyroid; parathyroid glands; thymus gland; adrenal glands; Langerhans islets in pancreatic gland; reproductive glands. Endocrine glands activity is not autonomous; it is under control of the central nervous system.

Humans adrenal gland is a pair organ consisting of the right and the left gland, which weighs a bit less and has a smaller size. Adrenal gland has two layers – cerebral and cortical. Each of these layers consists of special tissue and has a different incretory functions.

Medullary substance produces two hormones – adrenaline and noradrenaline, which are derivatives of tyrosine amino acid as to their chemical nature is concerned (fig. 66).

Adrenaline increases blood pressure and heartbeat, intensifies gaseous metabolism and heat production, stimulates glycogen decomposition in liver and increases sugar level in blood by activating enzymes – adenylate cyclase and phosphorylase. In muscles adrenaline intensifies glycogen decomposition and promotes lactic acid formation, accelerates lipids decomposition in adipose tissue. But adrenaline inhibits gastrointestinal tract function. Noradrenaline is similar in its action to adrenaline, but it's weaker. One gram of adrenal gland tissue contains about 0.49 mg of adrenaline and 0.09 mg of noradrenaline.

In human organism adrenaline oxidizes (and with that it loses its biological activity (fig. 67).

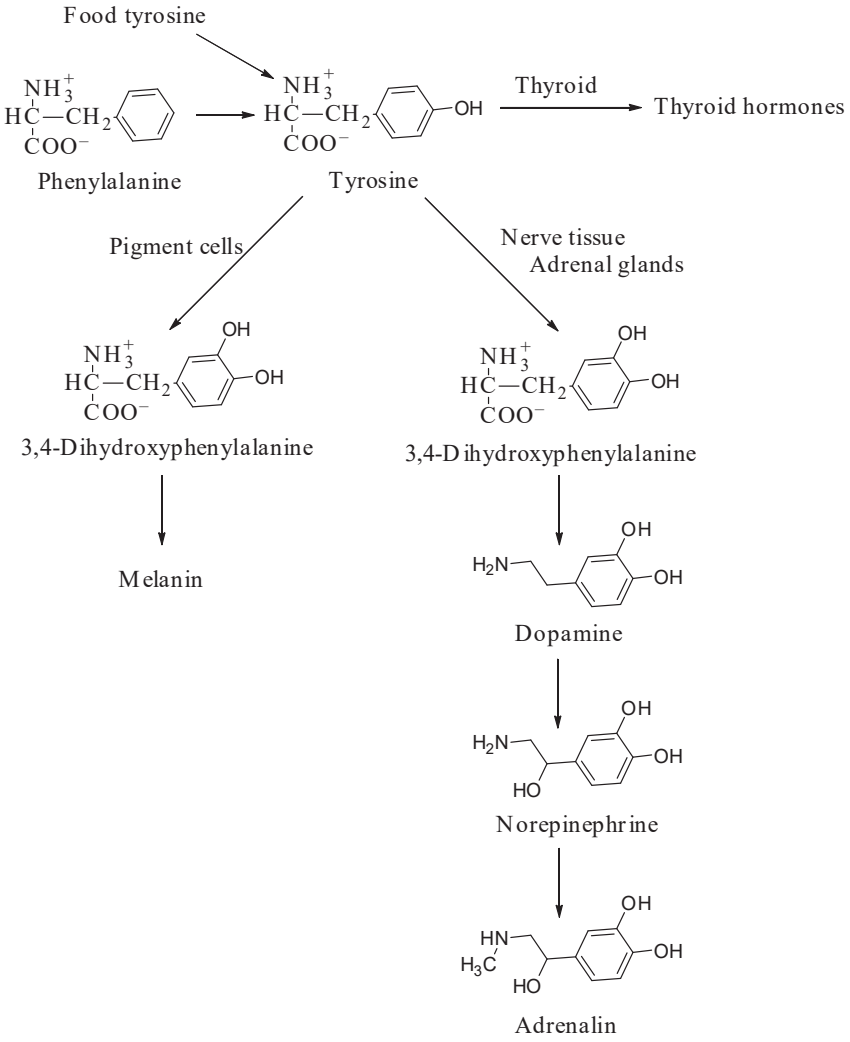


Figure 66. Adrenaline and noradrenaline production

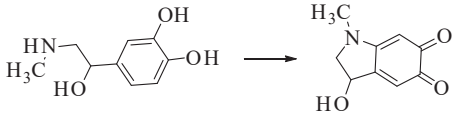


Figure 67. Oxidation of adrenaline into adrenochrome

Vitamin C (ascorbic acid) getting into the organism with food products is a strong deoxidizer and averts adrenaline oxidation process, and also it promotes reduction of the compounds formed in adrenaline oxidation. This capacity of vitamin C is proved in a model experiment taking as an example oxidation-

reduction reaction of adrenaline (reducer) and iodine (oxidizer) interaction. One can judge about course of adrenaline oxidation process by solution's pink coloration appearance due to oxididized adrenaline formation.

Procedure

Pour about 3–4 drops of 0,1 % adrenaline solution into two test tubes. Pour 1–2 drops of saturated sodium acetate solution into test-tube № 1 and add 0.1 % iodine solution in 0.2 % KI solution drop by drop until pink color appears, which indicates that adrenaline oxidation product has appeared.

Pour 2 drops of 5 % solution of ascorbic acid, 1–2 drops of saturated sodium acetate solution and the same number of drops of 0.1 % iodine solution in 0.2 % KI solution as was used for oxidizing adrenaline in the first tube into the second test-tube. Mention in the report if pink color appeared in test-tube № 2.

To identify vitamin C ability to reduce adrenaline oxidation products, pour drop by drop 5 % solution of ascorbic acid until pink colour disappears in test-tube № 1.

10.2. Gastrointestinal system influence on the degree of protein digestion

Nutrition is a vital condition of life. All life processes happening in the organism require particular metabolic costs. An organism gets this energy through the chemical breakdown of the substances contained. There is a constant process of dissimilation going on in the organism and simultaneously there is a process of assimilation. Dissimilation is destruction of living matter. Assimilation is recovery of the destructed matter by digesting and processing organic and inorganic substances of the environment.

The more active the organism activity is, the more active processes of dissimilation and assimilation are (metabolism).

Final products of oxidation and other chemical processes are secreted out of the organism together with the exhalant air (carbonic acid and water – in the form of vapor), with urine, feces and sweat (nitrogen-containing substances, organic acids, various salts).

Energy deliberated in the organism is partly spent for different life processes, muscle work, constant body temperature and partly it is lost as heat energy released into ambient environment.

Organism energy costs require constant filling in, which is carried out by nutrition.

Constant protein turnover, which tissues and organs are built of, is happening during life activity along with energy costs. Therefore, apart from the sources of energy our organism constantly needs building material for substances inherent to it. Both things are realized at the expense of nutrition.

So, nutrition pursues two objects:

– firstly, to provide organism with the substances which are source of energy (*energy role of nutrition*),

– and secondly, to provide organism with the substances necessary to build tissues and organs (*plastic role of nutrition*).

Digestion includes 3 main stages:

1) mechanic food chopping (chewing, attrition);

2) food moistening and swelling (due to physicochemical processes taking place when saliva and digestive juice act);

3) hydrolytic decomposition of the main food substances (proteins, fats, hydrocarbons) under specific enzymes action, each of them having an effect on its own substrate.

As a result of complex food substances hydrolysis there are generated monomers (amino acids, glycerin, higher fatty acids, and monosaccharaides) which are absorbed from intestine to blood and lymph, are transported to different tissues and take part in metabolism. If enzymes production is broken, digestive system work is broken too and also metabolism and synthesis of compounds is disturbed characteristic for the given organism.

To become familiar with the digestive system work and the degree of ovalbumin digestion with normal and decreased gastric acidity, one carries out ovalbumin hydrolysis in a model system and finds partly decomposed ovalbumin with the help of quality reaction for peptide bonds of protein (biuret test) in case of characteristic violet color with red or blue tint, depending on the number of peptide bonds in protein molecule.

Procedure

Put a small piece of caked ovalbumin into two test tubes. Pour 5 ml of gastric juice with normal acidity into one test-tube, and the same amount with decreased acidity into the other one.

Both test-tubes are incubated in thermostat at 37 °C for 45 min. After incubating both test-tubes are taken out of the thermostat and liquid is carefully poured out of each of them to other two test-tubes in a way to prevent ovalbumin pieces getting inside. Then add 2 ml of 10 % sodium hydroxide solution and 1 or 2 drops of 0.1 % copper sulphate (II) solution into each test-tube (Biuret test). Mention in the report which of the test-tubes shows characteristic color and how intensive it is. The conclusion is made about how gastric juice acidity influences the digestion process of proteins.

10.3. Enzymatic hydrolysis of complex carbohydrates

Carbohydrates play an important role in human nutrition, they account for 60–70 % in his diet. Human organism is incapable of synthesizing carbohydrates

from inorganic substances and gets them with food products; daily consumption rate is 450–600 g.

In the organism complex carbohydrates are digested in gastrointestinal tract and are absorbed into blood as monosaccharaides, mainly as glucose.

Vegetable food products contain dietary fibers that cannot be decomposed by gastrointestinal tract enzymes. If we look at their chemical nature, we'll see that they are polysaccharides: cellulose, hemicellulose, pectin substances. In case of shortage of dietary fibers in food products, human organism resistivity to environmental impact decreases. Dependence has been set between the lack of dietary fibers in a diet and such diseases as obesity, large intestine diseases (constipations, cancer), diabetes, atherosclerosis, ischemic heart disease and others.

In dietary rations methylcellulose is used as a substitute for digestible carbohydrates. It is a ballast substance, it increases the volume of food (absorbing a big amount of water), it promotes the development of satiation feeling, and it stimulates intestine walls movement activity. It has been established that methylcellulose influences the intensity of polysaccharides digestion and also it inhibits starch hydrolysis under pancreatic a-amylase action. Along with this glucose enters blood more slowly (it is the product of starch hydrolysis), it is important to prevent hyperglycemia. Hence, it's useful for the diabetes sufferers to include dishes and drinks containing methylcellulose into their diet.

To identify how methylcellulose influences starch digestion under pancreatic gland amylase action they compare its hydrolysis speed in control and experiment tests for disappearing of the blue color of test-tubes content in adding iodine. Experiment result evaluation is carried out with the help of color reactions: Trommer's and iodine-starch one. Unhydrolized starch gives blue coloring with I_2 (positive reaction) and negative Trommer's reaction, as it doesn't possess reducing power. When starch is only partly digested, dextrins are formed, giving reddish-brown coloring with I_2. Starch hydrolysis products (maltose and glucose) don't give reaction with I_2, but they enter Trommer's reaction.

Procedure

Three clean dry test-tubes are numbered (№ 1, 2, 3). Pour 1 ml of 1 % starch solution into each of them, then add 1 ml of water into test-tubes № 1 and № 2, and 1 ml of 1.5 % high-viscosity methylcellulose solution into test-tube № 3 (experiment probe).

To prepare methylcellulose solution pour 50 ml of boiling water on 1.5 g of methylcellulose and leave it for several minutes to swell, stirring the mixture from time to time. Then add 50 ml of ice-cold water, stir well and keep the solution in the refrigerator at 0–4 °C.

Pour 0.2 ml of 1 % pancreatine solution in 0.1 % $NaHCO_3$ solution into test-tubes № 2 и № 3. Test-tube № 1 without pancreatine serves as control. Insert the stoppers into all the test-tubes, stir the content and put the tubes in the thermostat

for 20 min at 37 °C. Then take out 5 drops of the solution under research from each tube and put it into two different test-tubes. Add 2 drops of 1 % solution of I_2 in KI into one of them, and 2 drops of 5 % $CuSO_4$ solution and 4 drops of 10 % of NaOH solution into another one and carefully heat to boiling. Note the obtained results and enter them in a tab. 17, make a conclusion about how methylcellulose influences starch hydrolysis speed.

Table 17

Experiment results

№ probe	Substrate	Enzyme	Reaction	
			with I_2	Trommer's
1	Starch	Water		
2	Starch	Pancreatine		
3	Starch + methylcellulose	Pancreatine		

10.4. Chemistry of milk

Milk is an important food product which is emulsion of fat in milk plasm, it contains water, triglycerides with oleic acid and palmitic acid, phospholipids (phosphatidylcholines and phosphatidyletanolamins), cholesterol, proteins (caseinogen, milk albumen, milk globulin), hydrocarbons (lactose, glucose), enzymes (amylase, lipase, catalase, dehydrogenase), vitamins (A, C, D, B group), mineral substances (K, Na, Ca, Mg, P, Cl, Fe).

Experiment 1. Identifying milk reaction with blue litmus and phenolphtalein

Milk of herbivorous and omnivorous animals has a neutral reaction on blue litmus, i. e. pH = 6.5–7.0. It is caused by the fact that there are different mono-substituted and disubstituted alkaline metals phosphates simultaneously in milk.

Procedure

Pour 1–2 drops of milk on blue litmus paper. Pour 1 ml of milk into a clean dry test-tube and add 1–2 drops of phenolphthalein solution. Record changing of indicators color and medium reaction in the report and also write down hydrolysis equation of the corresponding salts.

Experiment 2. Finding caseinogen

Milk contains caseinogen, which is a complex protein – phosphoproteid. Its prosthetic group contains a big amount of phosphoric acid fixed with the remnants of amino acids serine and threonine. Caseinogen is dissolved in weakly alkaline

solutions, doesn't coagulate in boiling, in milk it's in the form of water-soluble calcium salt. However, at the isoelectric point it loses its stability and precipitates.

Procedure

Pour 2.5–3 ml of milk into a test-tube and add 5 ml of distilled water. Stir the content well; add drop by drop 1 ml of 3 % CH_3COOH solution. Agitate intensively again and leave it for 5–10 minutes until protein precipitates. Filter the precipitation, pour the filtrate into another test-tube and is used to carry out reaction to find milk components.

The precipitate is washed by water, dissolve 1 % of NaOH solution on the filter. To prove the presence of protein in the solution, carry out Biuretic reaction. Add 10 drops of 10 % of NaOH solution and 1–3 drops of 2 % $CuSO_4$ solution into the test tube with the obtained solution, the mixture is lightly agitated. Appearance of violet coloring is observed.

Experiment 3. Finding milk sugar

Milk sugar – is lactose, disaccharide, composed of residues of α-glucose and β-galactose, with 1,4-glycoside bond, it has reducing properties and enters Trommer's reaction with the formation of Cu_2O precipitation of reddish-brown color.

Procedure

To identify lactose (milk sugar), do Trommer's reaction with the filtrate obtained in experiment 2.

Pour out 1 ml of the filtrate under research into a test-tube, add 5–6 drops of 10 % NaOH solution and drop by drop 2 % $CuSO_4$ solution until non-vanishing $Cu(OH)_2$ precipitates.

Heat the content of the test-tube carefully, note changing of color in the report during heating, write down corresponding reaction equations.

Experiment 4. Finding phosphoric acid salts

Procedure

Pour out 1 ml of filtrate formed in experiment 2 into a test-tube, add 5–6 drops of molybdenum acid ammonium in nitric acid (molybdenum reagent) and heat to boiling. Solution in the test-tube acquires yellow color, after cooling the test-tube content under cold water stream, a yellow crystalline precipitation of ammonium phosphomolybdate is formed (fig. 68).

$$3CaHPO_4 + 3NH_4OH \rightarrow Ca_3(PO_4)_2 \downarrow + (NH_4)_3PO_4 + 3H_2O$$

$$MgHPO_4 + 6HNO_3 \rightarrow Mg(NH_4)PO_4 \downarrow + H_2O$$

$$Ca_3(PO_4)_2 + 6HNO_3 \rightarrow 3Ca(NO_3)_2 + 2H_3PO_4$$

$$H_3PO_4 + 12(NH_4)_2MoO_4 + 21HNO_3 \rightarrow (NH_4)_2PO_4 \times 12MoO_3 + 21NH_4NO_3 + 12H_2O$$

Figure 68. Finding phosphoric acid salts

To prepare molybdenum reagent dissolve 7.5 g of ammonium phosphomolybdate in 100 ml of 32 % nitric acid solution.

Experiment 5. Finding calcium salts

Procedure

Pour out 1 ml of filtrate formed in experiment 2 into a test-tube, add 2–4 drops of 0.2 % ammonium oxalate solution. Calcium oxalate precipitates, which is not water-soluble. Note precipitation color in the report. Write down corresponding reaction equation.

10.5. Comparative analysis of food products

Experiment 1. Identifying β-carotene mass fraction

Plants contain carotenoid pigments, providing their color from bright red to yellow. Red pigment – β-carotene is a provitamin of retinal (vitamin A), it has the greatest biological value showing its antiradiation properties. In animals' organisms β-carotene is oxidized enzymically and gives two molecules of retinal.

β-Carotene is contained in the following food products (mcg%): carrots – 9, pepper – 2, tomatoes – 1, butter – 0.2–0.4. Vitamin A is contained only in animal origin products (mcg%): fish fat – 15, cod liver – 4, butter – 0.5, milk – 0.25.

To identify how stable β-carotene is during heating vegetable raw material they use colorimetric evaluation on spectrophotometer at wavelength 450 nm. β-Carotene light absorption is caused by the presence of conjugated π-bonds in its molecule, providing maximum absorption at 450–470 nm.

Carotene containing raw material cooked in some way (blanched, boiled, fried) can be used as an object of research (carrots, tomatoes, peppers).

Procedure

1. *Preparing material under research*

Take 1–2 g of vegetable material under research, grind it in a porcelain mortar with a small amount of crushed glass, add 20–25 ml of hexane. Leave it for 5–10 minutes and filter supernatant fluid on Buhner funnel. Cover precipitation with 10–15 ml of hexane and repeat the extraction of β-carotene several times until extract becomes colorless. Unite the obtained hexane extracts and place them in a graduated flask to 100 ml, fill the obtained volume to mark with hexane, stir the solution in the flask carefully.

2. *Identifying carotene mass fraction*

Solution undergoes colorimetric evaluation on spectrophotometer at wavelength 450 nm in cuvette with working length 10 mm. At the same time measure optical density of standard sample solution – potassium dichromate. Use hexane and distilled water as a comparison solution.

Calculate carotenoid content in terms of β-carotene according to the formula:

$$X_{car} = \frac{D \cdot 0.0208 \cdot V \cdot 100}{D_o \cdot m},$$

where X_{car} – content of β-carotene in vegetable raw material, mcg%; D – optical density of the solution under research; D_o – optical density of standard sample solution; 0.0208 – amount of β-carotene, corresponding in color with 1 ml of standard potassium dichromate solution, mcg; V – extract volume, ml; m – sample mass, g; 100 – percent translation coefficient.

Write down the results in the report (in the form of tab. 18).

Table 18

Experiment results

Sample under research	m, g	D	X_{car}, mcg%
1			
2			
3			

Experiment 2. Studying sorption capacity of pectin substances

Human diet should be enriched with the products rich with pectin, for example fruit and vegetables, as pectin substances play an important role due to their ability to bind and remove from the organism heavy metals ions (copper, lead, mercury). It especially concerns people who are on the territory contaminated by radionuclides and who have contact with heavy metals.

Pectin substances stimulate intestine peristalsis, increase bile production, absorb microorganism metabolism products and heavy metals salts. They are recommended for prophylactics of atherosclerosis, diabetes, cholelithiasis. Prophylactic norm of pectin approved by World Health Organization is 2–4 g per day and for people working in adverse conditions – 8–9 g per day. Excess amount of pectin substances in a diet is unhealthy as it can lead to partial food digestion, liposoluble vitamins and microelements (calcium, magnesium, iron, zinc) absorption disturbance.

Identifying copper ions concentration is carried out by photocolorimetric method in the form of copper ammine (II). In adding an excess ammonia solution to the solution containing $CuSO_4$, intensive blue color of copper ammine (II) appears with the maximum absorption at 620 nm.

Procedure

1. *Building calibration curve*

Prepare model solutions of initial 1 % $CuSO_4$ solution in numbered test-tubes according to the scheme:

solution № 1 – 2 ml of initial solution (10 mg/ml);
solution № 2 – 9 ml of initial solution + 1 ml of water;
solution № 3 – 8 ml of solution № 2 + 1 ml of water;
solution № 4 – 7 ml of solution № 3 + 1 ml of water;
solution № 5 – 6 ml of solution № 4 + 1 ml of water;
solution № 6 – 5 ml of solution № 5 + 1 ml of water;
solution № 7 – 4 ml of solution № 6 + 1 ml of water;
solution № 8 – 3 ml of solution № 7 + 1 ml of water;
solution № 9 – 2 ml of solution № 8 + 2 ml of water;
solution № 10 – 2 ml of solution № 9 + 2 ml of water.

Stir the content of test-tubes № 1–10 and pour out 2 ml of the obtained solutions into other 10 numbered test-tubes, add into each of them 1 ml of 5 % solution of NH_4OH and 2 ml of distilled water. Stir the content of the test-tubes and measure intensity of absorption of the colored solutions relative to distilled water on photoelectrocolorimeter with light filter with wavelength of 620 nm. Write the results of measurements into the tab. 19.

Table 19

Data for building gauge curve

Test-tube number	$CuSO_4$ concentration in the solution, mg/ml	Optical density
1		
2		
3		

Using data of the tab. 19 build a gauge studied solutions optical density – $CuSO_4$ concentration curve.

2. *Studying starch ability to bind copper ions*

Pour solutions under research into 5 test-tubes in the amounts shown in tab. 20.

Stir the content of the test-tubes, filter precipitation if necessary. Take out 2 ml of filtrate of each test-tube and place it into 5 numbered test-tubes, add 1 ml of 5 % NH_4OH solution and 2 ml of distilled water. Stir test-tubes content and measure intensity of absorption on photoelectrocolorimeter with light filter with wavelength of 620 nm. Copper ions concentration ($C_{residual}$, mg/ml) is found on the gauge curve.

Table 20

Experiment scheme and the obtained results

Solution composition, ml			Optical density	Amount of copper bound, mg
$CuSO_4$ (4 %)	Starch (1 %)	Water		
1.0	0.0	4.0		
1.0	1.0	3.0		
1.0	2.0	2.0		
1.0	3.0	1.0		
1.0	4.0	0.0		

The amount of bound copper (C, mg) is identified according to this formula:

$$C = (C_{initial} - C_{residual}),$$

where $C_{initial}$ – initial copper concentration in the solution, mg/ml; $C_{residual}$ – residual copper concentration in the solution, mg/ml.

Write the results obtained into the tab. 18.

3. *Studying pectin ability to bind copper ions*

Pour solutions under research into 5 test-tubes in amounts indicated in the tab. 21.

Table 21

Experiment scheme and the obtained results

Solution composition, ml			Optical density	Amount of copper bound, mg
$CuSO_4$ (4 %)	Pectin (0.5 %)	Water		
1.0	0.0	4.0		
1.0	0.5	3.5		
1.0	1.0	3.0		
1.0	2.0	2.0		
1.0	3.0	1.0		

Stir the content of the test-tubes, filter precipitation if necessary. Amount of copper bound by pectin is identified similarly by the above described method. Write the results obtained into the tab. 19.

STUDENT INDEPENDENT WORK

Independent work implies the whole range of student's self-activity both during study auditorium classes and at other time and place (in the library, at home), both in contact with a teacher and in his absence. In this regard in the course of mastering discipline «Nutrition physiology» the following kinds of students' independent work are used:

1) auditorium independent work, which is carried out under direct teacher's supervision;

2) out-of- auditorium independent work.

Thus, to prepare for lecture-discussion students are suggested questions for independent studying and further discussing.

1. In section 5 «Medical-biological significance and functions of the main food components»:

– significance of unsaturated fatty acids in human nutrition;

– cholesterol and its biological functions;

– disturbance of human organism provision with vitamins – hypo- , hyper- and avitaminosis;

– physiological functions of the main macro and microelements.

2. In section 6 «Modern notions about rational nutrition»:

– separate nutrition;

– vegetarianism;

– fasting;

– diets.

In the framework of students' independent work, the following current assessment procedures and tasks for them are provided for exemplary essays topics list.

Exemplary essays topics list

1. Physiological role of proteins, fats, carbohydrates.
2. Physiological role of water-soluble and fat-soluble vitamins.
3. Physiological functions of the main macro and microelements.
4. Carbohydrate metabolism and its regulation in human organism.
5. Protein metabolism and its regulation in human organism.
6. Fat metabolism and its regulation in human organism.
7. General characteristics of digestion processes in mouth cavity, stomach and intestinal canal.
8. The essence of substance and energy exchange, and significance of these processes for the organism life activity.
9. Energy consumption in labor and sport activity.

Exemplary home tasks topics list

1. Ecological, medical-biological, socio-economic problems of rational nutrition.
2. Modern view on the fundamentals of human rational nutrition.
3. Calculate and work out human daily dietary intake for particular age and job groups of population.
4. Characteristics of the structure and functioning of primary (microelement and microecological systems) regulatory mechanisms of human homeostasis sustaining.
5. Characteristics of structure and functioning of complex secondary regulatory mechanisms of human homeostasis sustaining (with the participation of immune system).
6. Characteristics of structure and functioning of complex secondary regulatory mechanisms of human homeostasis sustaining (with the participation of endocrine system).
7. Characteristics of structure and functioning of complex secondary regulatory mechanisms of human homeostasis sustaining (with the participation of nervous system).

Exemplary written works topics list

1. Proteins heat treatment influence on their biological value.
2. Protein and fat hydrolysis influence on their nutritive value.
3. Losses of the particular vitamins when processing raw materials.
4. Reasons of mineral substances losses in the ready product in comparison with raw material.
5. Nutritive and biological value of food products.
6. Organism requirements in essential nutrition factors.
7. Proteins functions and biological value in nutrition.
8. Amino acids score calculation of the most widespread food products.

Exemplary topics list of express quizzes at laboratory practice

1. Food factors and their influence on neurohumoral system.
2. Food factors influence on digestive system.
3. Biocatalysis and enzymes action mechanism.
4. Enzyme hydrolysis of the main nutritive substances – proteins, fats, complex carbohydrates.
5. Raw material nutritive value.

Exemplary control questions list for the preparation for assessment of academic progress in the subject «Nutrition physiology»

1. History and evolution of human nutrition.
2. Role of nutrition in health sustaining and in civilization diseases emerging.
3. Types of digestion. Processes of absorption and fixation of nutrients.

4. Brief characteristics of structure and functioning of primary regulatory mechanisms of human homeostasis sustaining.

5. Brief characteristics of structure and functioning of complex secondary regulatory mechanisms of human homeostasis sustaining.

6. Characterize the role of gastrointestinal tract micro flora in the main nutrient metabolism.

7. Enumerate the main groups of food products, containing essential and regulatory nutritive substances.

8. Characterize the composition and nutritive value of grain products.

9. Characterize the composition and nutritive value of meat and its substitute products.

10. Characterize the composition and nutritive value of milk and dairy products.

11. Characterize the composition and nutritive value of fruit and vegetables products.

12. Characterize the composition and nutritive value of oils and fats products and of various sweets.

13. Biological value of food.

14. Food components recommended consumption rates.

15. What are the human daily requirements in the main nutrients?

16. Describe physiological role of proteins.

17. What is protein-calorie deficiency?

18. Characterize physiological role of fats.

19. Characterize physiological role of carbohydrates.

20. Characterize physiological role of vitamins.

21. Characterize physiological role of mineral substances.

22. How significant are unsaturated fatty acids in human nutrition?

23. Characterize cholesterol and its role in human organism.

24. What's hypo- hyper- and avitaminosis? Give examples.

25. Characterize fundamentals of rational nutrition.

26. Modern pyramid of healthy nutrition and principles of its construction.

27. Modern human dietary intake.

28. Analysis of alternative notions about human nutrition – separate nutrition, fasting, diets, vegetarianism.

29. Nutritive value of raw materials. Influence of raw materials technological processing on ready product nutritive value.

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Учебное издание

Селезнева Ирина Станиславовна
Глухарева Татьяна Владимировна

ГОМЕОСТАЗ И ПИТАНИЕ ЧЕЛОВЕКА

HOMEOSTASIS AND HUMAN NUTRITION

Учебное пособие

Заведующий редакцией *М. А. Овечкина*
Редактор *Е. И. Маркина*
Корректор *Е. И. Маркина*
Компьютерная верстка *Г. Б. Головина*

Подписано в печать 03.12.21. Формат 70×100/16.
Бумага офсетная. Печать офсетная.
Уч.-изд. л. 8,00. Усл. печ. л. 9,35. Тираж 30 экз. Заказ 230.

Издательство Уральского университета
620083, Екатеринбург, ул. Тургенева, 4.

Отпечатано в Издательско-полиграфическом центре УрФУ
620083, Екатеринбург, ул. Тургенева, 4.
Тел.: +7 (343) 358-93-06, 358-93-22
Факс +7 (343) 358-93-06
http://print.urfu.ru


УНИВЕРСИТЕТСКОГО КНИГОИЗДАНИЯ
УНИВЕРСИТЕТСКАЯ КНИГА
2020


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