KHARKOV NATIONAL MEDICAL UNIVERSITY
Physiology department

WORKBOOK

FOR INDIVIDUAL STUDENTS' WORK

PHYSIOLOGY OF VISCERAL SYSTEMS:

DIGESTION & NUTRITION

ENERGY METHABOLISM & THERMOREGULATION

EXCRETION

Name_____

Faculty_____

Group_____ course_____

2020

МІНІСТЕРСТВО ОХОРОНИ ЗДОРОВ'Я УКРАЇНИ
Харківський національний медичний університет

Physiology of visceral systems: Digestion & Nutrition Energy metabolism & Thermoregulation Excretion

Manual for individual work of second-year students (English-medium)

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Introduction

This Workbook combines information about physiology of following functional systems which are crucial to control homeostatic parameters of our organism: 1) digestion and nutrition, 3) energy metabolism, 4) thermoregulation, 5) excretion.

The life is impossible without making up for the nutrients in the organism which are continuously consumed by the cells in the metabolism process. The most of the nutrients enter into the food composition but they are in the condition that is not ready for assimilation. Utilization of proteins, lipids and carbohydrates for satisfaction of energetic and plastic organism necessities becomes possible just only after their physical and chemical processing in the gastro-intestinal tract. As a result these substances are transformed into the rather simple water-soluble chemical compounds – *nutrients* which don't have the species specificity, but they keep the energetic and plastic value.

Metabolism and energy exchange is a complex of biochemical reactions and connected with them energetic processes that supply the vital functions of living beings. The energy released during metabolic reactions then is used to exert various processes in an organism such as maintenance of body temperature, blood circulation, respiration, muscles contraction, etc.

Excretion is also significant feature of living beings as nutrition and respiration and its impairment inevitably leads to disbalance of homeostatic parameters, violation of metabolism and vital functions.

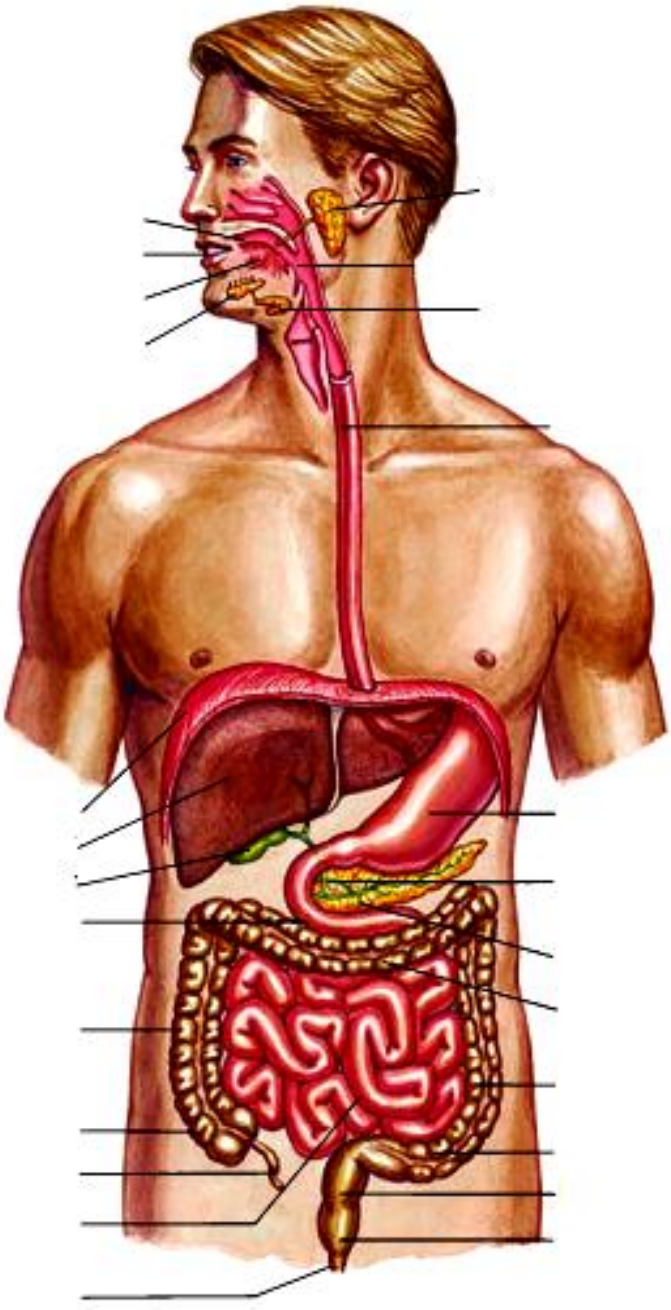
Creation of this manual is an attempt of physiology department teachers to help students to make out the tremendous amount of information from different textbooks and Internet sites, because we have chosen key questions which are essential for understanding of physiology of respiration, nutrition and excretion, mechanisms of thermoregulation and excretion as well as their disorders.

Good luck!

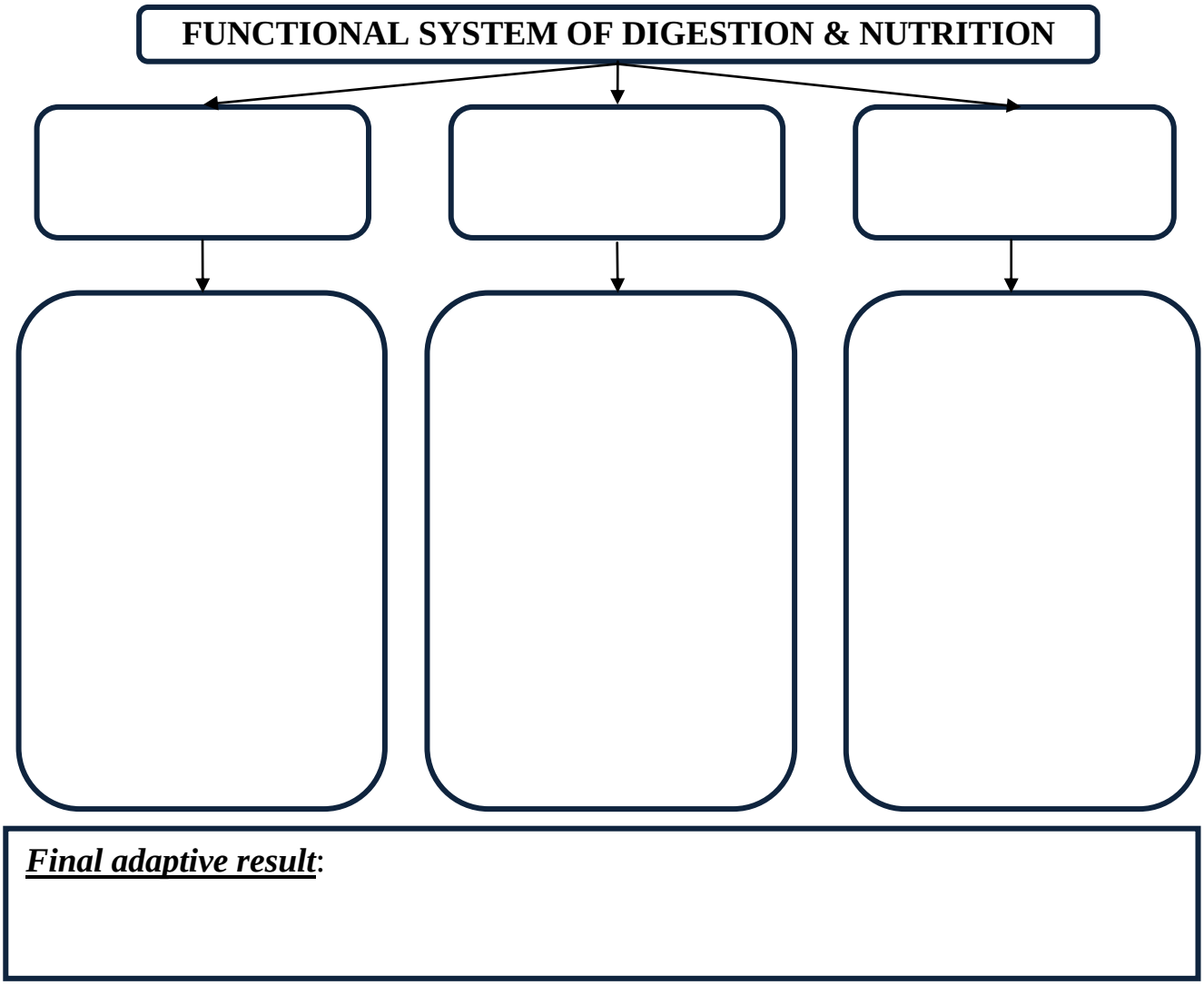
PHYSIOLOGY OF DIGESTION AND NUTRITION FUNCTIONAL SYSTEM

1. GENERAL CHARACTERISTIC OF DIGESTIVE SYSTEM

Task 1.1. *Use your knowledge from anatomy course to label organs of digestion system*



Task 1.2. Digestive functional system consists of three principle components. *Complete the scheme* ***"Digestive functional system"***



Task 1.3. *Give definition of digestion and explain the processes of food digestion*

_____
_____
_____
_____
_____
_____

Task 1.4. *Name the functions of GIT*

*1.*_____
_____
_____

*2.*_____
_____
_____

*3.*_____
_____
_____

*4.*_____
_____
_____
*5.*_____
_____
_____
*6.*_____
_____
_____

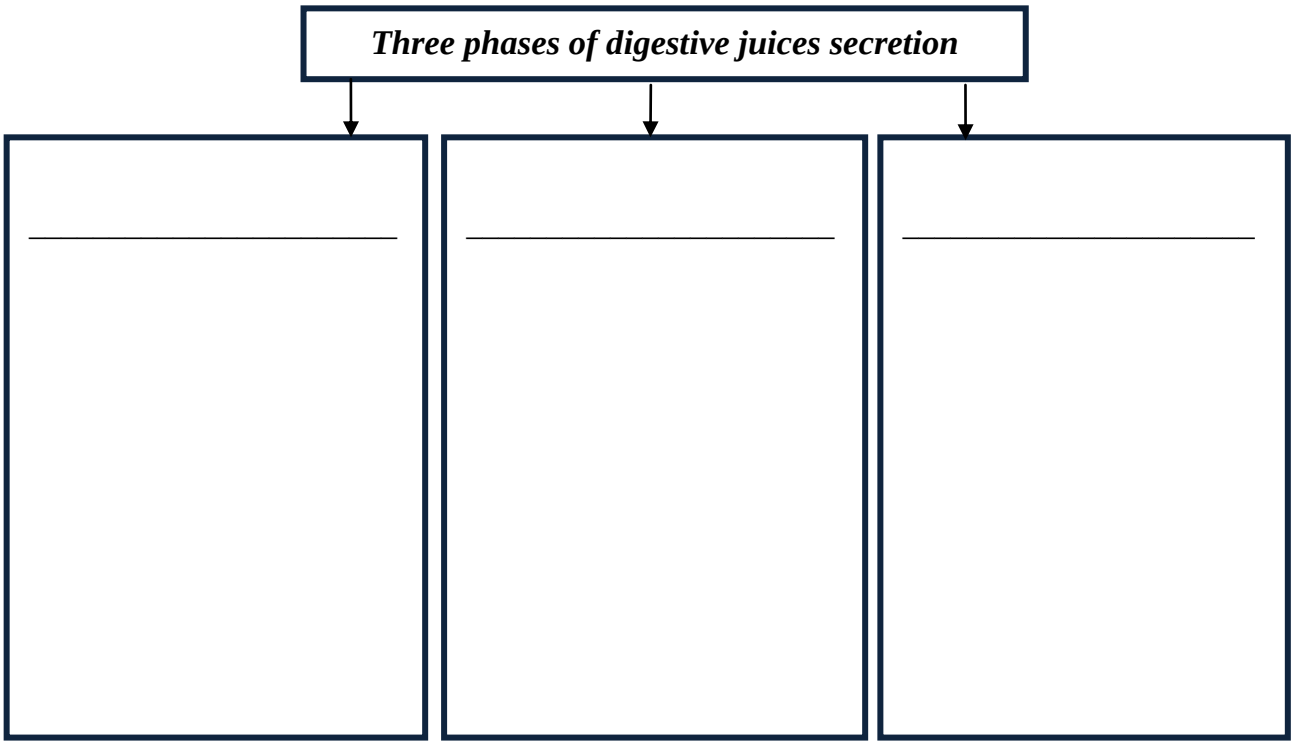
Task 1.5. There are two types of digestion according to localization of digestive process. *Please, list these types and define them*

*1.*_____
*2*_____
- ✓ _____
- ✓ _____

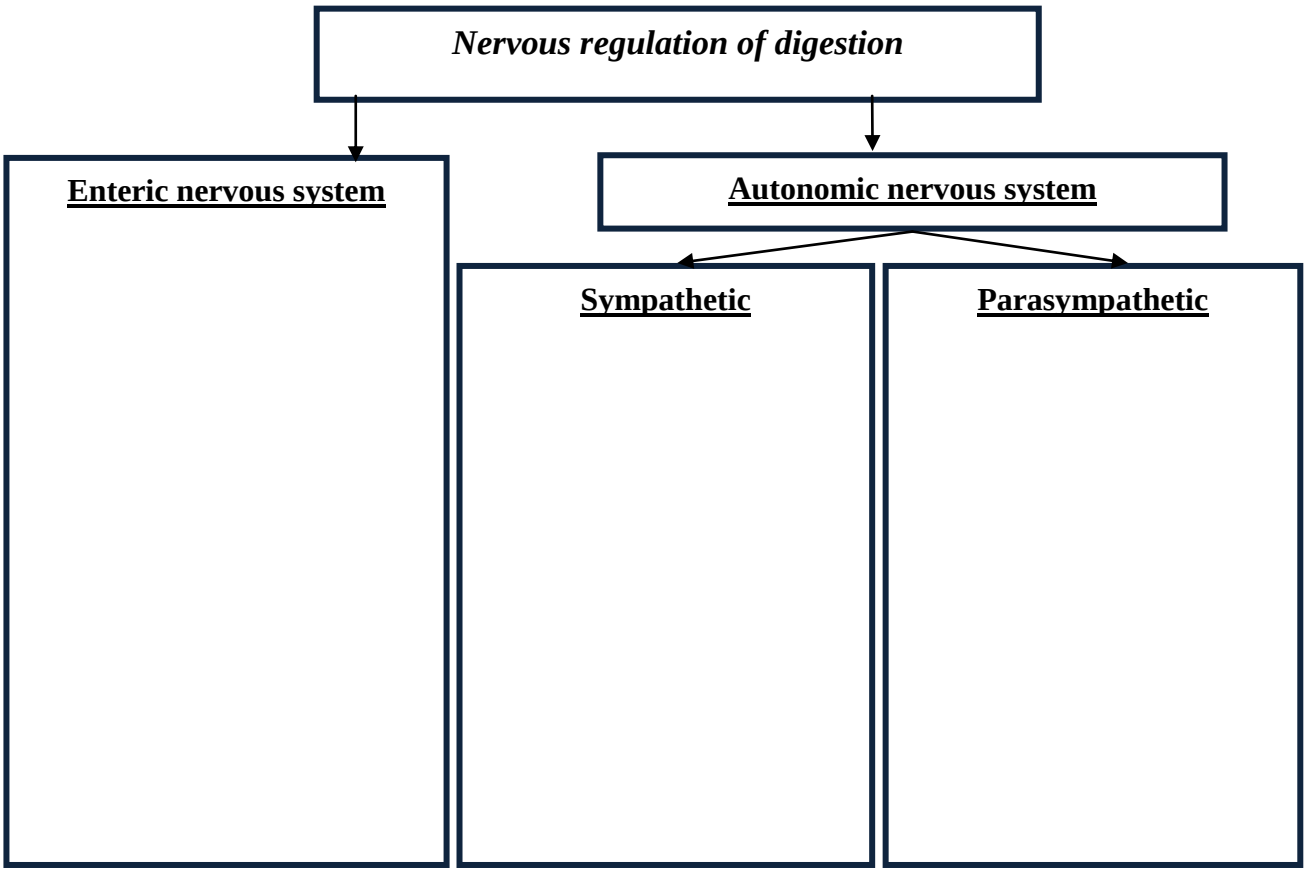
Task 1.6. Gastrointestinal regulatory substances. Fill in the table.

Substances	Sourse	Effect
Gastrin		
Cholecystokinin (CCK)		
Secretin		
Glucose-Dependent Insulinotropic Peptide		
Motilin		
Pancreatic polypeptide		
Enteroglucagon		
Glucagon-like peptide-1 (GLP-1)		
Somatostatin		
Histamine		

Task 1.7. Secretion of digestive juices occurs in three phases. *Please, define these phases and their significance*



Task 1.8. *Define the main principles of neuronal regulation of digestion*



Task 1.9. Neurotransmitters and Neuromodulators in the Enteric Nervous System

Substance	Source	Action
Acetylcholine		
Noradrenaline		
VIP		
Gastrin-releasing peptide		
enkephalins		
Neuropeptide Y		
Substance P		

Task 1.10. Define the role of circular and longitudinal muscles of the gastrointestinal tract and types of contractions.

Circular muscles	
longitudinal muscles	
Phasic contractions	
Tonic contractions	

Task 1.11. Define the origin and role of slow waves in motility.

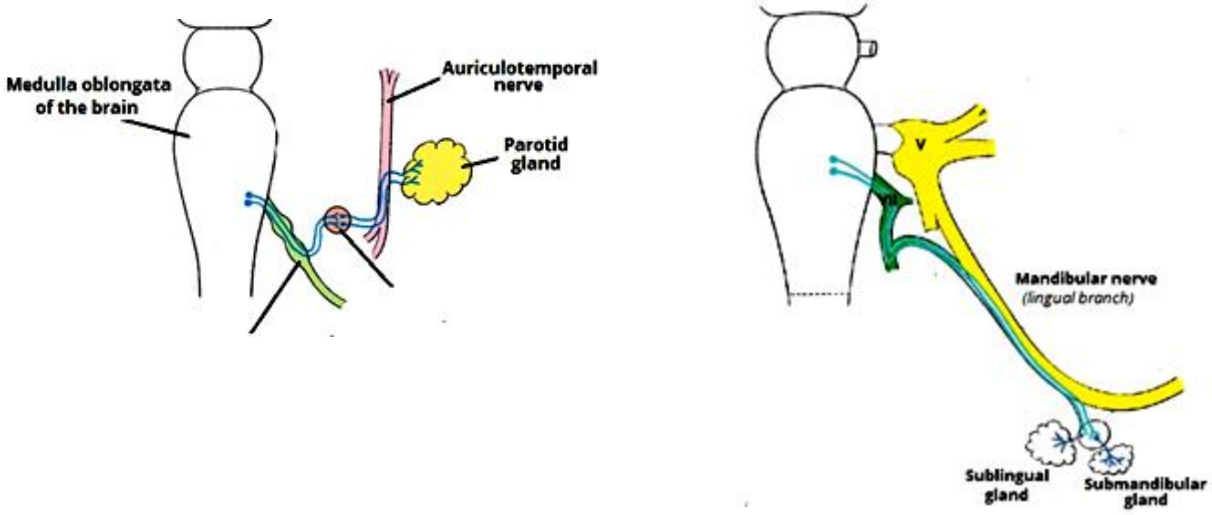
Definition	
Origin	
Function	

2. DIGESTION IN THE MOUTH

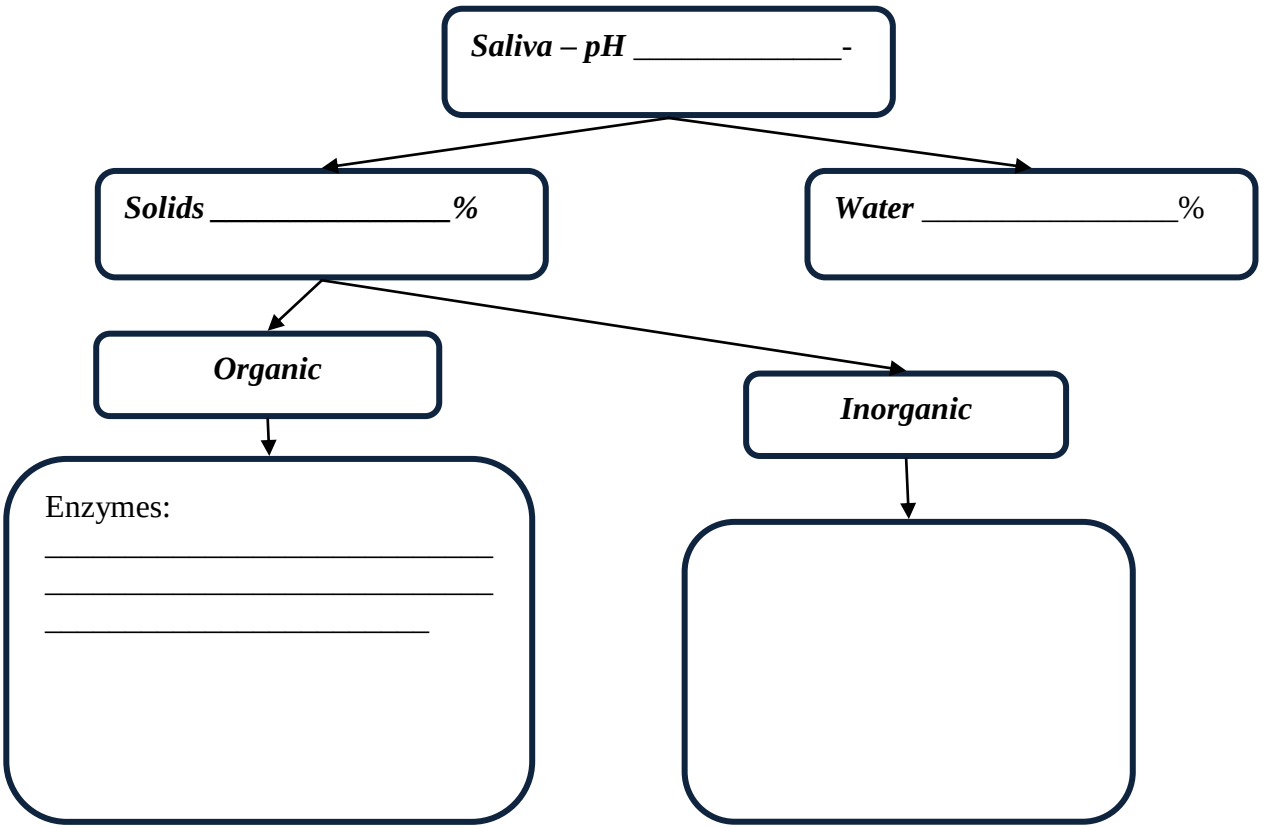
Task 2.1. *Define the significance of digestion in the mouth*

- There are 3 major salivary glands:
- _____, _____, _____.
- The _____ are composed of serous cells and secrete an aqueous fluid composed of water, ions, and enzymes.
- The _____ and _____ glands are mixed glands and have both serous and mucous cells secrete mucin glycoproteins for lubrication.
- The acinar cells produce _____
- The ductal cells _____.

Task 2.2. *Fill in the illustration about innervation of salivary glands.*



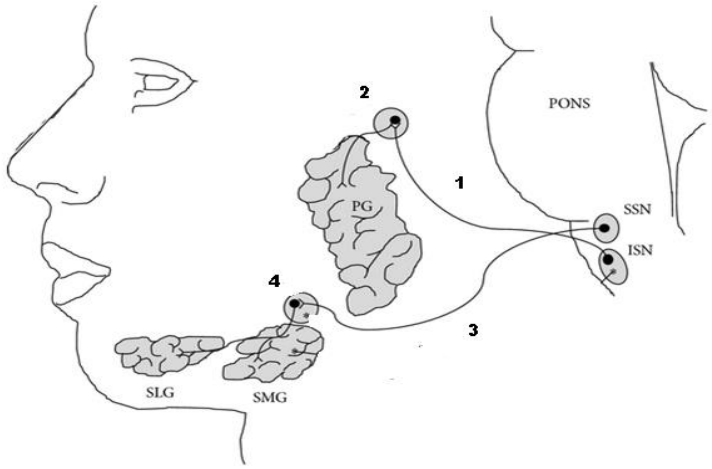
Task 2.3. Composition of saliva.



Task 2/4. Steps of saliva formation:

	Acinar cells	**Ductal cells**
Function		
Composition (osmolarity of saliva)	**Initial saliva is _____**	**Final saliva is _____**

Task 2.5. Explain autonomic innervation of salivary glands. Define cranial nerves and ganglia.



SSN – superior salivary nucleus
ISN – inferior salivary nucleus
PG – parotid gland
SLG – sublingual gland
SMG – submandibular gland
1. _____
2. _____
3. _____
4. _____

Task 2.6. Autonomic regulation of salivation. Fill in the table

Component of reflex arch	Parasympathetic	Sympathetic
Stimulus		
Aff nerves		
Nerve center		
Preganglionicfiber		
Ganglion		
Postganglionic fiber		
Neurotransmitter		
Tarter cells		
Receptors		
Effect		

Task 2.7. Mechanical digestion in the mouth includes two processes – chewing and swallowing. *Define the importance of chewing*

_____

_____

_____

Stimulus	Aff nerves	Nerve center	Eff nerves	Target cells

Task 2.8. *List the stages of swallowing*

1)_____

_____

_____

_____

_____

2)_____

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3)_____

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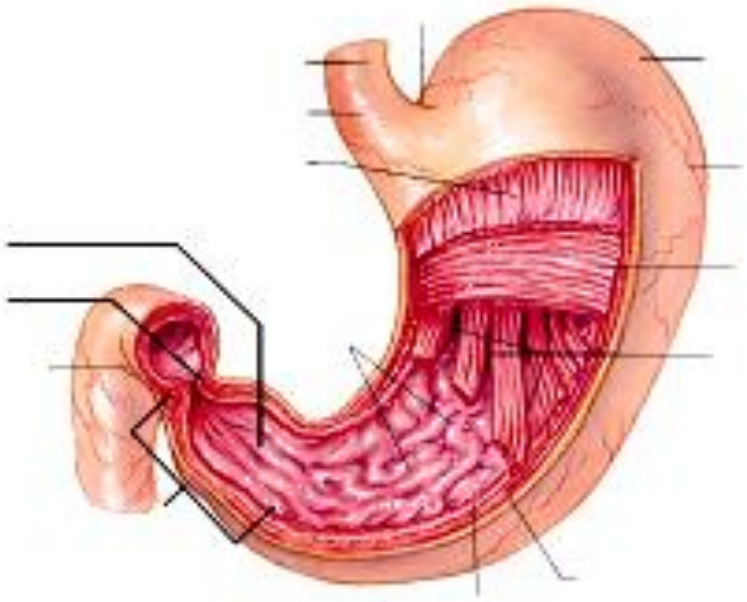
_____

3. DIGESTION IN THE STOMACH

Task 3.1. *Label anatomical structure of stomach*



Task 3.2. *Define the peculiarities of digestion in the stomach*

1)_____

_____

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2)_____

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3)_____

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_____

_____

Task 3.3 *List and describe the functions of the stomach*

1)_____

_____

2)_____

_____

3)_____

_____

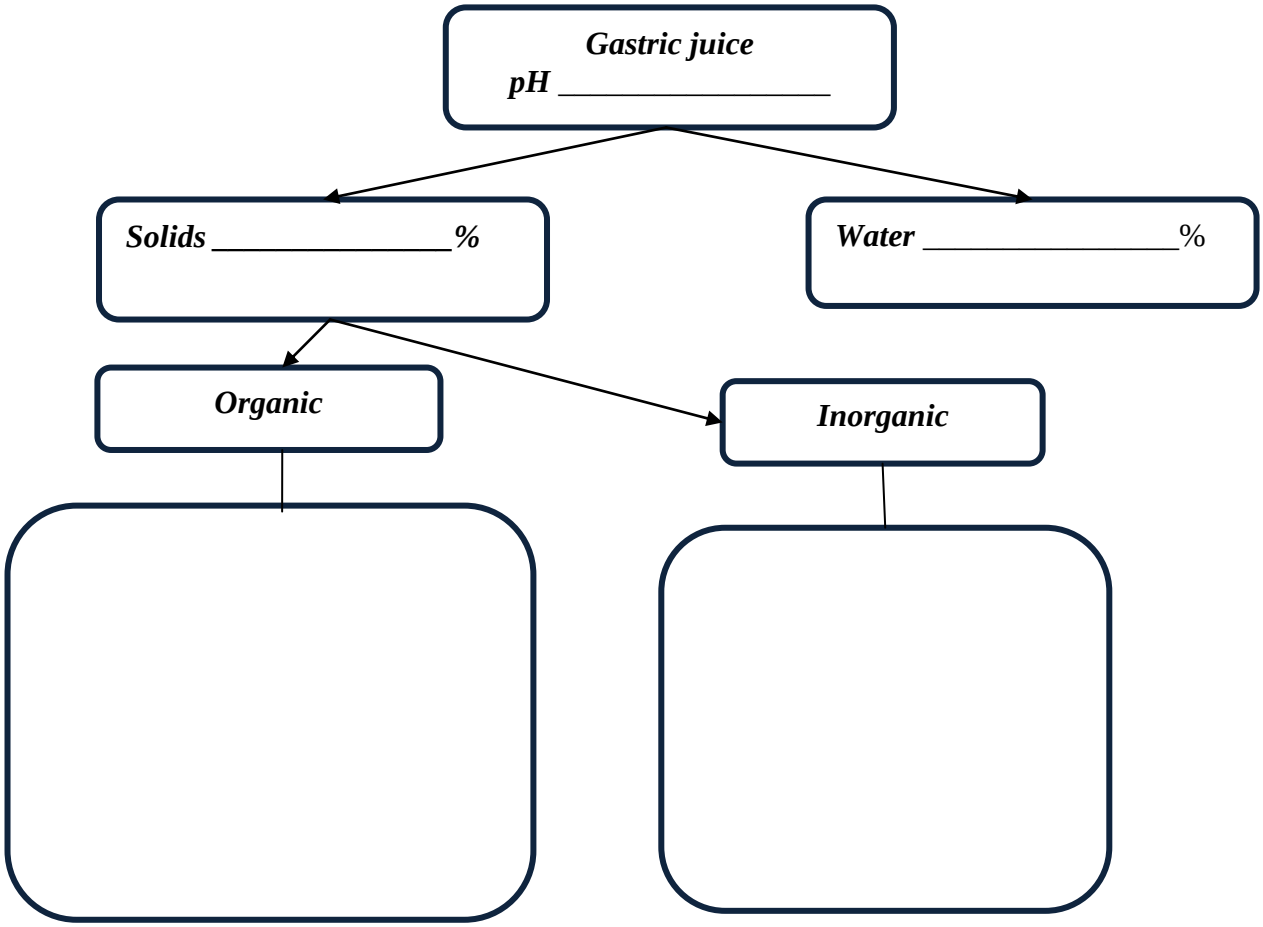
4)_____

_____

5)_____

_____

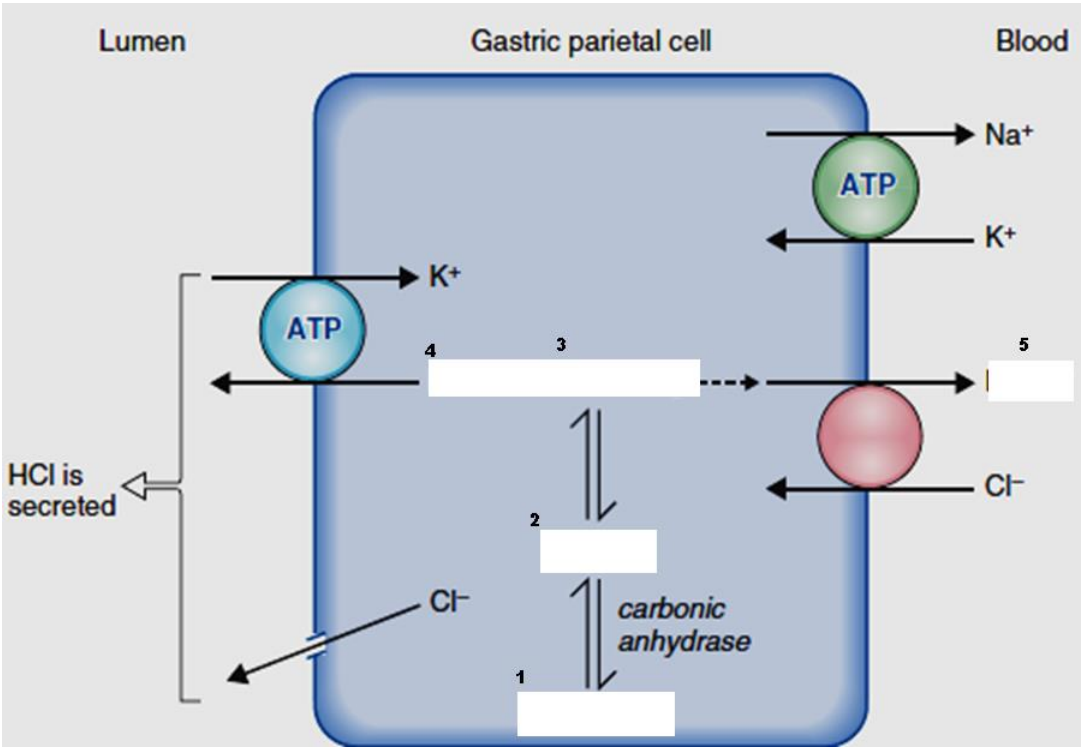
Task 3.4. *Complete the scheme* ***"Composition of gastric juice"***



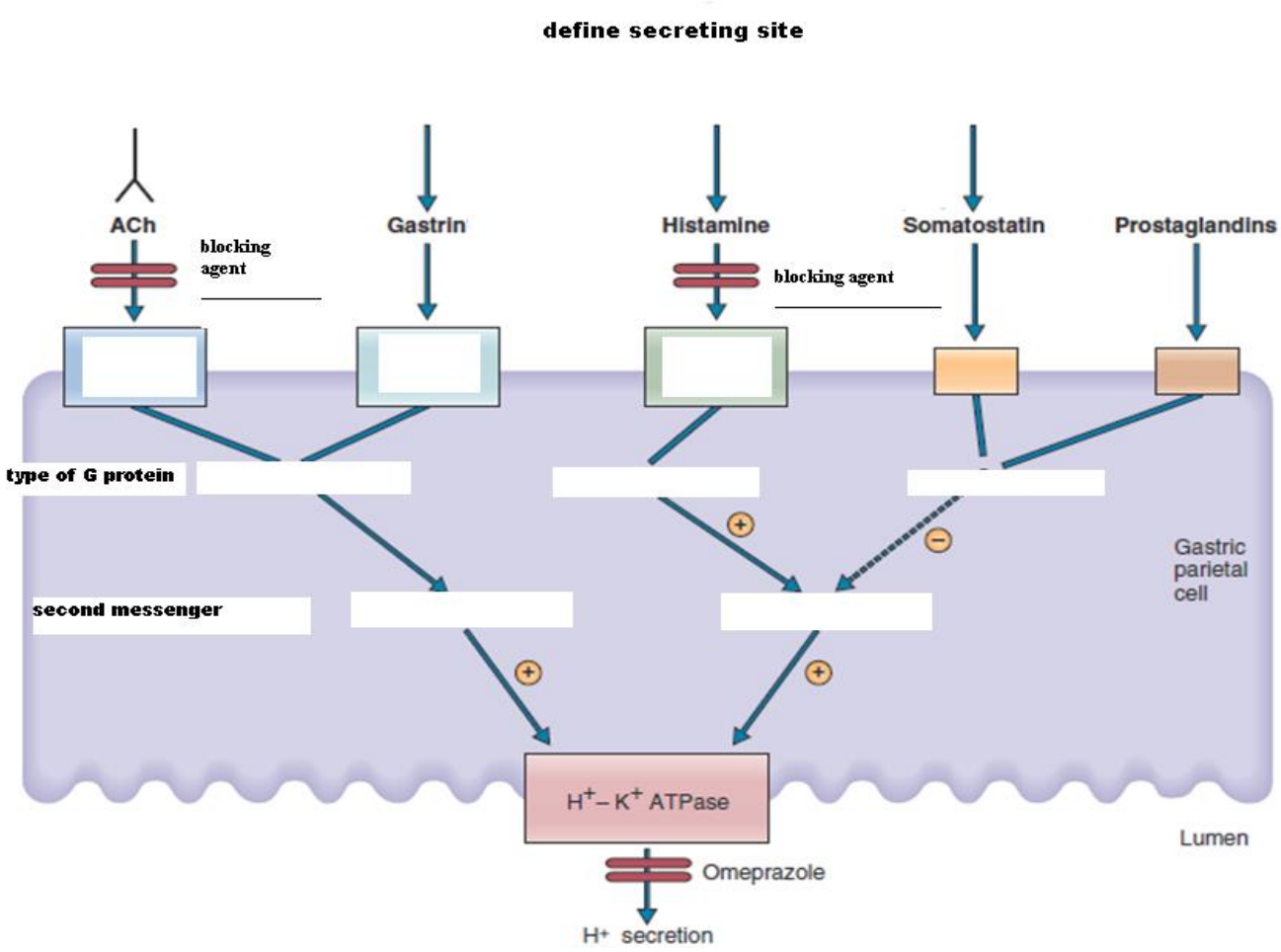
Task 3.5. Secretory function of the stomach is provided by activity of its exocrine cells. *Please, complete the following scheme*

Type of cell	location	secretion
Chief (peptic) cells		
Parietal cells		
Accessory (mucous) cells		
ECL (enterochromaphin-like cells)		
D cells (antrum)		
G-cells		

Task 3.6. HCl Production and Secretion. Fill in the illustration.



Task 3.7. Parietal cell membranes contain receptors for four chemical messengers. List them and explain how their alter HCL secretion



Task 3.8. *List the physiological significance of hydrochloric acid of gastric juice*

1) _____

_____

2) _____

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3) _____

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4) _____

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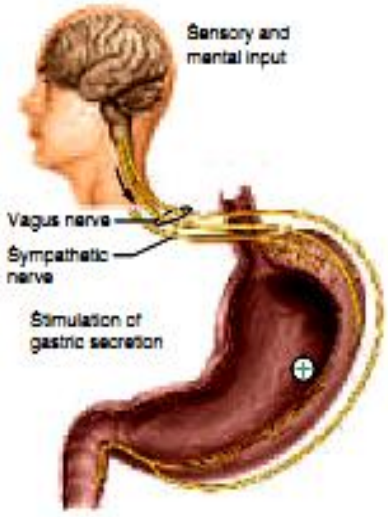
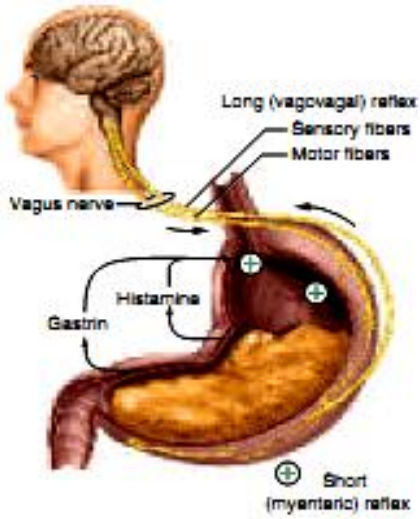
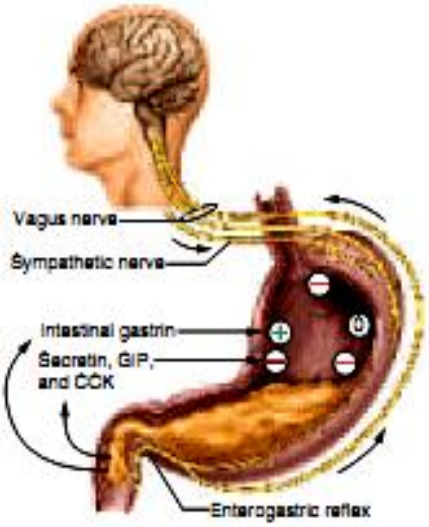
5) _____

_____

6) _____

_____

Task 3.9. Regulation of gastric secretion occurs in three stages: *cephalic*, *gastric* and *intestinal*. *Please, define functions of each phase*

A. Cephalic phase	***B. Gastric phase***	***C. Intestinal phase***
		
Function:	**Function:**	**Function:**

Task 3.10. *List the functions accessory cells*

1)_____

_____

*2)*_____

_____

List protective and damaging factors to gastric mucous membrane

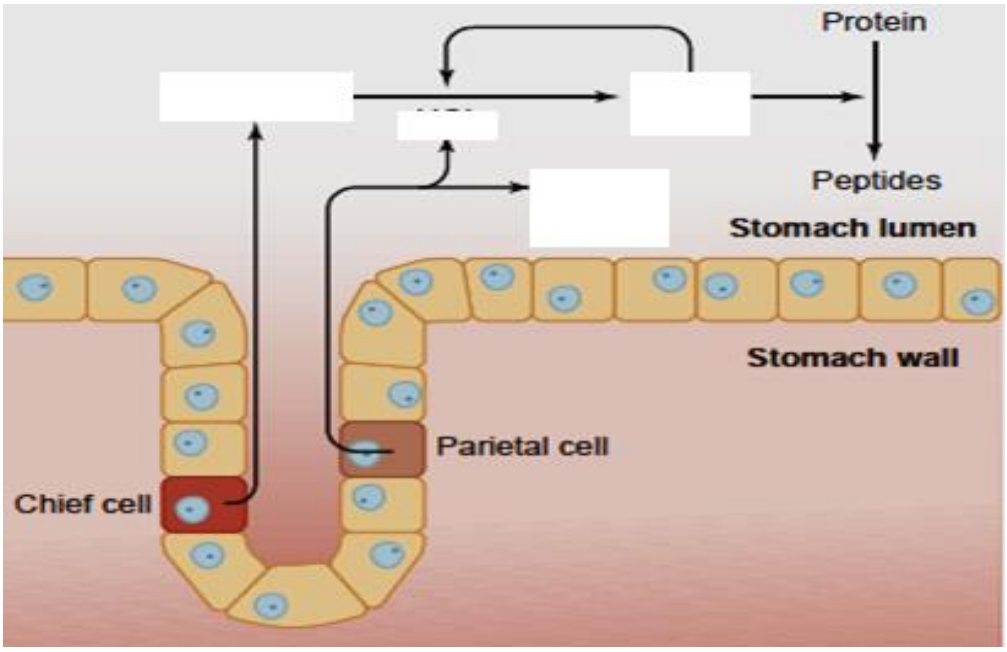
protective factors	damaging factors

Task 3.11. *Define the role of pepsin in gastric juice*

_____

_____

Fill in the illustration.



Task 3.12. Define the role of intrinsic factor.

_____
_____
_____
_____

Task 3.13. *List other enzymes of gastric juice and define their functions*

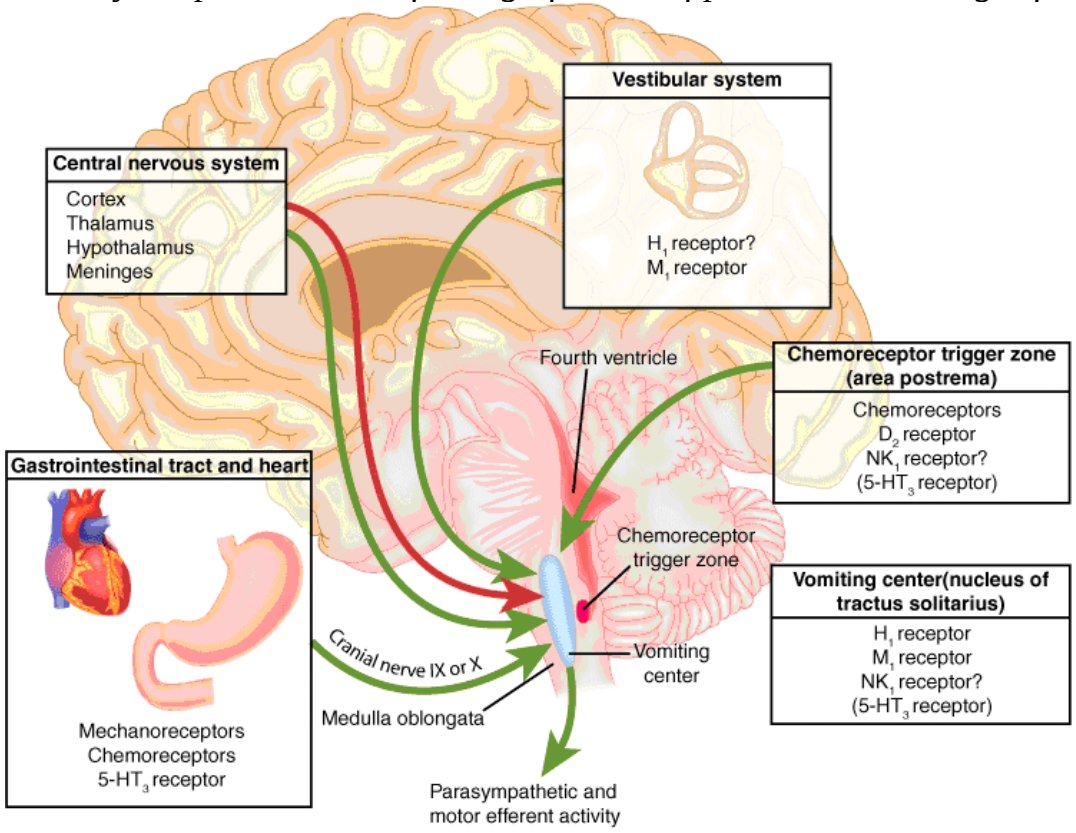
*1)*_____

*2)*_____

Task 3.14. There are three components of gastric motility. Name them and define function.

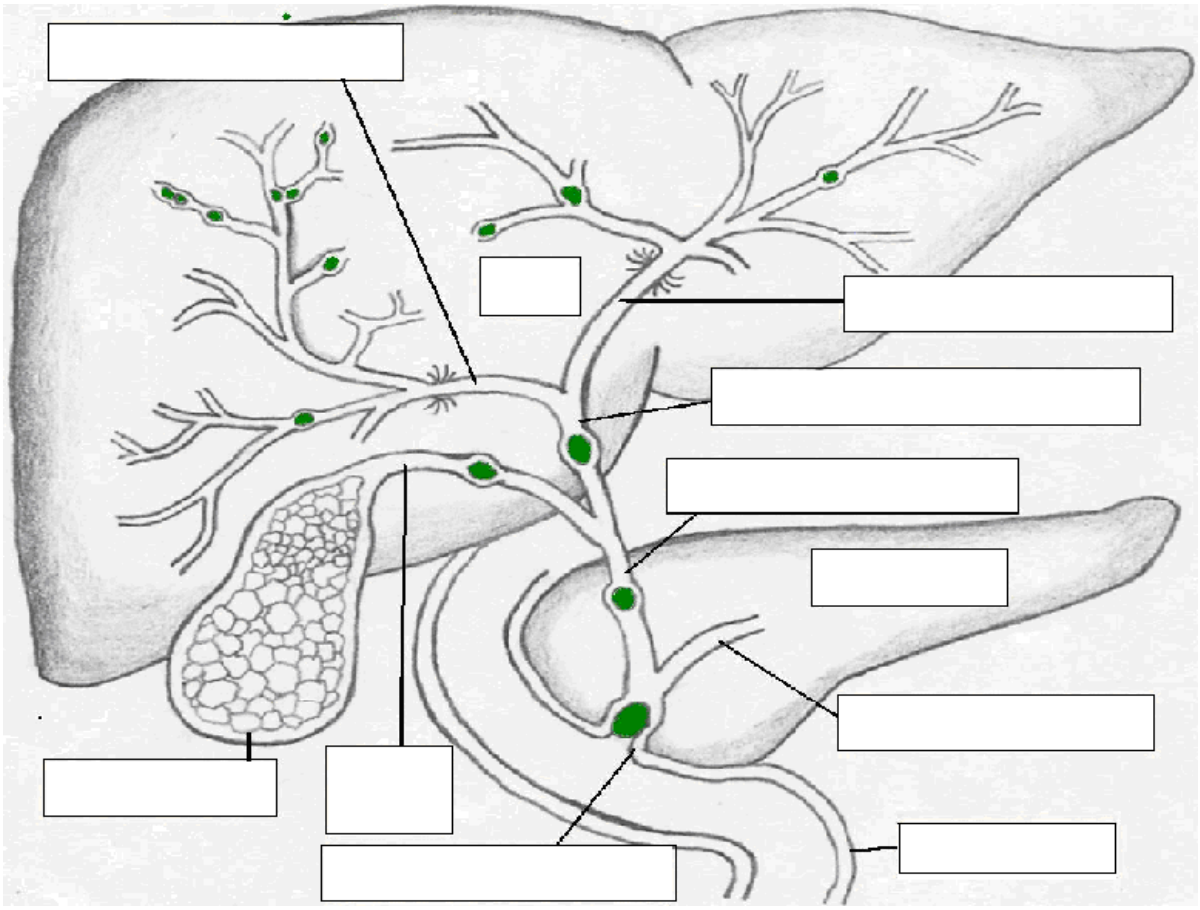
	Component	*Significance*	*Mechanism*
1	*Receptive Relaxation*		
2	*Mixing*		
3	*Gastric Emptying*		

Task 3.15. *Study the picture and define significance of protective vomiting reflex*



4. DIGESTION IN DUODENUM.
ROLE OF PANCREATIC JUICE AND BILE IN DIGESTION

Task 4.1. *Revise your knowledge from anatomy course and label the picture*



Task 4.2. *Define peculiarities of digestion in the duodenum*

1)_____

_____

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2)_____

_____

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3)_____

_____

_____

Task 4.3. *Name the functions of pancreas*

1)_____

_____

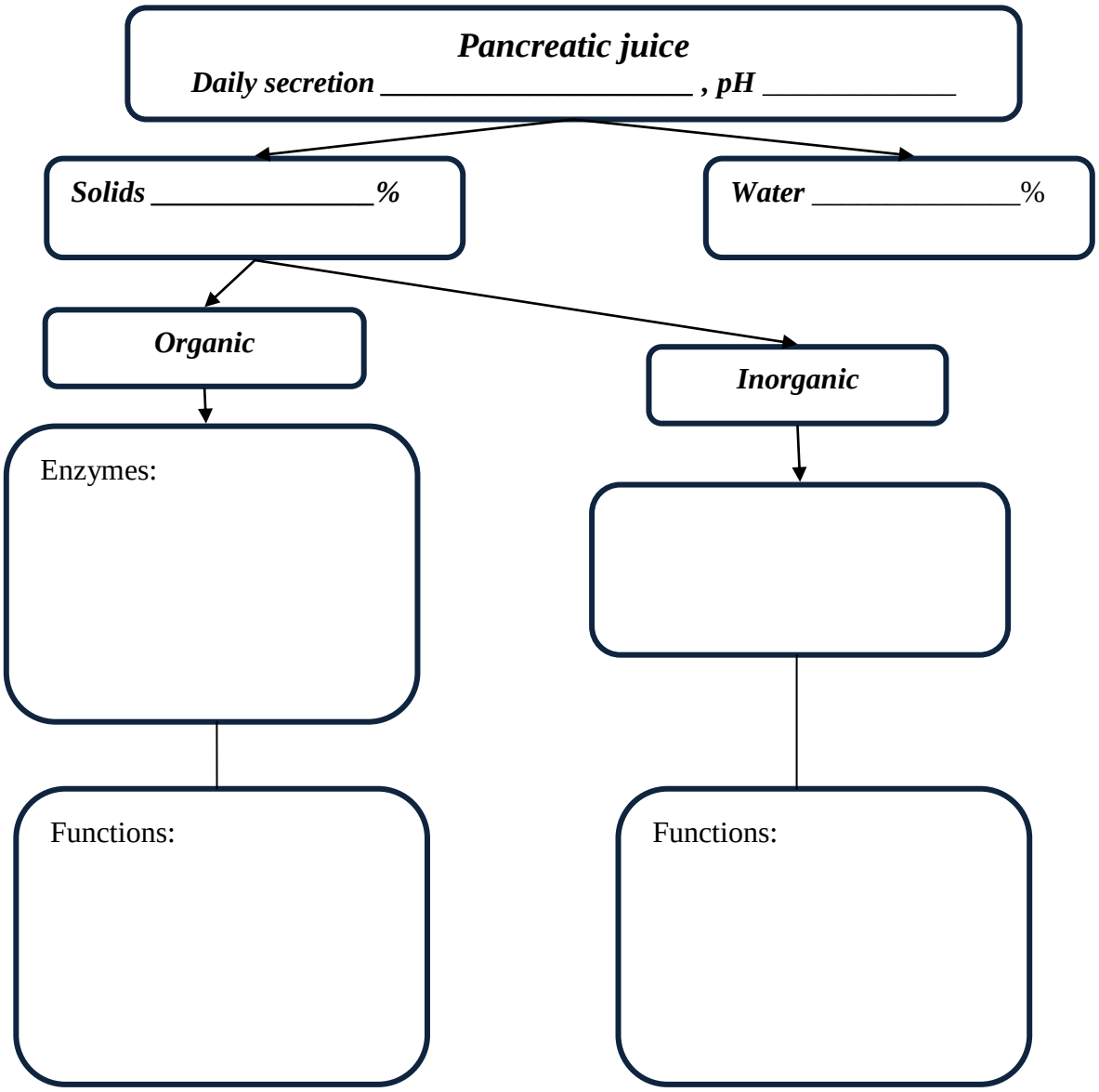
_____

2)_____

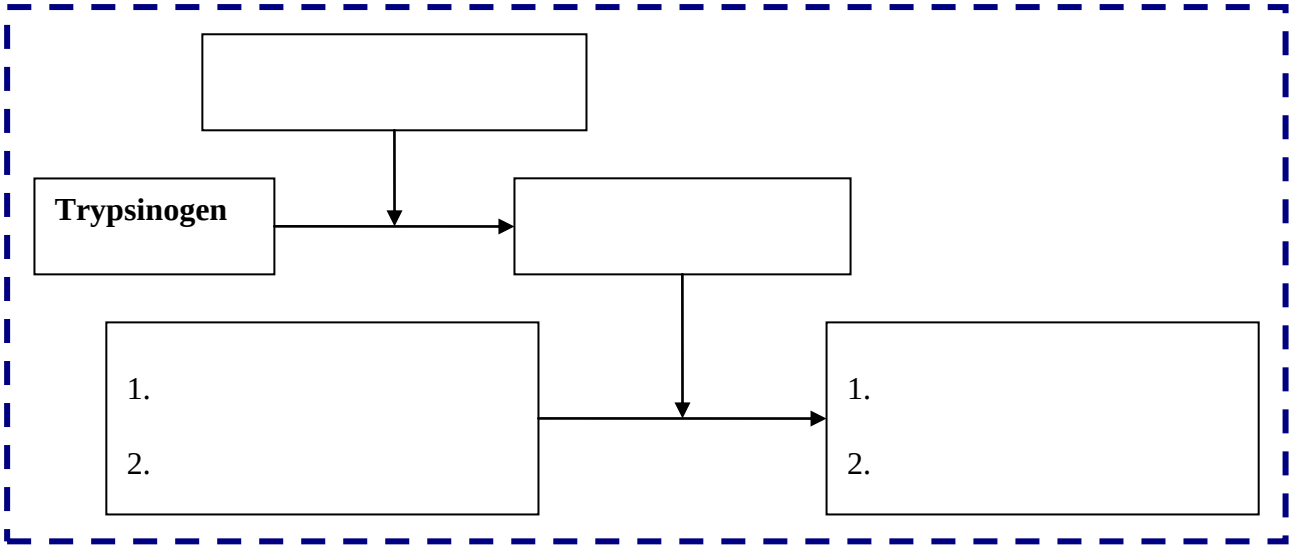
_____

_____

Task 4.4. *Define the composition of pancreatic juice*



Task 4.5. *Draw the scheme of pancreatic proteolytic enzymes activation*



Task 4.6. *Name pancreatic enzymes and their function*

	Digestion of proteins	***Digestion of CH***	***Digestion of liids***
Enzymes			
Function			

Task 4.7. *Define factors which prevent digestion of pancreas itself*

_____

_____

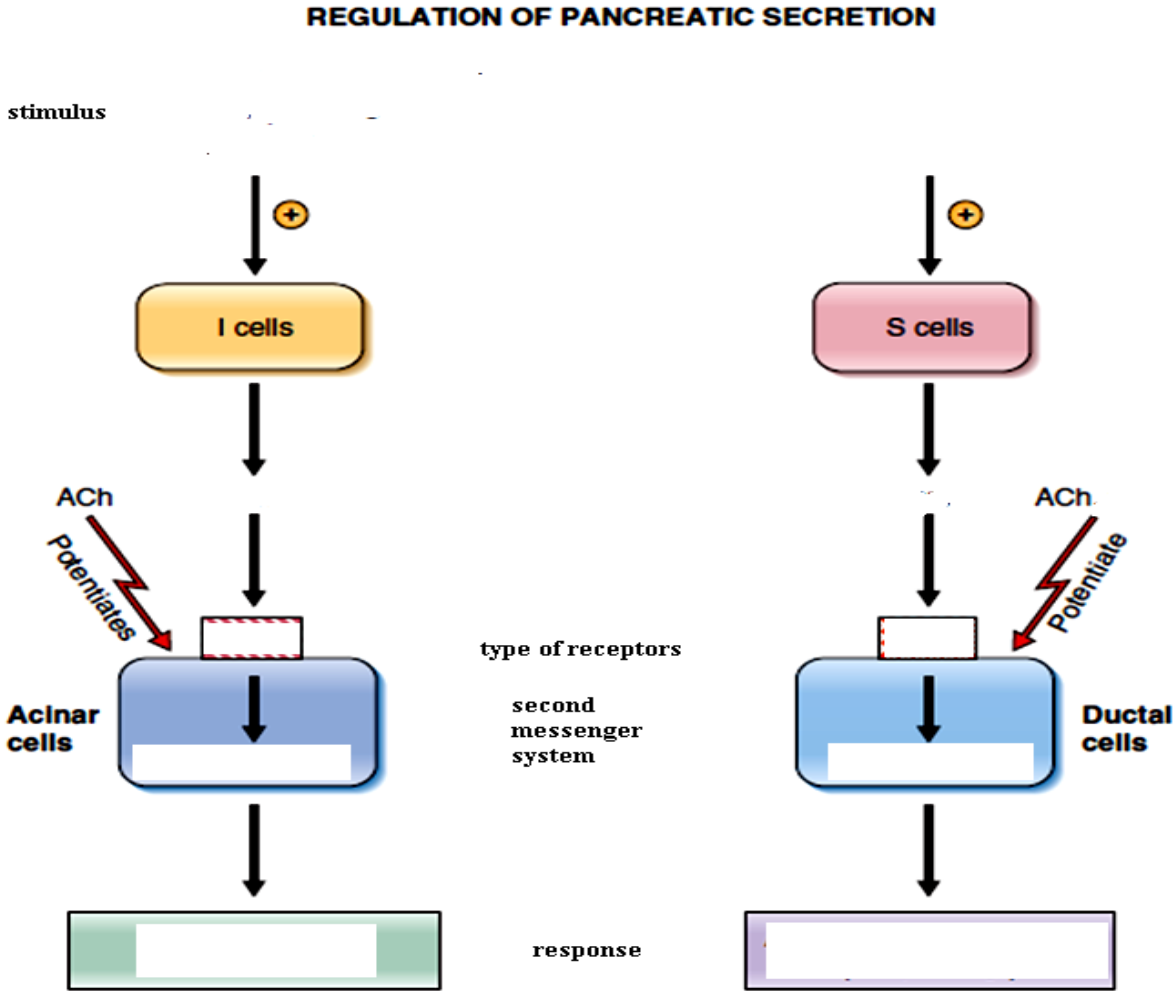
_____

Task 4.8. *Define the role of bicarbonate ions*

_____

_____

Task 4.9. *Describe pancreatic secretion. Fill in the illustration.*



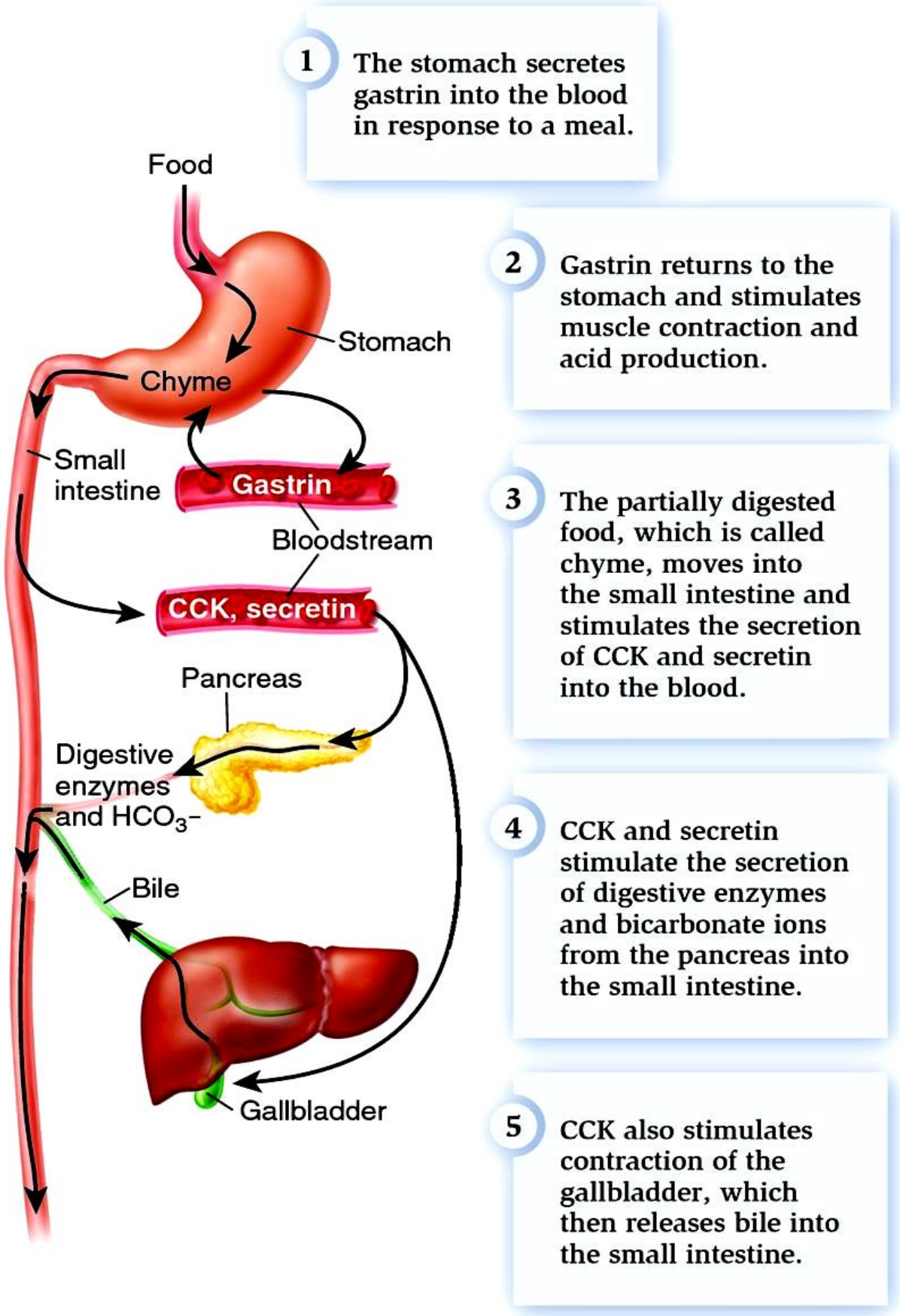


Figure 4.1. Cascade of gastrointestinal hormones

Task 4.10. Describe the stages of bile secretion by liver

1)_____

_____

2)_____

_____

Task 4.11. Define the functions of bile and gall blader

1)_____

2)_____

3)_____

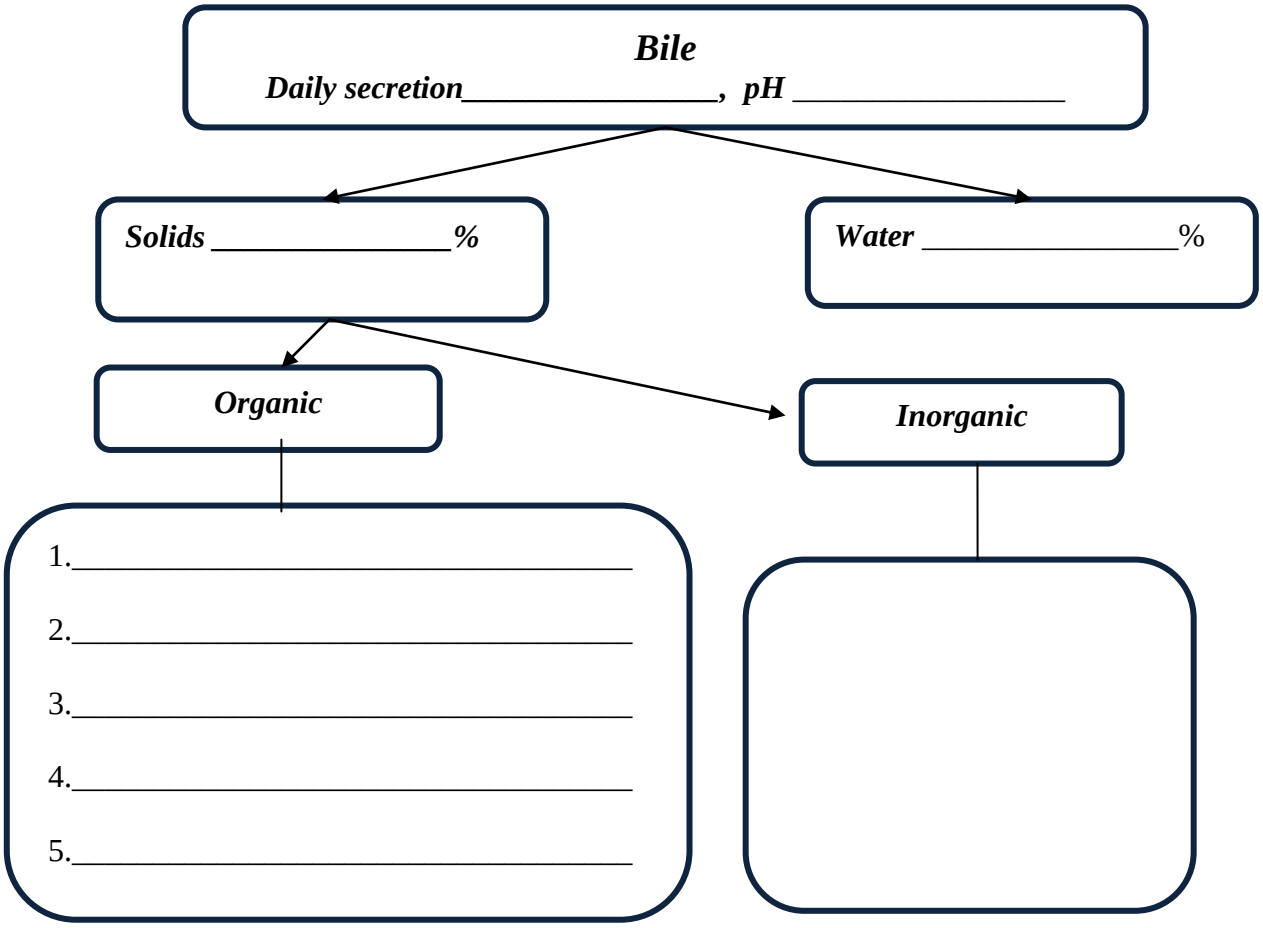
4)_____

5)_____

6)_____

7)_____

Task 4.12. *Complete the table* ***"Bile composition"***



Task 4.13. *Explain differences between cystic and hepatic bile. Give their characteristics*

_____

_____

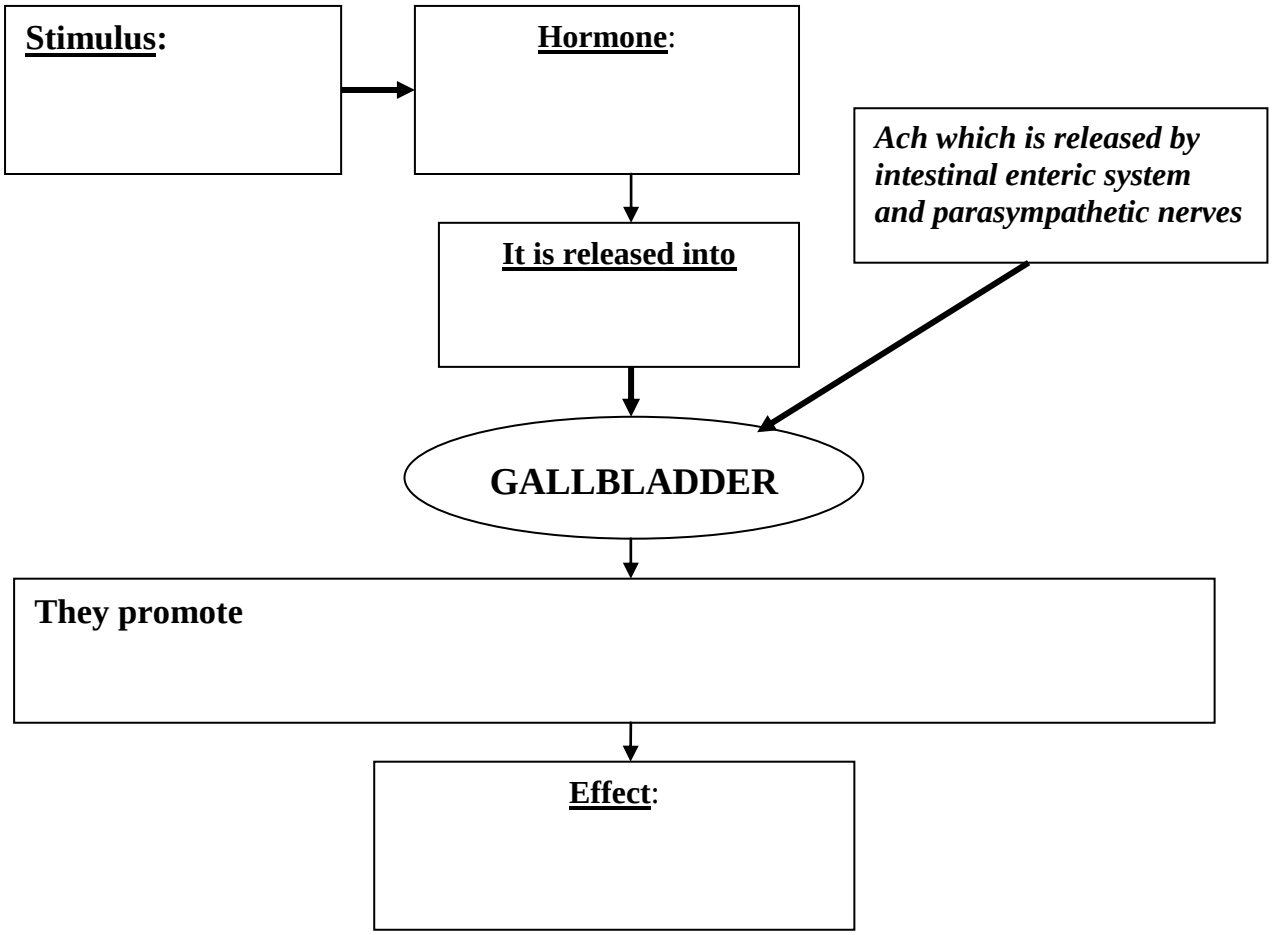
_____

_____

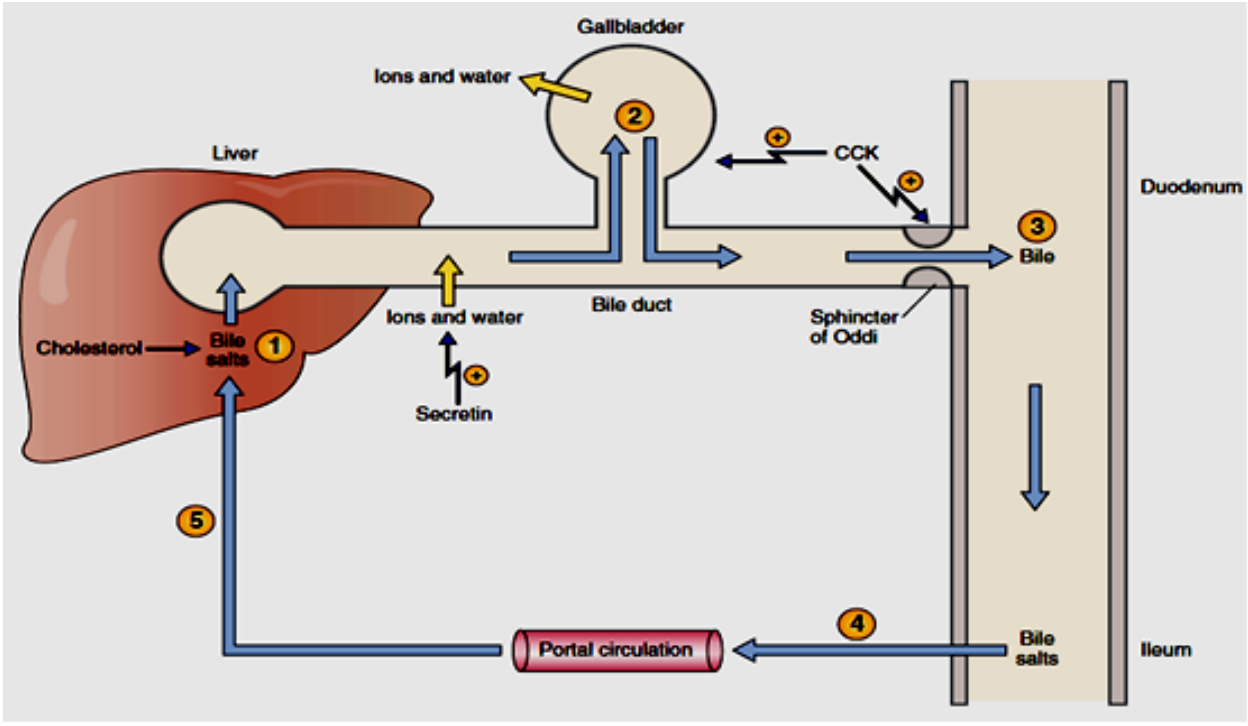
Hepatic bile_____, ***pH***_____.

Cystic bile_____, ***pH***_____.

Task 4.14. *Complete the scheme* ***"Regulation of bile secretion"***

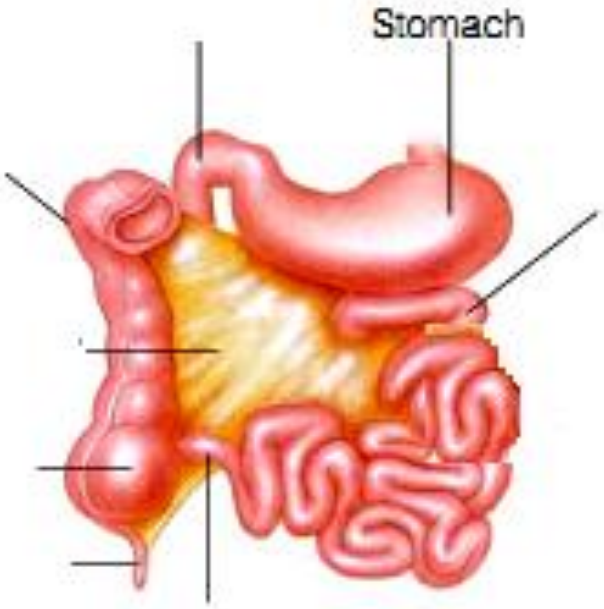


Task 4.15. Enterohepatic circulation of bile salts the fecal loss is about 600 mg/day (out of the total bile salt pool of 2.5 g)



5. DIGESTION IN SMALL AND LARGE INTESTINE

Task 5.1. *Label departments of small and large intestine*



Task 5.2. *Complete the table* ***"Composition of intestinal juice"***

Intestinal juice – pH _____

Solids _____***%***

Water _____%

Organic

Inorganic

Enzymes:

1.

2.

3.

Ions:

Study and memorize major digestive enzymes and their functions

Table 5.1. Characteristics of major digestive enzymes

Enzyme	*Site of action*	*Source*	*Substrate*	*Optimum pH*	*Products*
Salivary amylase	Mouth	Saliva	Starch	6.7	Maltose
Pepsin	Stomach	Gastric glands	Protein	1.6–2.4	Shorter polypeptides
Pancreatic amylase	Duodenum	Pancreatic juice	Starch	6.7-7.0	Maltose, maltriose, oligosaccharides
Trypsin, chymotrypsin, carboxypeptidase	Small intestine	Pancreatic juice	Polypeptides	8.0	Amino acids, dipeptides, and tripeptides
Pancreatic lipase	Small intestine	Pancreatic juice	Triglycerides	8.0	Fatty acids and monoglycerides
Maltase	Small intestine	Brush-border of epithelial cells	Maltose	5.0–7.0	Glucose
Sucrase	Small intestine	Brush-border of epithelial cells	Sucrose	5.0–7.0	Glucose+fructose
Lactase	Small intestine	Brush-border of epithelial cells	Lactose	5.8–6.2	Glucose+galactose
Aminopeptidase	Small intestine	Brush-border of epithelial cells	Polypeptides	8.0	Amino acids, dipeptides, and tripeptides

Table 5.2. Brush-border enzymes attached to the cell membrane of microvilli in the small intestine

Category	*Enzyme*	*Functions*
Disaccharidase	Sucrase	Digests sucrose to glucose and fructose; deficiency produces gastrointestinal disturbances
	Maltase	Digests maltose to glucose
	Lactase	Digests lactose to glucose and galactose; deficiency produces gastrointestinal disturbances (lactose intolerance)
Peptidase	Aminopeptidase	Produces free amino acids, dipeptides, and tripeptides
	Enterokinase	Activates trypsin (and indirectly other pancreatic juice enzymes); deficiency results in protein Malnutrition
Phosphatase	Ca2+, Mg2+-ATPase	Needed for absorption of dietary calcium; enzyme activity regulated by vitamin D
	Alkaline phosphatase	Removes phosphate groups from organic molecules; enzyme activity may be regulated by vitamin D

Task 5.3. *Define types of digestion in small intestine*

1)_____

2)_____

Task 5.4. *Define peculiarities of digestion in the small intestine*

1. _____
   _____
2. _____
   _____
3. _____
   _____

Task 5.5. Describe 2 pathways of absorption.

1)_____
_____

2)_____
_____

Task 5.6. Carbohydrates digestion

Level	***Type of CH***	***Enzyme***	***Product***	***Monomer***	***Absorption***
mouth					
stomach					
duodenum					
Jejunum, ileun					

Task 5.7. Proteins digestion

Level	**enzyme**	**product**	**monomer**	**absorption**
Stomach				
Duodenum				
Jejunum, Ileum				

Task 5.8. Lipids digestion

Level	Enzyme	Product	Absorption
mouth			
stomach			
Small intestine			

Define the role of colipase

_____

_____

_____

Task 5.9. Small Intestinal Motility

	Segmentation Contractions	*Peristaltic Contractions*
Significance		
mechanism		

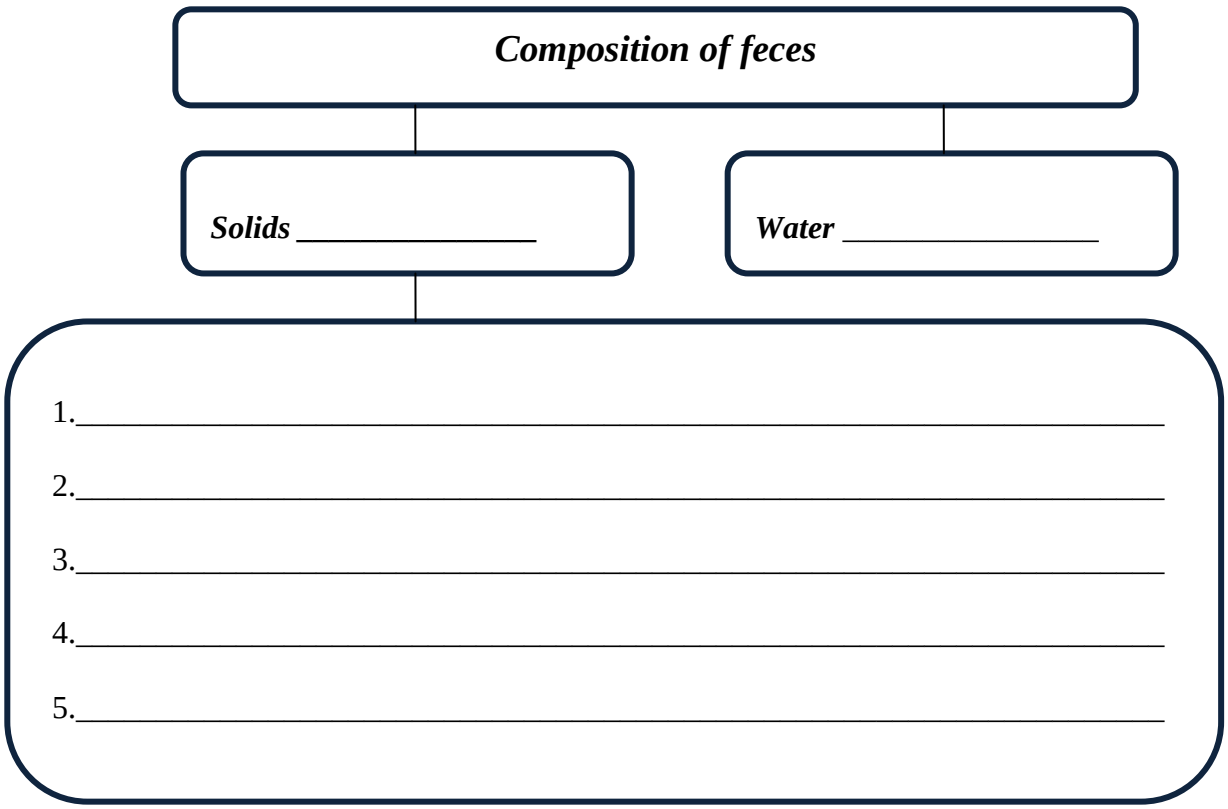
Task 5.10. *Define peculiarities of digestion in large intestine and principal functions of the colon*

1)_____
2)_____
3)_____
4)_____
5)_____
6)_____
7)_____

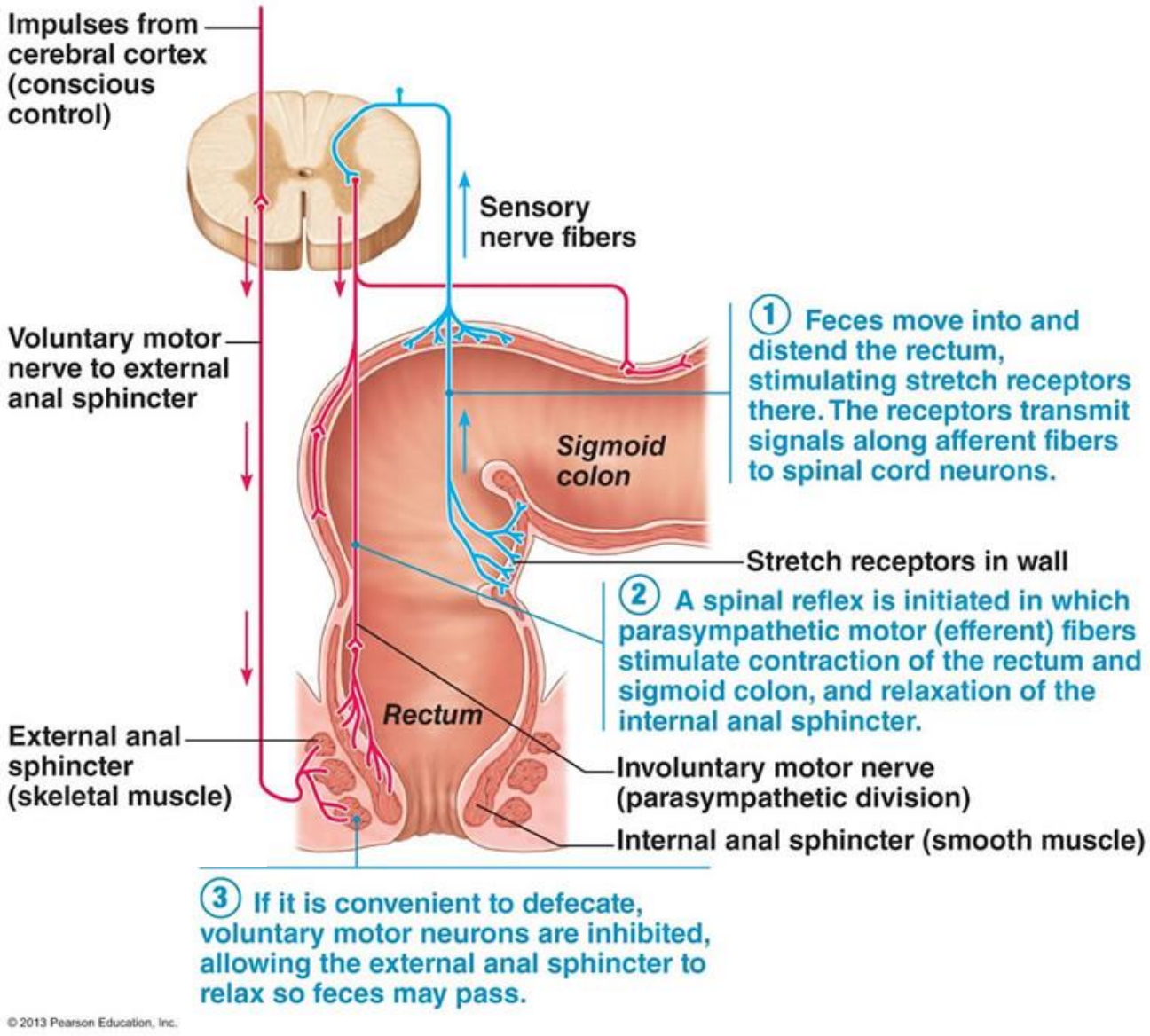
Task 5.11. *Define the significance of bacteria of large intestine.*

1)_____
2)_____
3)_____
4)_____
5)_____
6)_____
7)_____

Task 5.12. *Complete the scheme* **"*Composition of feces*"**



Task 5.13. *Study the following illustration and draw the scheme of defecation reflex: stimuli → afferent nerve → center → efferent nerve → target structures*



Task 5.14. Explain Gastrocolic Reflex

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6. PHYSIOLOGICAL BASIS OF HUNGER AND SATIETY

Task 6.1. *Define stimuli that cause the feeling of hunger*

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Task 6.2. *Describe the nuclei of feeding center and the role of anorexigenic and orexigenic neurons*

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What types of satiety are known?

1) _____

2) _____

Task 6.3. Name hormones regulating feeling of hunger and satiety. Fill in the table.

Hormone	Effect
Leptin	
Insulin	
Peptide YY (PYY)	
Ghrelin	

Task65.4. *Draw the scheme* ***"Functional system of nutrition"***

7. PHYSIOLOGY OF METABOLISM AND ENERGY EXCHANGE

OUTLINE

1. Functions and stages of metabolism
2. ATP role in metabolism
3. Metabolism of carbohydrates, lipids and proteins
4. Nitrogen balance; its significance and regulation
5. Methods of metabolism examination

1. Functions and stages of metabolism

Nutrition is the starting point and basis for all human functions. From the time a single-celled, fertilized egg divides in two, nutrition provides the matter needed for cell division, growth, and development. It is the source of fuel that provides the energy for all biological work and of the raw materials for replacement of worn-out biomolecules and cells. The fact that it provides only the raw materials means, further, that chemical change – *metabolism* – lies at the foundation of form and function. Digestive system function is to break *foodstuffs* down into usable form (*nutrients*) and absorbs them into the blood and lymph. Now let's consider these nutrients in more depth, follow their fate after absorption, and explore related issues of metabolism and body heat.

Organism is an opened thermodynamic system which exchange substances, energy and information with external environment. The need for energy arises because living matter is thermodynamically unstable system that will run down unless energy is continuously added.

Metabolism *and* ***energy exchange*** *is a complex of biochemical reactions and connected with them energetic processes that supply the vital functions of living beings.* These reactions consist in biological oxidation (aerobic or anaerobic) of organic compounds which contain energy. The energy released during metabolic reactions then is used to exert various processes in an organism such as maintenance of body temperature, blood circulation, respiration, muscles contraction, etc.

The importance of metabolism becomes obvious if we compare apparent (clinical) death and biological one. Clinical death is reversible process which is characterized by absence of breathing and cardiac arrest. But, despite the inhibition of the most vitally important functions, during 5–6 minutes there is minimal level of metabolism. In contrast, biological death is irreversible state because of stoppage of all metabolic reactions which can't be restored.

So, functions of metabolism are as following:

1. Metabolism supplies organism's *plastic requirements*, i.e. chemical substances which are necessary for building and renewal of its structural components (mainly proteins function).
2. Metabolism provides all vital functions of organism with *energy* (mainly function of carbohydrates and fats).

Metabolism and energy exchange occurs in *3 stages*: 1) food intake and nutrients treatment in the gastrointestinal tract (GIT); 2) metabolism proper which is the totality of cellular catabolic and anabolic reactions; and 3) elimination of different wastes by excretory organs – kidneys, GIT, lungs, skin.

Sources of energy. The energy for our organism is derived from *foodstuffs*. Proper nutrition requires adequate energy sources: minimum quantities of protein containing all essential amino acids, carbohydrates, essential fats, minerals, vitamins and trace elements, in addition, water must be available. Daily requirements and principle functions of these foodstuffs are summarized in *table 5.1*.

Table 7.1 Foodstuffs classes and their principle functions

Foodstuffs	Daily requirement	Representative functions
Water	2–2,5 L	Solvent; coolant; reactant or product in many metabolic reactions (especially hydrolysis and condensation); dilutes and eliminates metabolic wastes; supports blood volume and pressure
Carbohydrates	125–175 g	Fuel; a component of nucleic acids, ATP and other nucleotides, glycoproteins, and glycolipids
Lipids	80–100 g	Fuel; plasma membrane structure; myelin sheaths of nerve fibers; hormones; eicosanoids; bile salts; insulation; protective padding around organs; absorption of fat-soluble vitamins; vitamin D synthesis; some blood-clotting factors
Proteins	44–66 g (0.75 g/kg of body weight)	Muscle contraction; ciliary and flagellar motility; structure of cellular membranes and extracellular material; enzymes; major component of connective tissues; transport of plasma lipids; some hormones; oxygen binding and transport pigments; blood-clotting factors; blood viscosity and osmolarity; antibodies; immune recognition; neuromodulators; buffers; emergency fuel
Minerals	0.05–3.3 mg	Structure of bones and teeth; component of some structural proteins, hormones, ATP, phospholipids, and other chemicals; cofactors for many enzymes; electrolytes; oxygen transport by hemoglobin and myoglobin; buffers; stomach acid; osmolarity of body fluids
Vitamins	0.002–60 mg	Coenzymes for many metabolic pathways; antioxidants; component of visual pigment; one hormone (vitamin D)

At the first stage of metabolism during the digestion process biopolymers (proteins, carbohydrates, fats and nucleic acids) are subsequently hydrolyzed in the GIT. Their decomposition results in formation of ***nutrients***. Nutrients are low molecular weight compounds (*tab. 5.2*) which have no specificity (they are the same in any species) and can be freely absorbed by enterocytes of intestinal wall. Absorbed monomers are transported by blood and lymph toward peripheral tissues where they take part in metabolism, either catabolic or anabolic reactions.

Second stage is metabolism proper which is inseparable unity of two processes – ***catabolism*** and ***anabolism***. *In the catabolic reactions (dissimilation) chemical compounds are oxidized with releasing of energy.* In contrast, *anabolic reactions (assimilation) accompanying by energy consumption result in synthesis of chemical compounds which are necessary for organism* – proteins, phospholipids, neurotransmitters, secretions and others. In healthy person anabolism and catabolism are well balanced. During intensive growth, heavy physical work, pregnancy and in the postpartum period anabolic reactions are predominant. However, in elder persons, during starvation, exhaustion and cachexia, long-term stress catabolism predominates over anabolism.

Table 7.2 Foodstuffs and Nutrients

Foodstuffs	Nutrients
Carbohydrates	Monosaccharides: glucose, fructose, galactose, etc.
Lipids	Glycerol, fatty acids, phosphoric acid, cholesterol
Proteins	Amino acids

2. ATP role in metabolism

All the energy foods – carbohydrates, fats, and proteins – can be oxidized in cells, and during this process, large amounts of energy are released. The same foods can also be burned with pure oxygen outside the body in an actual fire, also releasing large amounts of energy; in this case, however, the energy is released suddenly, all in the form of heat. The energy needed by the physiologic processes of the cells is not heat but energy to cause mechanical movement in the case of muscle function, to concentrate solutes in the case of glandular secretion, and to effect other functions. To provide this energy, the chemical reactions must be “coupled” with the systems responsible for these physiologic functions. This coupling is accomplished by special cellular enzyme and energy transfer systems.

Adenosine triphosphate (ATP) is an essential link between energy-utilizing and energy-producing functions of the body (*Fig. 5.1*). For this reason, ATP has been called the “energy currency” of the body, and it can be gained and spent repeatedly.

The amount of free energy in each of high energy bonds per mole of ATP is about 12,000 calories under the usual conditions of temperature and concentrations of the reactants in the body. Therefore, in the body, removal of each of the last two phosphate radicals liberates about 12,000 calories of energy. After loss of one phosphate radical from ATP, the compound becomes ADP, and after loss of the second phosphate radical, it becomes adenosine monophosphate (AMP).

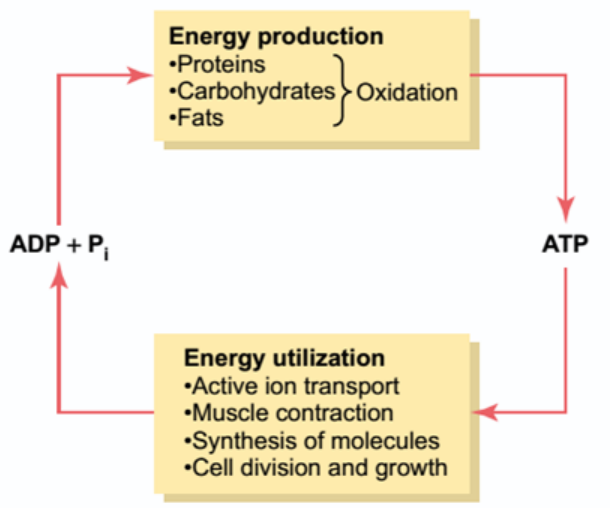


Figure 7.1. Adenosine triphosphate (ATP) is the central link between energy-producing and energy-utilizing systems of the body. *ADP - adenosine diphosphate; Pi - inorganic phosphate.*

ATP is present everywhere in the cytoplasm and nucleoplasm of all cells, and essentially all the physiologic mechanisms that require energy for operation obtain it directly from ATP (or another similar high energy compound – guanosine triphosphate [GTP]). In turn, the food in the cells is gradually oxidized, and the released energy is used to form new ATP, thus always maintaining a supply of this substance. All these energy transfers take place by means of coupled reactions.

Table 7.3. Usage of ATP (in average) for different physiological processes

Physiological processes	Percentage of ATP
For synthesis of proteins	27 %
For Na^+,K^+-pump	24 %
For Ca^{2+}-pump	6 %
For synthesis of urea	3%
For muscles contraction, secretion, etc.	Rest 40 %

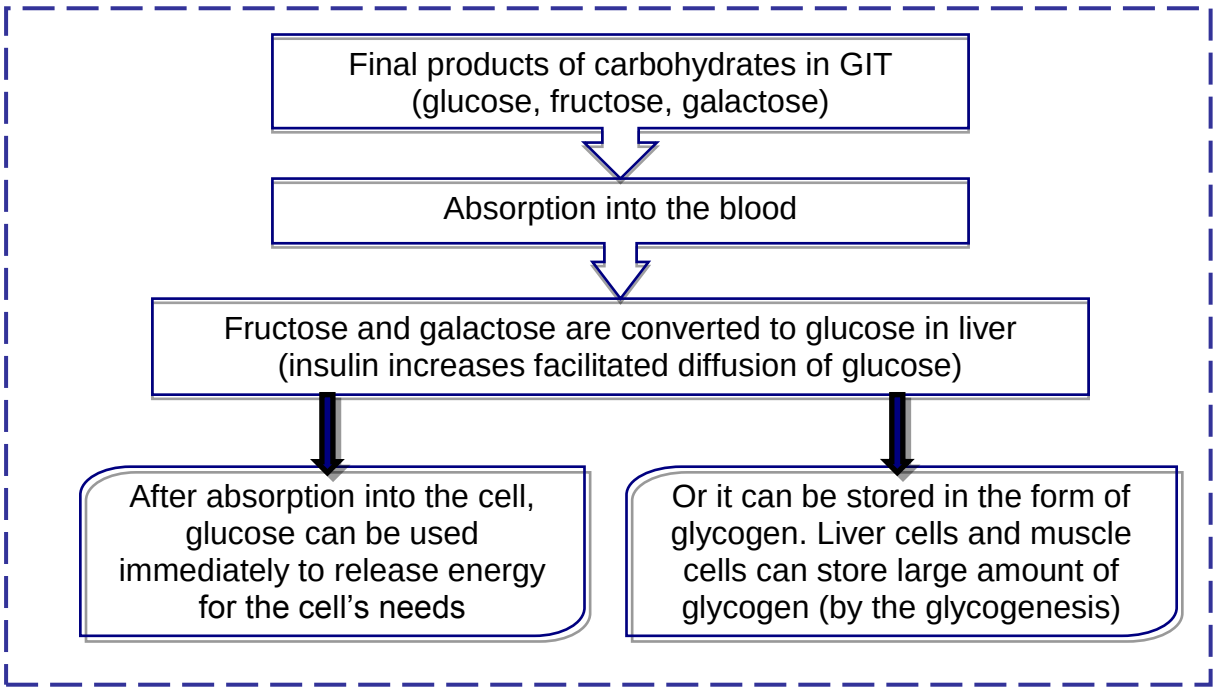
Let's explain how the energy from carbohydrates, fats and proteins can be used to form ATP in the cells. Normally, 90 per cent or more of all the carbohydrates utilized by the body are used for this purpose.

3. Metabolism of carbohydrates, lipids and proteins

Metabolism of carbohydrates

A well-nourished adult has about 440 g of carbohydrate in the body, most of it in three places: about 325 g of muscle glycogen, 90 to 100 g of liver glycogen, and 15 to 20 g of blood glucose.

Sugars function as a structural component of other molecules including nucleic acids, glycoproteins, glycolipids, ATP, and related nucleotides (GTP, cAMP, etc.), and they can be converted to amino acids and fats. Most of the body's carbohydrate, however, serves as *fuel* – an easily oxidized source of chemical energy. Most cells meet their energy needs from a combination of carbohydrates and fats, but some cells, such as neurons and erythrocytes, depend almost exclusively on carbohydrates. Even a brief period of hypoglycemia (deficiency of blood glucose) causes nervous system disturbances felt as weakness or dizziness. So, adequate amount of glucose must be present in the blood for several hours between meals.



When glucose is not immediately required for energy the extra glucose is converted into fat. When the glycogen-storing cells (primary liver and muscle cells) approach saturation with glycogen, the additional glucose is converted into fat in liver and fat cells and is stored in fat in adipose cells.

When it is necessary to re-form glucose from glycogen the ***glycogenolysis*** must be activated (phosphorylation), which is stimulated by *adrenaline* or by *glucagon*. When the body's stores of carbohydrates decrease below normal, moderate quantities of glucose can be formed from amino acids and the glycerol portion of fat through ***gluconeogenesis,*** which is regulated by *corticotropin* and *glucocorticoids* (cortisol). The liver plays a key role in maintaining blood glucose levels during fasting by these both ways.

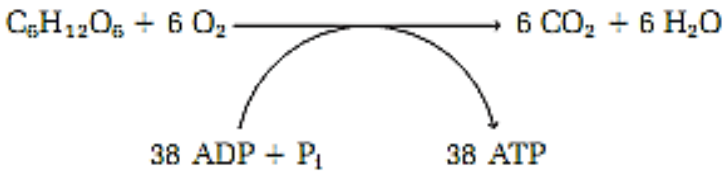
Glucose catabolism. There are three major pathways of glucose catabolism:

1) ***glycolysis***, which splits a glucose molecule into two molecules of pyruvic acid;

2) ***anaerobic fermentation***, which occurs in the absence of oxygen and reduces pyruvic acid to lactic acid; and

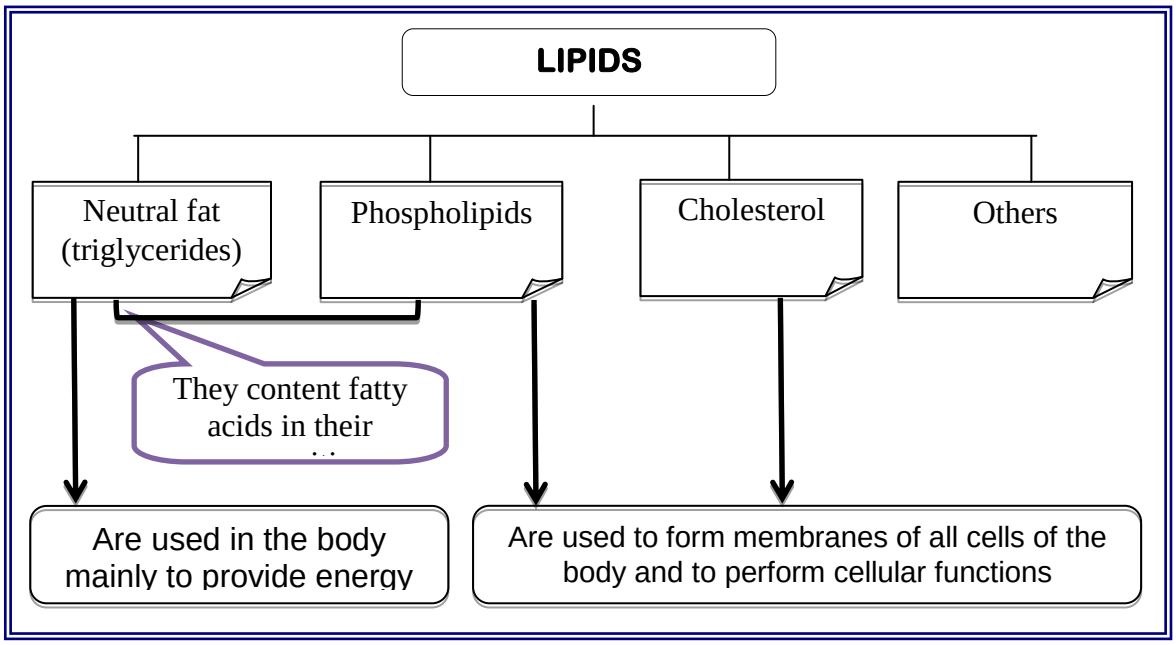
3) ***aerobic respiration***, which occurs in the presence of oxygen and oxidizes pyruvic acid to carbon dioxide and water.

The pathways of glucose catabolism can be represented in the summary equation:



Metabolism of lipids

The reference male and female are, respectively, about 15 % and 25 % fat by weight. Fat accounts for most of the body's stored energy. Lesser amounts of phospholipid, cholesterol, and other lipids also play vital structural and physiological roles.



A well-nourished adult meets 80 % to 90 % of his or her resting energy needs from fat. Fat is superior to carbohydrates for energy storage for two reasons: 1) carbohydrates are hydrophilic, absorb water, and thus expand and occupy more space in the tissues. Fat, however, is hydrophobic, contains almost no water, and is a more compact energy storage substance. 2) Fat is less oxidized than carbohydrate and contains over twice as much energy (9 kcal/g of fat compared with 4 kcal/g of carbohydrate). A man's typical fat reserves contain enough energy for 119 hours of running, whereas his carbohydrate stores would suffice for only 1.6 hours.

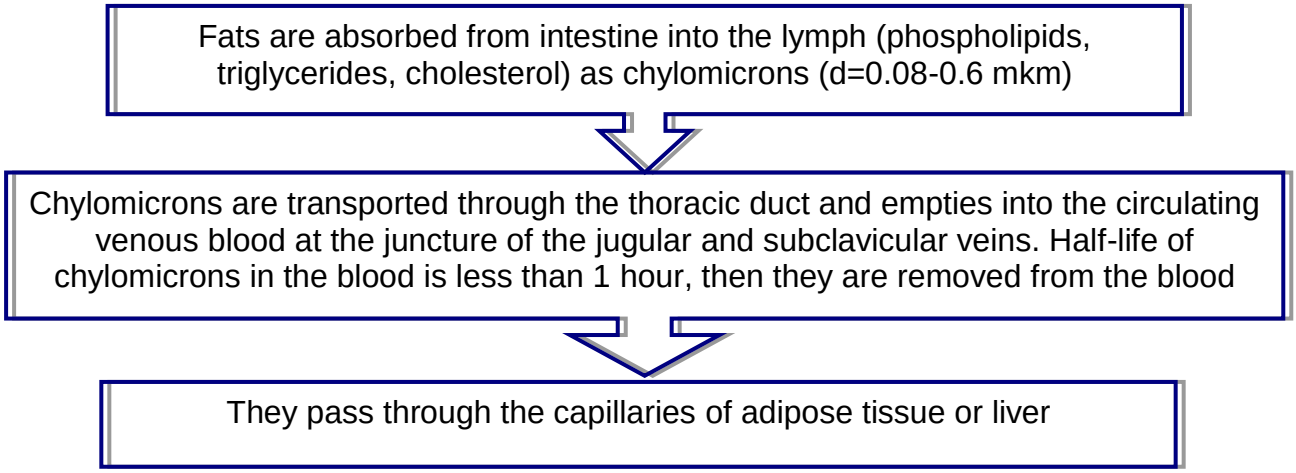
Fat has ***glucose-sparing*** and ***protein-sparing*** effects – as long as enough fat is available to meet the energy needs of the tissues, protein is not catabolized for fuel and glucose is spared for consumption by cells that cannot use fat, such as neurons.

Vitamins A, D, E, and K are fat-soluble vitamins, which depend on dietary fat for their absorption by the intestine. People who ingest less than 20 g of fat per day are at risk of vitamin deficiency because there is not enough fat in the intestine to transport these vitamins into the body tissues.

Phospholipids and ***cholesterol*** are major structural components of plasma membranes and myelin. Cholesterol is also important as a precursor of steroid hormones, bile acids, and vitamin D. Thromboplastin, an essential blood-clotting factor, is a lipoprotein. Two fatty acids – arachidonic acid and linoleic acid – are precursors of prostaglandins and other eicosanoids.

In addition to its metabolic and structural roles, fat has important protective and insulating functions.

Lipids are an important part of the diet and must be transported to all cells of the body, yet they are hydrophobic and will not dissolve in the aqueous blood plasma. This problem is overcome by complexes called **lipoproteins** – tiny droplets with a core of cholesterol and triglycerides and a coating of proteins and phospholipids. The coating not only enables the lipids to remain suspended in the blood, but also serves as a recognition marker for cells that absorb them.

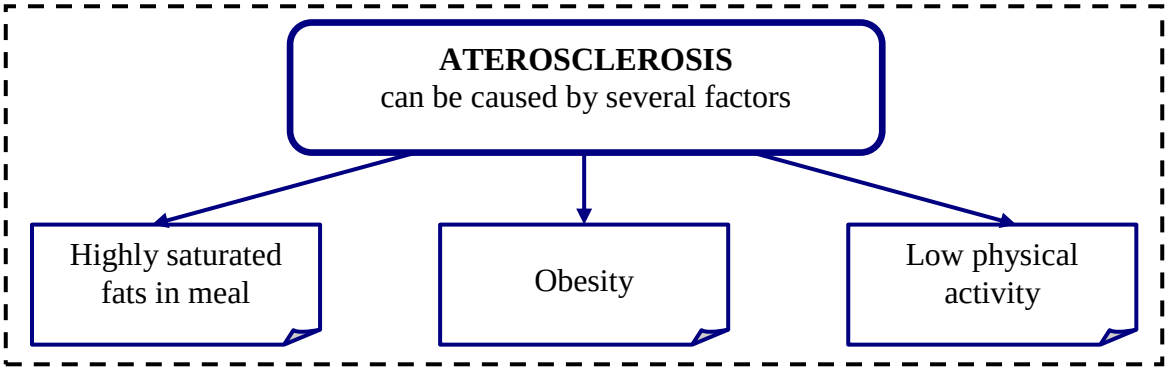


Lipoproteins are classified into four major categories by their density: 1) **chylomicrons**, 2) **high-density lipoproteins (HDLs)**, 3) **low-density lipoproteins (LDLs)**, and 4) **very low–density lipoprotein (VLDLs)**. Notice that the higher the proportion of protein to lipid, the higher the density. Lipoproteins vary not only in size and density but more importantly in composition and function.

Chylomicrons form in the absorptive cells of the small intestine and then pass into the lymphatic system and ultimately the bloodstream. Endothelial cells of the blood capillaries have a surface enzyme called **lipoprotein lipase** that hydrolyzes triglycerides into glycerol and free fatty acids (FFAs). These products can then pass through the capillary walls into adipocytes, where they are resynthesized into storage triglycerides. Some FFAs, however, remain in the blood plasma bound to albumin. The remainder of a chylomicron after the triglycerides have been extracted, called a chylomicron remnant, is removed and degraded by the liver.

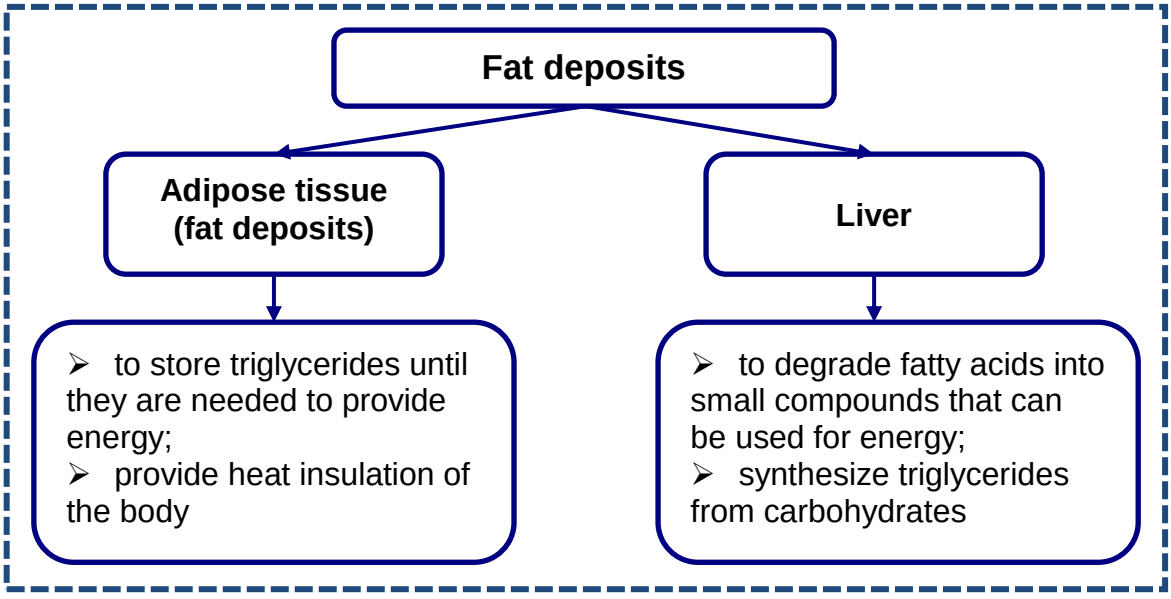
VLDLs which are produced by the liver, transport lipids to the adipose tissue for storage. When their triglycerides are removed in the adipose tissue, the VLDLs become LDLs and contain mostly cholesterol. Cells that need cholesterol (usually for membrane structure or steroid hormone synthesis) absorb LDLs by receptor-mediated endocytosis, digest them with lysosomal enzymes, and release the cholesterol for intracellular use.

HDL production begins in the liver, which produces an empty, collapsed protein shell. This shell travels in the blood and picks up cholesterol and phospholipids from other organs. The next time it circulates through the liver, the liver removes the cholesterol and eliminates it in the bile, either as cholesterol or as bile acids. HDLs are therefore a vehicle for removing excess cholesterol from the body. High concentration of cholesterol in form of low-density lipoproteins can cause atherosclerosis.



To prevent atherosclerosis: 1) Maintaining healthy weight, being physically active; 2) Eating a diet that contains mainly unsaturated fat with low cholesterol content (ocean fish); 3) Preventing hypertension by diet and physical activity; 4) Controlling blood glucose level; 5) Avoiding cigarette smoking.

Triglycerides are stored primarily in the body's adipocytes, where a given molecule remains for about 2 to 3 weeks. Although the total amount of stored triglyceride remains quite constant, there is a continual turnover as lipids are released, transported in the blood, and either oxidized for energy or redeposited in other adipocytes. Synthesizing fats from other types of molecules is called *lipogenesis*, and breaking down fat for fuel is called *lipolysis*.



Lipolysis. The use of fats by the body for energy is as important as the use of carbohydrates is. The first stage in using triglycerides for energy is their hydrolysis into fatty acids and glycerol. Then, both the fatty acids and the glycerol are transported in the blood to the active tissues, where the will be oxidized to give energy. Glycerol, on entering the active tissue, is immediately changed by intracellular enzymes into *glycerol-3-phosphate*, which enters the glycolytic pathway for glucose breakdown and is thus used for energy.

Degradation and oxidation of *fatty acids* occur only in the mitochondria. The fatty acid molecule is degraded in the mitochondria by progressive release of two-carbon segments in the form of acetyl coenzyme A (acetyl-CoA). This process is called the *beta-oxidation* process for degradation of fatty acids. After initial degradation of fatty acids to acetyl-CoA, their final breakdown is precisely the same as that of the acetyl-CoA formed from pyruvic acid during the metabolism of glucose. And the extra hydrogen atoms are also oxidized by the same *chemiosmotic oxidative system of the mitochondria* that is used in carbohydrate oxidation, liberating large amounts of adenosine triphosphate (ATP). Thus, a total of ***146 molecules of ATP*** are formed during the complete oxidation of 1 molecule of stearic acid.

It is common knowledge that a diet high in sugars causes us to put on fat and gain weight. ***Lipogenesis*** employs compounds such as sugars and amino acids to synthesize the triglyceride precursors, glycerol and fatty acids (*Fig. 5.2*). PGAL, one of the intermediates of glucose oxidation, can be converted to glycerol. As glucose and amino acids enter the citric acid cycle by way of acetyl-CoA, the acetyl-CoA can also be diverted to make fatty acids. The glycerol and fatty acids can then be condensed to form a triglyceride, which can be stored in the adipose tissue or converted to other lipids.

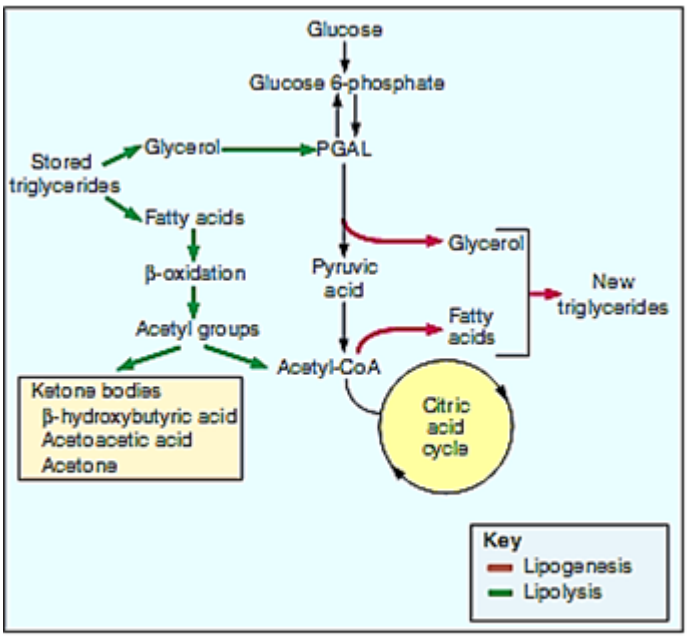


Figure 7.2. Common pathways of carbohydrates, lipids and proteins metabolism

Importance of fat synthesis and storage

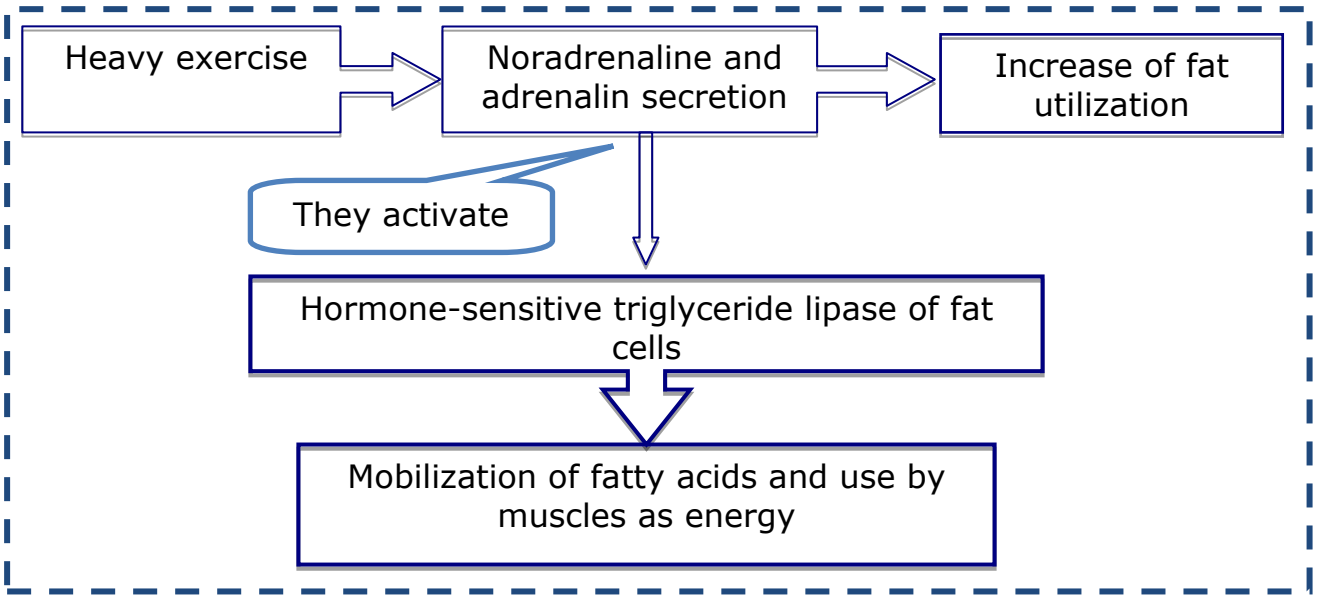
Fat synthesis from carbohydrates is especially important for two reasons:

1. The ability of the different cells of the body to store carbohydrates in the form of glycogen is generally slight; a maximum of only a few hundred grams of glycogen can be stored in the liver, the skeletal muscles, and all other tissues of the body put together. In contrast, many kilograms of fat can be stored. Therefore, fat synthesis provides a means by which the energy of excess ingested carbohydrates (and proteins) can be stored for later use.

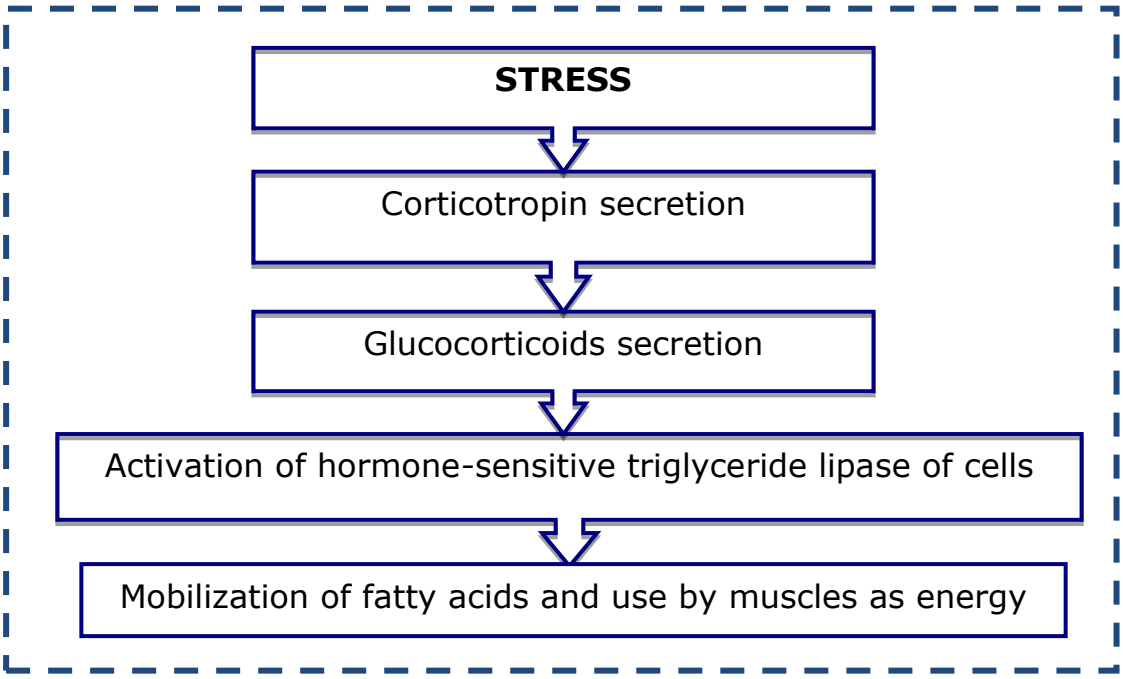
2. Each gram of fat contains almost two and a half times the calories of energy contained by each gram of glycogen. Therefore, for a given weight gain, a person can store several times as much energy in the form of fat as in the form of carbohydrate, which is exceedingly important when an animal must be highly motile to survive.

Humoral regulation of fat utilization

1. Humoral regulation during physical work.



2. Humoral regulation of lipids metabolism during stress-reaction.

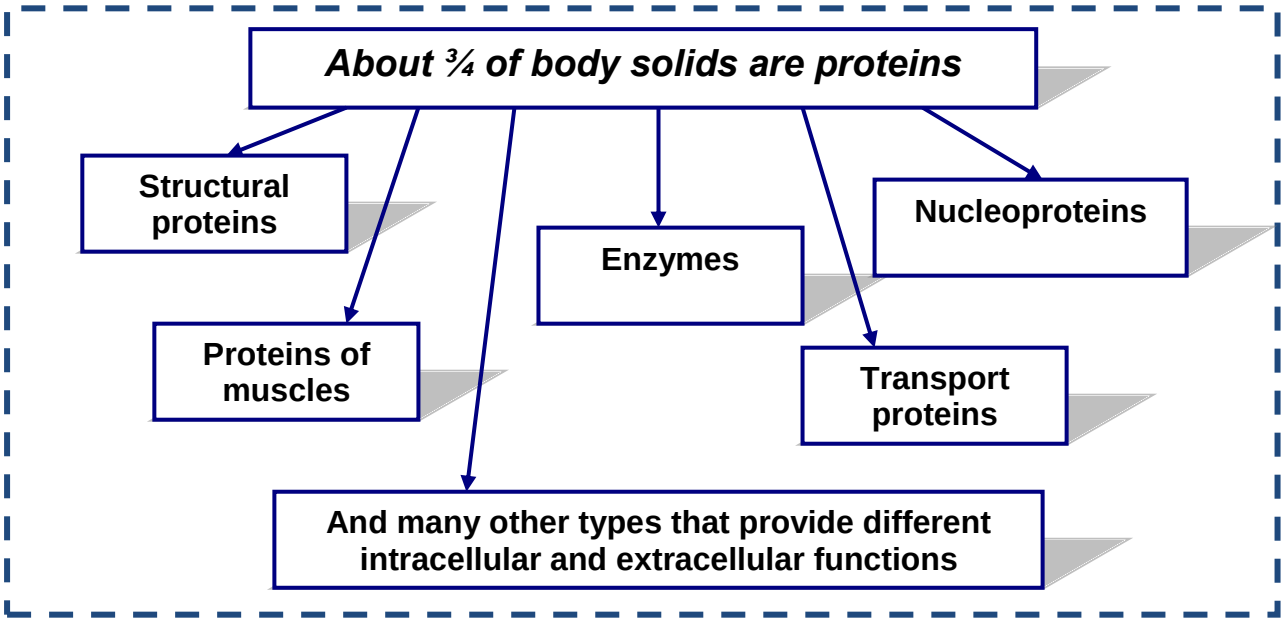


3. Growth hormone has similar but weaker effect.

4. Thyroid hormone causes rapid mobilization of fat by increasing metabolic rate.

5. Insulin lack (diabetes mellitus) leads to poor fat synthesis because glucose does not enter the fat and liver cells satisfactorily. Lack of glucose in fat cells makes it difficult for tissues to form triglycerides.

Metabolism of proteins



Protein constitutes about 12 % to 15 % of the body's mass; 65 % of it is in the skeletal muscles. Proteins are responsible for muscle contraction and the motility of cilia and flagella. They are the major structural component of all cellular membranes, with multiple important roles such as membrane receptors, pumps, ion channels, and cell-identity markers. Fibrous proteins such as collagen, elastin, and keratin make up much of the structure of bone, cartilage, tendons, ligaments, skin, hair, and nails. Globular proteins include antibodies, hormones, neurotransmitters, hemoglobin, myoglobin, and about 2 000 enzymes that control nearly every aspect of cellular metabolism. They also include the albumin and other plasma proteins that maintain blood viscosity and osmolarity and transport lipids and some other plasma solutes. Proteins buffer the pH of body fluids and contribute to the resting membrane potentials of all cells. No other class of biomolecules has such a broad variety of functions.

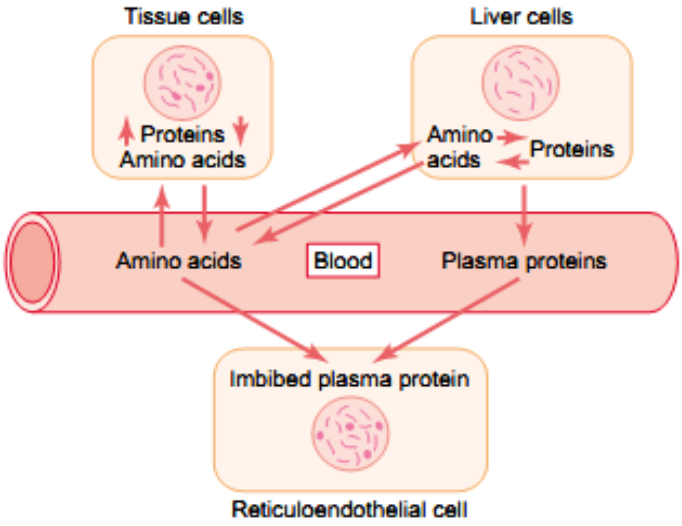
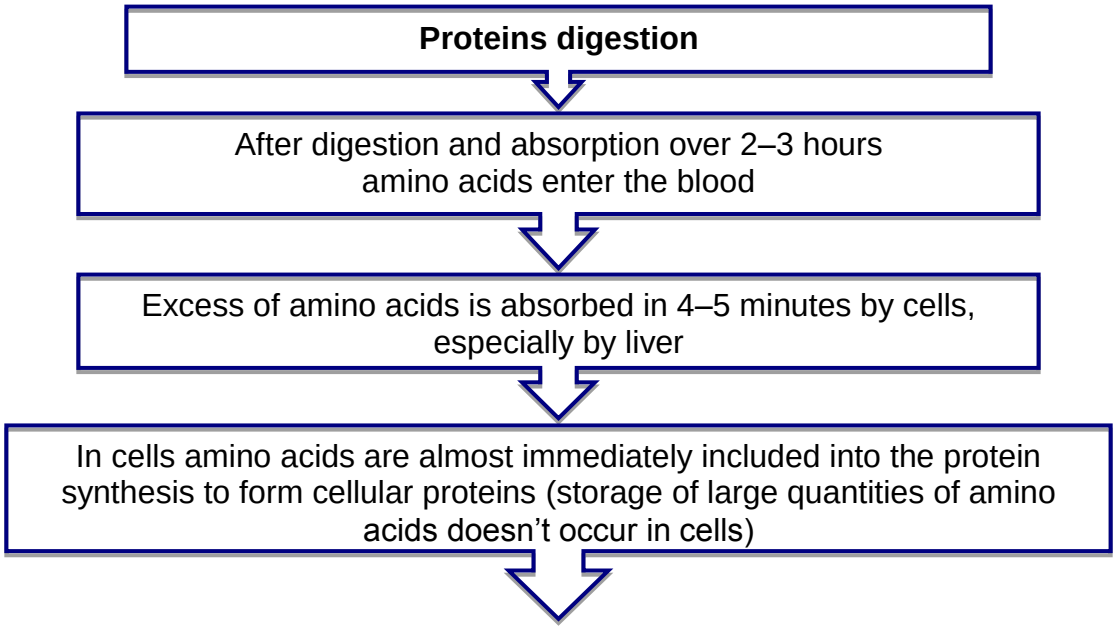


Figure 7.3. Maintenance of amino acids balance in different compartments of organism

For persons of average weight, the daily requirement of protein is 44 to 60 g, depending on age and sex. A higher intake is recommended, however, under conditions of stress, infection, injury, and pregnancy. Infants and children require more protein than adults relative to body weight. Excessive protein intake, however, overloads the kidneys with nitrogenous waste and can cause renal damage. This is a risk in certain high-protein fad diets.

The principal constituents of proteins are amino acids (AA). Total protein intake is not the only significant measure of dietary adequacy. The nutritional value of a protein depends on whether it supplies the right amino acids in the proportions needed for human proteins. Adults can synthesize 12 of the 20 amino acids from other organic compounds when they are not available from the diet, but there are ***8 essential amino acids*** that we cannot synthesize: *isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.* (Infants also require *histidine*.) In addition, there are 2 amino acids hat can only be synthesized from essential amino acids – *cystine* from *methionine* and tyrosine from phenylalanine. The other 10 (9 in infants) are called ***inessential amino acids*** – not because the body does not require them but because it can synthesize its own when the diet does not supply them.



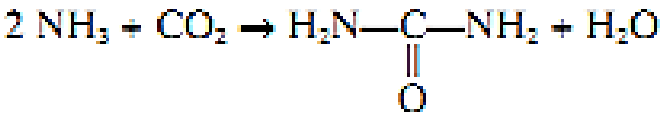
Cells do not store surplus amino acids for later use. When a protein is to be synthesized, all of the amino acids necessary must be present at once, and if even one is missing, the protein cannot be made. High-quality ***complete proteins*** are those that provide all of the essential amino acids in the necessary proportions for human tissue growth, maintenance, and nitrogen balance. ***Lower-quality*** incomplete proteins lack one or more essential amino acids. For example, cereals are low in lysine, and legumes are low in methionine.

There is a constant state of equilibrium among the plasma proteins (albumins, globulins and fibrinogen) and AMA of plasma and tissue proteins. The ratio of total tissue proteins in the body remains relatively constant at about 33:1.

Clinical application

Some bodybuilders and other "power athletes" take powdered or liquid amino acid mixtures ("predigested protein") in the belief that simple amino acids are absorbed more easily and rapidly or that they somehow contribute more to muscle building. Such beliefs are unfounded. Dietary proteins are rapidly digested and absorbed, and there is no added benefit to taking predigested protein. Amino acid supplements have not been shown to increase muscle mass, strength, or endurance. Moreover, they may be harmful to the health. Concentrated amino acid solutions osmotically retain water in the intestines and cause cramps and diarrhea. The catabolism of excess amino acids produces extra nitrogenous waste, which places undesirable stress on the liver and kidneys.

Use of proteins for energy. Once the cells are filled to their limits with stored protein, any additional amino acids in the body fluids are degraded and used for energy or are stored mainly as fat or secondarily as glycogen. This degradation occurs almost entirely in the liver, and it begins with *deamination*. The ammonia released during deamination of amino acids is removed from the blood almost entirely by conversion into urea; two molecules of ammonia and one molecule of carbon dioxide combine in accordance with the following net reaction:



Essentially all urea formed in the human body is synthesized in the liver. In the absence of the liver or in serious liver disease, ammonia accumulates in the blood. This is extremely toxic, especially to the brain, often leading to a state called hepatic coma.

Once amino acids have been deaminated, the resulting ketoacids can, in most instances, be oxidized to release energy for metabolic purposes. In general, the amount of ATP formed for each gram of protein that is oxidized is slightly less than that formed for each gram of glucose oxidized.

4. Nitrogen balance, its significance and regulation

Proteins are our chief dietary source of nitrogen. ***Nitrogen balance*** is a state in which the rate of nitrogen ingestion equals the rate of excretion (chiefly as nitrogenous wastes). Growing children exhibit a state of ***positive nitrogen balance*** because they ingest more than they excrete, thus retaining protein for tissue growth. Pregnant women and athletes in resistance training also show positive nitrogen balance. When excretion exceeds ingestion, a person is in a state of ***negative nitrogen balance***. This indicates that body proteins are being broken down and used as fuel. Proteins of the muscles and liver are more easily broken down than others; thus negative nitrogen balance tends to be associated with muscle atrophy. Negative nitrogen balance may occur if carbohydrate and fat intake are insufficient to meet the need for energy. Carbohydrates and fats are said to have a protein-sparing effect because they prevent protein catabolism when present in sufficient amounts to meet energy needs.

Nitrogen balance can be calculated with help of following equation

$$NB = \frac{N_{assimilated}}{N_{excreted}} = \frac{N_{food} - N_{feces}}{N_{urine}}$$

In average proteins contain 16 per cent of nitrogen. Someone can calculate with ease that 1 gram of nitrogen is released when 6.25 grams of protein are broken down.

Table 7.4. Humoral regulation of proteins metabolism

Hormone	Effect
Growth hormone	increases synthesis of cellular proteins
Insulin	lack of insulin reduces synthesis of proteins (it accelerates transport of AA into cells)
Glucocorticoids	increase breakdown of most tissue proteins that leads to increase of amino acids concentration in blood
Testosterone	increase protein deposition in tissues, especially contractile proteins of muscles
Estrogen	has similar effect to testosterone but weaker
Thyroxin	increases metabolic rate and indirectly affects protein metabolism; causes protein rapid degradation and use for energy in case of insufficient carbohydrates and fats content

Nitrogen balance is affected by some hormones. *Growth hormone* and *sex steroids* promote protein synthesis and positive nitrogen balance during childhood, adolescence, and pregnancy. *Glucocorticoids*, on the other hand, promote protein catabolism and negative nitrogen balance in states of stress.

5. Methods of metabolism examination

According the 1st law of thermodynamics, energy doesn't arise from anywhere and doesn't disappear, it just transforms from one form to another one. This statement is also true for living beings. It means that there is the balance between input of energy and its expenditure. Energy expenditure characterizes intensity of metabolism.

The Calorie. *To discuss the metabolic rate of the body and related subjects intelligently, it is necessary to use some unit for expressing the quantity of energy released from the different foods or expended by the different functional processes of the body. Most often, the Calorie is the unit used for this purpose. It will be recalled that 1 calorie—spelled with a small "c" and often called a* ***gram calorie****—is the quantity of heat required to raise the temperature of 1 gram of water on 1°C.The calorie is much too small a unit when referring to energy in the body. Consequently, the Calorie—sometimes spelled with a capital "C" and often called a kilocalorie, which is equivalent to 1000 calories—is the unit ordinarily used in discussing energy metabolism.*

Metabolic rate means the amount of energy liberated in the body per unit of time, expressed in such terms as kcal/hr or kcal/day.

Foodstuffs have different caloric value. ***Caloric value*** is equal to amount of heat which is released during burning or oxidation of 1 gram of food.

Metabolic rate can be measured by two ways – direct and indirect calorimetry. ***Direct calorimetry*** is an immediate measurement of spent heat with help of calorimeter. *Calorimeter* is an airtight chamber with thermal insulation from external environment that no heat can leak through the walls of the chamber (*Fig. 7.4*). Heat liberated by a person placed into the chamber warmth water circulating in its tubes. The rate of heat gain by the water bath, which can be measured with an accurate thermometer, is equal to the rate at which heat is liberated by the subject's body. Oxygen is supplied into the chamber and the excess of carbon dioxide and water vapors are absorbed.

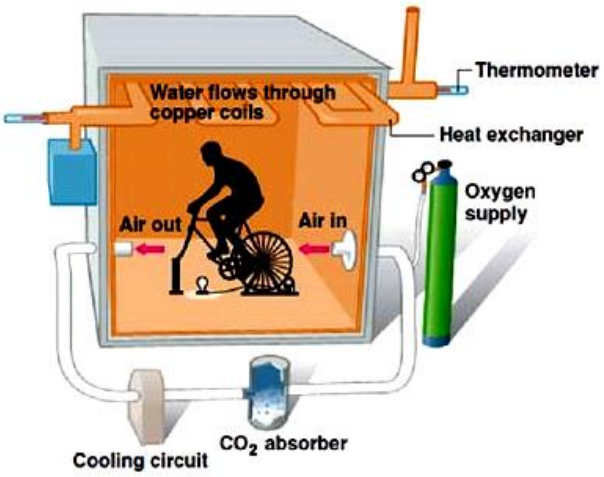


Figure 7.4. Chamber for direct calorimetry

Metabolic rate can also be measured by ***indirect calorimetry*** with a spirometer, an apparatus that can be used to measure the gases composition of inhaled and expelled air: 1) determination of consumed O_2 – *incomplete gases analysis* and 2) both consumed O_2 and released CO_2 – *complete gases analysis*.

Because more than 95 per cent of the energy expended in the body is derived from reactions of oxygen with the different foods, the whole-body metabolic rate can also be calculated with a high degree of accuracy from the rate of oxygen utilization. When 1 liter of oxygen is metabolized with *glucose 5.01 Calories* of energy are released; when metabolized with *starches 5.06 Calories* are released; with *fat – 4.70 Calories*; and with *protein 4.60 Calories*. So, ***caloric equivalent of O_2 – is amount of heat generated after utilization of 1 L of O_2 by organism***.

For the average diet, *the quantity of energy liberated per liter of oxygen used in the body averages about 4.8 Calories*. This is called the ***Energy Equivalent of oxygen***.

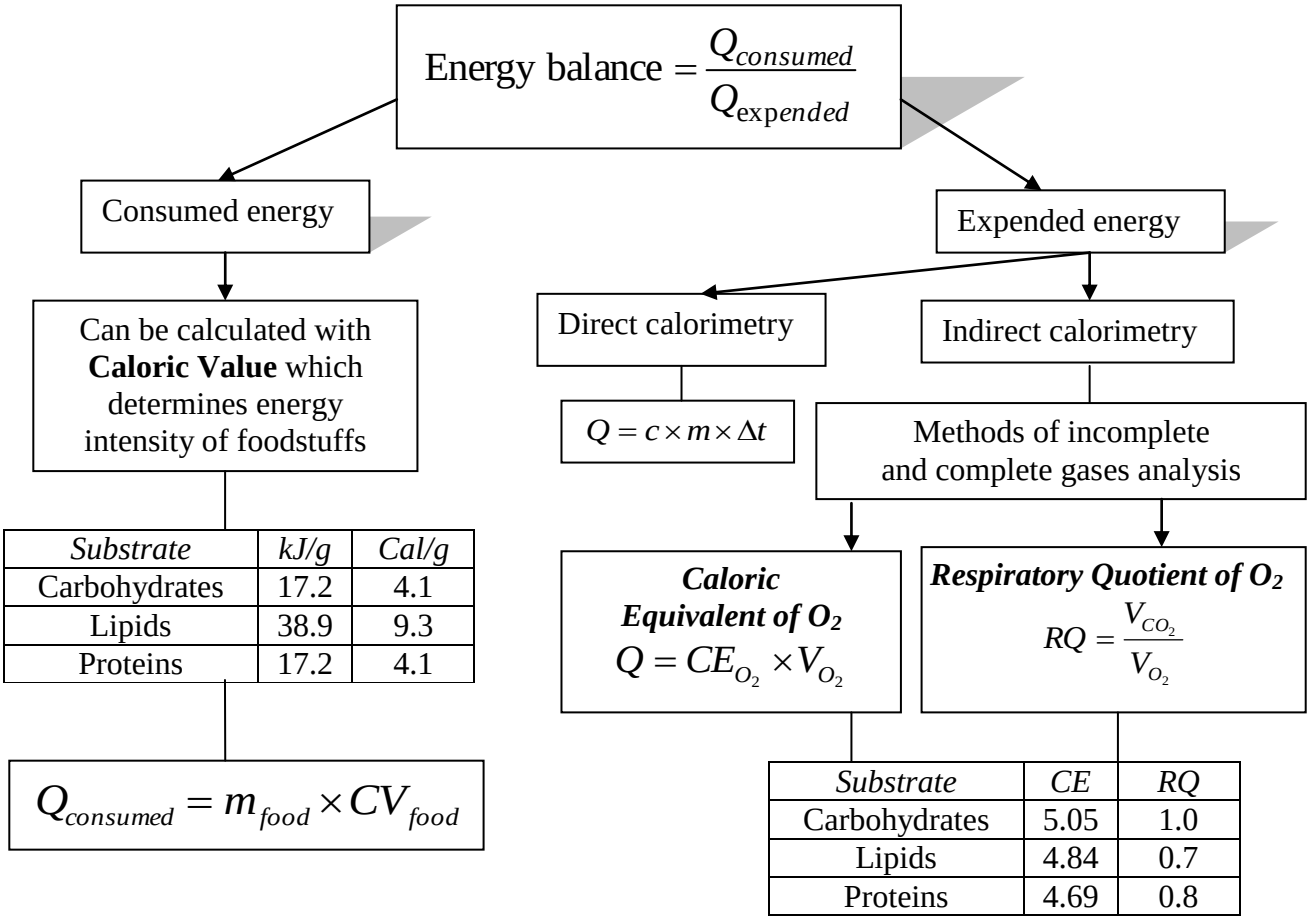
If the amount of consumed O_2 and amount of liberated CO_2 are known, energy expenditure can be calculated with help of ***Respiratory Quotient*** *(RQ). RQ is the ratio of produced CO_2 to utilized O_2.*

$$RQ = \frac{V_{CO_2}\, liberated}{V_{O_2}\, consumed}$$

RQ depends on the type of oxidized substances. For carbohydrates, RQ = 1.00, as can be seen from reaction: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$, where amount of CO_2 is equal to O_2.

For the fat tripalmitin the reaction is $2C_{51}H_{98}O_6 + 145O_2 \rightarrow 102CO_2 + 98H_2O$.

So, respiratory quotient for fats RQ = 102/145 = 0.7. For proteins RQ is equal 0.8.



Substrate	*kJ/g*	*Cal/g*
Carbohydrates	17.2	4.1
Lipids	38.9	9.3
Proteins	17.2	4.1

Substrate	*CE*	*RQ*
Carbohydrates	5.05	1.0
Lipids	4.84	0.7
Proteins	4.69	0.8

Figure 7.5. Scheme summarizing methods of energy metabolism examination

Energy output can also be partitioned into two main components, including energy used for 1) performing essential metabolic functions of the body ***(the basal metabolic rate – BMR***); 2) performing various physical activities, digesting, absorbing, and processing food, and maintaining body temperature (***working metabolic rate***).

Basal metabolic rate must be determined in standard conditions:

1) Before examination person must not have eaten for at least 12 hours;
2) Person must be examined after night restful sleep;
3) For examination physical and mental rest are necessary;
4) In comfortable temperature 18–20єC (68–80єF)

Metabolic rate depends upon age, height, weight, body surface area, sex, physical activity, mental state, absorptive or postabsorptive status; thyroid, male sex hormones, growth hormone increase BMR. Aside from physical activity, some factors that raise the metabolic rate and caloric requirements include pregnancy, anxiety (which stimulates epinephrine release and muscle tension and can cause acceleration of MR in 40–90 %), fever (MR rises about 14 % for each 1°C of body temperature), eating (MR rises after a meal), and the catecholamine and thyroid hormones. TMR is relatively high in children and declines with age. Therefore, as we reach middle age we often find ourselves gaining weight with no apparent change in food intake.

Specific dynamic action of food is effect of food intake leading to increase of MR and energy expenditure. After food intake MR increases in 1 hour, reaches maximum in 3 hours and remain at these level during several hours. Proteins possess the highest specific dynamic effect. Proteins digestion increases MR in 30 %, fats and carbohydrates – in 14–15 %.

Some factors that lower TMR include apathy, depression, and prolonged starvation. In weight-loss diets, loss is often rapid at first and then goes more slowly. This is partly because the initial loss is largely water and partly because the TMR drops over time, fewer dietary calories are "burned off," and there is more lipogenesis even with the same caloric intake.

Memorize!
Highest BMP (to 1 kg of Body Weight) is typical for 6 month children, and then it gradually decreases and in puberty is about equal to adult. After 40 years old it gradually decreases.
BMR in 70 kg man is 1700 kcal, in women it is lower on 10 %

Each intake of food should be 20 min or longer with chewing movements about 30 times for any portion because of prolonged chewing impulses from mouth receptors are sent to ventral medial nuclei of hypothalamus (center of saturation) and primary saturation is formed.

Main physiological principles of adequate nutrition

1. Sufficient energy with food/
2. Optimal quantity and optimal balance (ratio) of different food components/
3. Adequate daily distribution of diet (dietary intake)/

Energy intensity of diet has to correspond to organism's needs: 1) caloric content of diet for men is in 20 per cent as much as for women; 2) it depends on nature of work (from 2400 to 4300 Cal/day). For students caloric content of food is in range from 2400 (girls) to 2800 (boys) Cal/day.

8. FUBCTIONAL SYSTEM OF BODY TEMPERATURE CONSTANCY (ISOTHERMIA)

OUTLINE

1. Principles of human isothermia
2. Mechanisms of heat production and loss
3. Neural regulation of body temperature
4. Body temperature regulation in different ambient conditions

1. Principles of human isothermia

The main principles of living beings are metabolism and energy exchange which are accompanied by heat production during biological oxidation of proteins, fats and carbohydrates. There is direct interconnection between the metabolism intensity and amount of heat produced in the organism.

Heat produced in organism is reflected in body temperature. The body temperature of mammals and human is maintained at the relatively constant level independently from the surrounding temperature fluctuations. The constancy of body temperature is called *isothermia*. It is the significant feature of warm-blooded (*homoiothermal*) animals and human. Constant temperature is necessary for crucial physiological processes in the organism: 1) metabolic reactions (both energetic and plastic), 2) functional processes such as enzymes activity, secretion of juices, working of membrane transport systems, excitability and excitation conduction, rate of heart beating, etc.

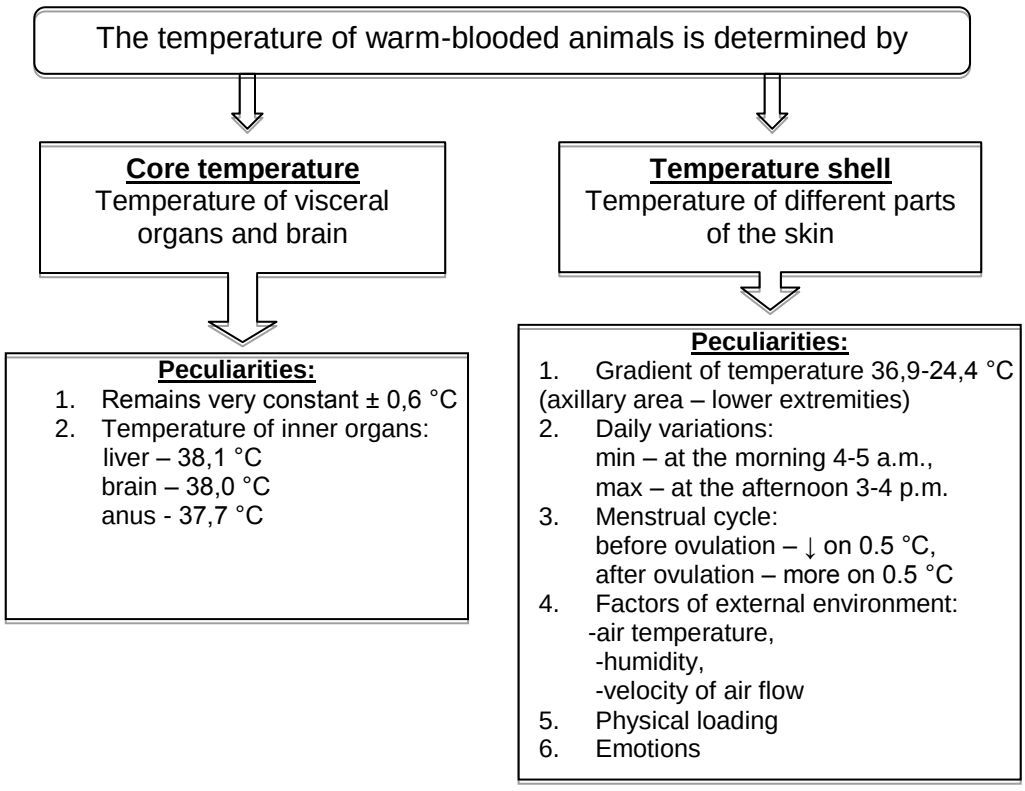


Figure 8.1. Peculiarities of body temperature

The ability of warm blooded animals and human to maintain constant body temperature is supplied by continuous action of ***physiological system of temperature regulation***. Its components are 1) *temperature receptors* detecting the changes of temperature in the external and internal environment; 2) center of thermoregulation in the hypothalamus – so called *hypothalamic thermostat*; 3) *effector (executive) organs* of thermoregulation. *The main function of this system is to maintain the temperature which is optimal for the metabolic reactions, i.e. "normal body temperature"*.

"Normal" body temperature depends on when, where, and in whom it is measured. Body temperature fluctuates about 1°C (1.8°F) in a 24-hour cycle. It tends to be lowest in the early morning and highest in the late afternoon. Temperature also varies from one place in the body to another one (*Fig. 8.1*).

The most important is the ***core temperature*** – the temperature of organs in the cranial, thoracic, and abdominal cavities (*fig. 8.1*). Rectal temperature is relatively easy to measure and gives an estimate of core temperature: usually 37.2° to 37.6°C (99.0°–99.7°F). It may be as high as 38.5°C (101°F) in active children and some adults.

Shell temperature is the temperature closer to the surface, especially skin and oral temperature. Here heat is lost from the body and temperatures are slightly lower than rectal temperature. Adult oral temperature is typically 36.6° to 37.0°C (97.9–98.6°F) but may be as high as 40 °C (104 °F) during hard exercise. ***Comfortable temperature*** in case of humidity 50 % is 18–20 °C for easy dressed man and 28 °C for stripped man. Average body temperature is 33–34 °C.

2. Heat production and loss

The core temperature is maintained as constant parameter due to the ***endogenous thermoregulation*** which results in the stable balance between the heat produced in the organism (*heat production*) and the heat dispersed by the organism into the external environment (*heat loss*) (*Fig. 8.2*).

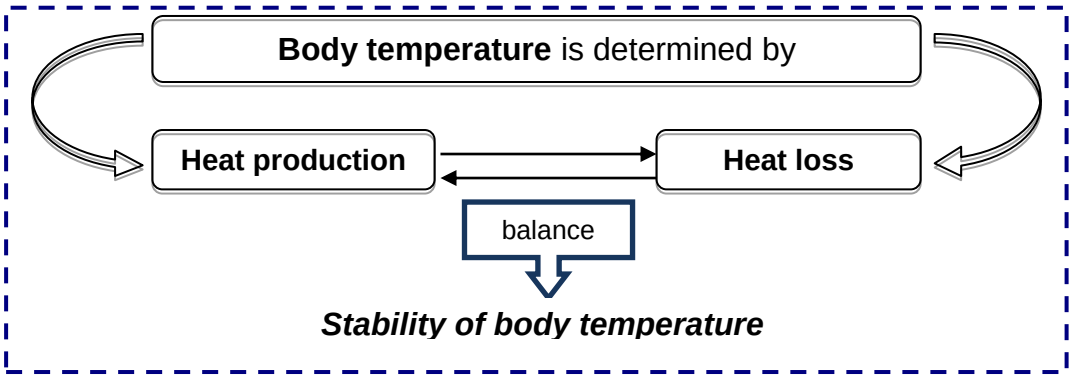


Figure 8.2. Endogenous thermoregulation

Heat production

Most body heat comes from *exergonic* (energy-releasing) chemical reactions such as nutrient oxidation and ATP use. A little heat is generated by joint friction, blood flow, and other movements.

The most important of these factors that affect the metabolic rate are as following: 1) basal rate of metabolism of all the cells of the body; 2) extra rate of metabolism caused by muscle activity, including muscle contractions caused by shivering; 3) extra metabolism caused by the effect of thyroxine (and, to a less extent, other hormones, such as growth hormone and testosterone) on the cells; 4) extra metabolism caused by the effect of adrenalin, noradrenalin, and sympathetic stimulation on the cells; 5) extra metabolism caused by increased chemical activity in the cells themselves, especially when the cell temperature increases; and 6) extra metabolism needed for digestion, absorption, and storage of food (*thermogenic effect of food*).

At rest, most heat is generated by the brain, heart, liver, and endocrine glands; the skeletal muscles contribute about 20 % to 30 % of the total resting heat. Heat production during muscles contraction is called ***contractile thermogenesis*** (*Fig. 8.3*). Increased muscle tone or exercise greatly increases heat generation in the muscles, however, in vigorous exercise, they produce 30 to 40 times as much heat as the rest of the body and it is the most significant in adults.

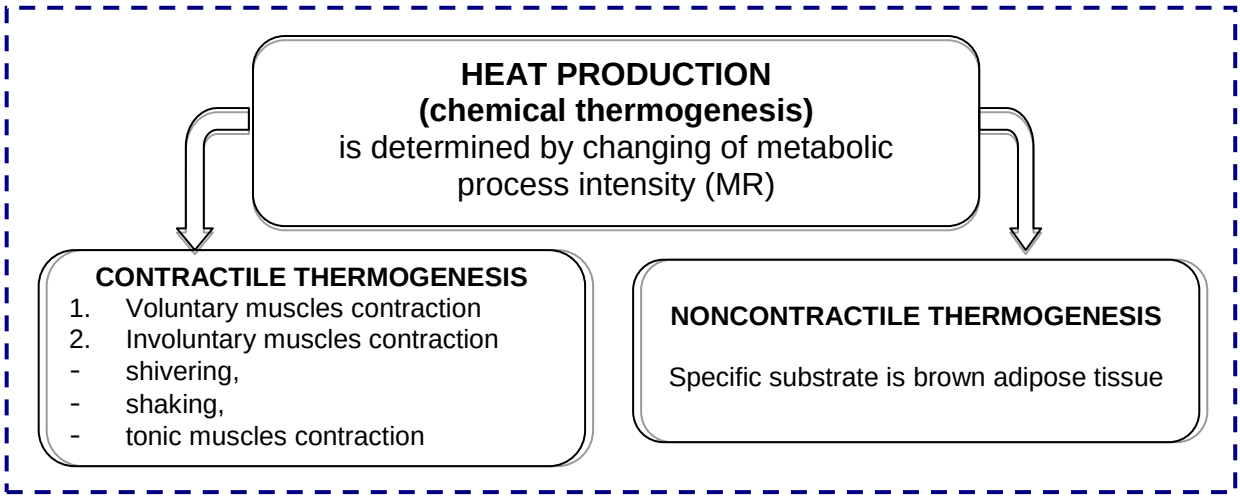


Figure 8.3. Chemical thermogenesis

Noncontractile thermogenesis is typical for organisms which are adapted to cold climate and for newborns. Specific substrate for this process is *brown fat.* This tissue is colorized by numerous sympathetic fibers which contain granules with noradrenalin. Brown fat takes about 1–2 % of body weight; it is located in the region of neck, in the interscapular space and in the mediastinum near the aorta, vena cava and sympathetic chain. Adipocytes of brown fat are abundant with mitochondria surrounding small drops of fat in their cytoplasm. Oxidation of fatty acids in mitochondria here occurs without the synthesis of ATP; therefore *heat production in brown fat is in 3 times higher than in skeletal muscles.* This tissue has strong ***sympathetic innervation*** and due to activation of CNS in case of cold temperature there are *intensification of circulation, increase of metabolic rate* and *temperature rising.*

This mechanism has a great importance for maintenance of normal body temperature in neonates because of their imperfect thermoregulation which develops

during first year of life. Oxidation of brown fat in infants can increase the rate of heat production by 100 %.

Heat release. The organism loses heat in four main ways which are *radiation*, *conduction*, *convention* and *evaporation* (Fig 8.4)

***1. Radiation*.** In essence, heat means molecular motion. All molecular motion produces radiation in the infrared (IR) region of the electromagnetic spectrum (wave length ϭ = 5–20 mkm). When IR radiation is absorbed by an object, it increases its molecular motion and raises its temperature. Therefore IR radiation removes heat from its source and adds heat to anything that absorbs it. Our bodies continually receive IR from the objects around us and give off IR to our surroundings. Since we are usually warmer than the objects around us, we usually lose more heat this way than we gain.

The amount of heat loosing by radiation is proportional to the total surface area of the body and the difference of skin temperature and surrounding temperature. When environmental temperature is 20 єC and humidity 40–60 % the radiation of adult person is about 40–50 % from total heat loss. If the temperatures of body and surrounding become equal irradiation is impossible.

2. Conduction *is the way of heat loss which takes place during immediate contact of the body with any objects.* As the molecules of our tissues vibrate with heat energy, they collide with other molecules and transfer kinetic energy to them. The warmth of the body therefore adds to the molecular motion and temperature of the clothes one wears, the chair one sits in, and the air around person.

The amount of heat which organism gives to surrounding by way of conduction is proportional to these factors: 1) mean temperatures of contact objects, 2) the total contact area, 3) duration of contact and 4) thermal conductivity of the object. Dry air and adipose tissue have low thermal conductivity; they are insulators preventing heat loss. In contrast, the humid air and especially water possess high thermal conductivity (thermal conductivity of water is in 28 times more then air's one). Because of this the prolonged stay in the cold water leads to the quick hypothermia due to the intensive heat loss.

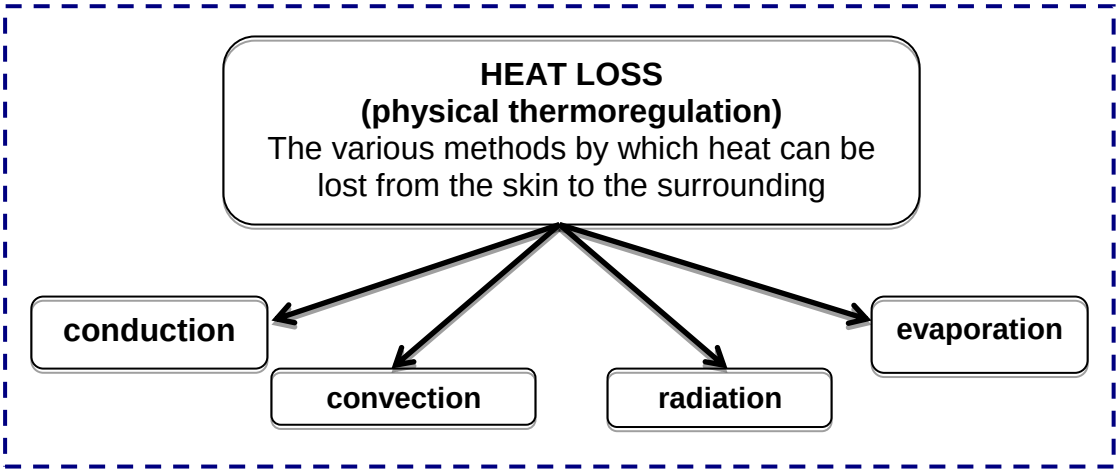


Figure 8.4. Main routs of heat loss in the organism

3. Convection *is the removal of heat from the body by convection air currents.* Actually, the heat must at first be conducted. Conductive heat loss is aided by convection, the motion of a gas (or fluid) due to uneven heating. Air is a fluid that becomes less dense and therefore rises as it is heated. Thus warm air rises from the body and is replaced by cooler air from below. The same is true for water; for example, when you swim in a lake or take a cool bath.

In standard conditions (air temperature 20 єC, humidity 40–60 %) conduction and convection supply about 25–30 % of heat loss. In case of forced convection (wind, ventilation) heat loss is also intensified.

Radiation, convection and conduction together are called "dry heat loses". But these processes are ineffective when the temperatures of the body and surrounding become equal. Under these conditions, the only means by which the body can rid itself of heat is by *evaporation*.

4. Evaporation *– is the manner of heat loss because this heat is used for the physical process of water evaporation.* When water evaporates from the body surface, 0.58 Calorie (kilocalorie) of heat is lost for each gram of water that evaporates. There are ***insensible*** and ***sensible evaporations***. Even when a person is not sweating, water still evaporates insensibly from the skin, mucosa and lungs at a rate of about 600 to 700 ml/day. This causes continual heat loss at a rate of 16 to 19 Calories per hour. This *insensible* evaporation through the skin and lungs cannot be controlled for purposes of temperature regulation because it results from continual diffusion of water molecules through the skin and respiratory surfaces. The *sensible loss of heat i*s ***sweating***. Loss of heat by evaporation of sweat can be controlled by regulating the rate of sweating.

3. Neural regulation of body temperature

Sweating is regulated by the autonomic nervous system. Stimulation of the *anterior hypothalamus-preoptic area* in the brain either electrically or by excess heat causes sweating. The nerve impulses from this area that cause sweating are transmitted in the autonomic pathways to the *spinal cord* and then through *sympathetic nerves* to the skin everywhere in the body. It should be recalled from the previous studying of the autonomic nervous system that the sweat glands are innervated by cholinergic nerve fibers (fibers that secrete acetylcholine but that run in the sympathetic nerves along with the adrenergic fibers). These glands can also be stimulated to some extent by adrenalin or noradrenalin circulating in the blood, even though the glands themselves do not have adrenergic innervation. This is important during exercise, when these hormones are secreted by the adrenal medullae and the body needs to lose excessive amounts of heat produced by the active muscles.

When the surrounding temperature is 20 єC the rate of evaporation is about 36 gram of water per hour (20 % from total heat loss). But high environmental temperature, heavy physical work and some other factors stimulate sweating which can reach 500–2000 gram per hour. Evaporation by way of sweating becomes ineffective when air humidity is about 100 %.

Evaporation is the most important mechanism of adaptation to hot climate. During acclimatization the concentration of sodium chloride in the sweat decreases. That supplies progressively better conservation of body salt. Most of this effect is caused by increased secretion of aldosterone by the adrenal glands, which results from a slight decrease in sodium chloride concentration in the extracellular fluid and plasma. An unadapted person who sweats profusely often loses 15 to 30 grams of salt each day for the first few days. After 4 to 6 weeks of acclimatization, the loss is usually 3 to 5 g/day.

Out from the comfortable temperature adaptive reactions develop and regulate the intensity of heat production or its loss.

Thermoreceptors

Receptors which are adapted to detect temperature are free nerve endings of afferent nerve fibers of Aд and C types. Depending on their localization thermoreceptors are of two types: 1) ***peripheral receptors*** and 2) ***receptors of deep organs***.

Peripheral thermoreceptors are localized in the *skin*, *cutaneous* and *subcutaneous vessels*, and *skeletal muscles*. The skin is endowed with both cold and warmth receptors. There are far more cold receptors than warmth receptors − in fact, 10 times as many in many parts of the skin. Therefore, peripheral detection of temperature mainly concerns detecting cool and cold instead of warm temperatures.

Afferent impulses from peripheral thermoreceptors are transmitted by spinothalamic tract, and after their relation in the specific and nonspecific thalamic nuclei arrive to the somatosensory cortex (postcentral gyrus). Analysis of this information in the cortex hemispheres supplies formation of specific sensations such as “warmth”, “hot”, “cold”, “cool”, “comfort”, “discomfort” and determine appropriate behavior of person.

Thermoreceptors of deep organs are localized in the *CNS* (preoptic area of hypothalamus, spinal cord, reticular formation, limbic system, cortex), in the *abdominal viscera* (stomach, respiratory tract), and in or around the *great veins* in the upper abdomen and thorax. The deep receptors function differently from the skin receptors because they are exposed to the body core temperature rather than the body surface temperature. Yet, like the skin temperature receptors, they detect mainly cold rather than warmth (except the hypothalamus preoptic area, where warm receptors are in 5 times more as cold receptors). It is probable that both the skin and the deep body receptors are concerned with preventing hypothermia – that is, preventing low body temperature.

Nervous center of temperature regulation

Hypothalamus is crucial nervous structure for temperature regulation. Center of thermoregulation occupies medial preoptic area of anterior hypothalamus and its posterior part. If in the experiment these regions of hypothalamus are destroyed or their connections with other brain structures are cut, experimental animals loose their temperature control forever.

In the hypothalamic center of thermoregulation four main types of thermosensitive neurons are found:

1. Thermosensitive neurons of preoptic area. They "measure" the temperature of arterial blood flowing through the brain vessels. These neurons are very sensitive and they are able to distinct temperature fluctuations just 0.011єC. It's notable that warm receptors amount here is in 4–6 times more then cold receptors, so hypothalamic preoptic area, in contrast to other receptive fields, is activated when core temperature rises.

2. Afferent neurons of anterior hypothalamus. These neurons collect information from peripheral and central thermoreceptors (including receptors of hypothalamus), process it and compare real body temperature with the co-called "set-point" ("set-point" temperature of our organism is 37.1єC when heat production and heat loss are balanced).

3. Efferent neurons activate heat production or heat loss dependently from current conditions. ***Center of heat production*** is the collection of neurons in the ***posterior hypothalamus***, ***center of heat loss*** is located in the ***anterior hypothalamus***.

4. Intercalary neurons supply intercommunication between different regions of hypothalamus.

Effector (executive) organs of thermoregulation

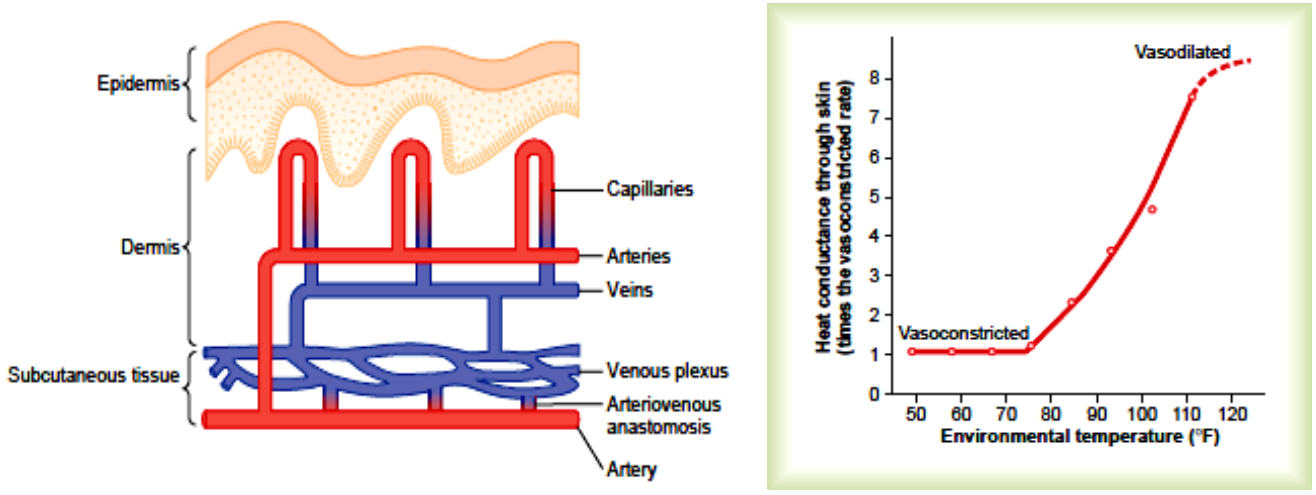
There are no special organs of temperature regulation. A lot of physiological systems take part in thermoregulation process such as cardio-vascular, respiration, excretion systems, skeletal muscles, skin etc.

The *skin*, the *subcutaneous tissues*, and especially the fat of the subcutaneous tissues act together as ***a heat insulator*** for the body. The fat is important because it conducts heat only *one third* as readily as other tissues. When no blood is flowing from the heated internal organs to the skin, the insulating properties of the normal male body are about equal to three quarters the insulating properties of a usual suit of clothes. In women, this insulation is even better. The insulation beneath the skin is an effective means of maintaining normal internal core temperature, even though it allows the temperature of the skin to approach the temperature of the surroundings.

At the natural conditions the isothermia is achieved by regulation of subcutaneous vessels lumen and ***blood flow to the skin from the body core provides heat transfer*****.** Blood vessels are distributed profusely beneath the skin. Especially important is a continuous venous plexus that is supplied by inflow of blood from the skin capillaries (*fig. 8.5-A*). In the most exposed areas of the body – the hands, feet, and ears – blood is also supplied to the plexus directly from the small arteries through highly muscular *arteriovenous anastomoses.*

The rate of blood flow into the skin venous plexus can vary tremendously – from barely above zero to as great as 30 per cent of the total cardiac output. A high rate of skin flow causes heat to be conducted from the core of the body to the skin with great efficiency, whereas reduction in the rate of skin flow can decrease the heat conduction from the core to very little.

Figure 8.5-B shows quantitatively the effect of environmental air temperature on conductance of heat from the core to the skin surface and then conductance into the air, demonstrating an approximate eightfold increase in heat conductance between the fully vasoconstricted state and the fully vasodilated state. Therefore, the skin is an effectively controlled "heat radiator" system, and the flow of blood to the skin is a most effective mechanism for heat transfer from the body core to the skin.



A *B*

Figure 8.5. Heat loss regulation by subcutaneous capillaries:
A – schematic representation of subcutaneous blood circulation;
B – dependence between the temperature rise and state of subcutaneous vessels

Heat conduction to the skin by the blood is controlled by the degree of vasoconstriction of the arterioles and the arteriovenous anastomoses that supply blood to the venous plexus of the skin. This vasoconstriction is controlled almost entirely by the *sympathetic nervous system* in response to changes in body core temperature and changes in environmental temperature.

Body temperature regulation in different ambient conditions

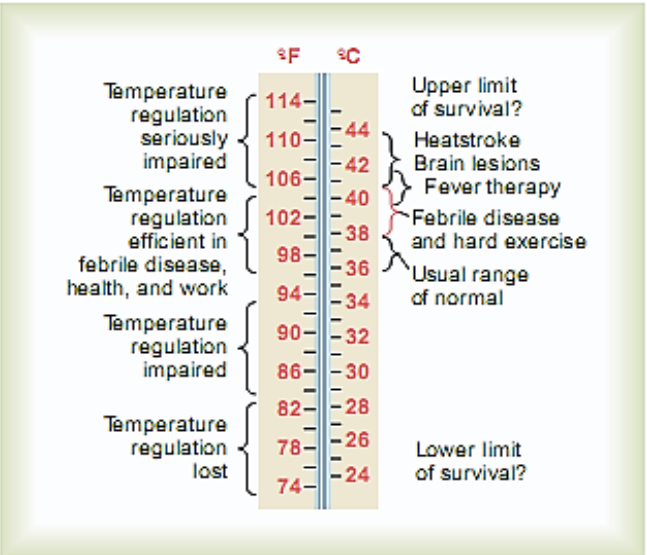
Temperature-decreasing mechanisms when the body is too hot

The temperature control system uses three important mechanisms to reduce body heat when the body temperature becomes too great (*Fig. 8.6*):

1. Vasodilation of skin blood vessels. In almost all areas of the body, the skin blood vessels become intensely dilated. This is caused by inhibition of the sympathetic centers in the posterior hypothalamus that cause vasoconstriction. Full vasodilation can increase the rate of heat transfer to the skin as much as eightfold.

2. Sweating. Rise of surrounding temperature leads to a sharp increase in the rate of evaporative heat loss resulting from sweating when the body core temperature rises above the critical level of 37 °C (98.6 °F). An additional 1 °C increase in body temperature causes enough sweating to remove 10 times the basal rate of body heat production.

3. Decrease in heat production. The mechanisms that cause excess heat production, such as shivering and chemical thermogenesis, are strongly inhibited.



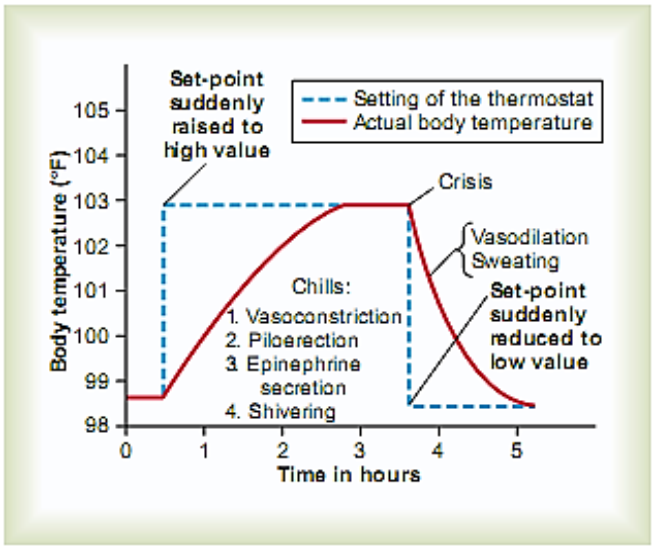


Figure 8.6. Abnormalities of body temperature caused by different factors

Temperature-increasing mechanisms when the body is too cold

When the body is too cold, the temperature control system institutes exactly opposite procedures (*Fig 8.6*). They are:

1. Skin vasoconstriction throughout the body. This is caused by stimulation of the posterior hypothalamic sympathetic centers.

2. Piloerection. Piloerection means hairs "standing on end." Sympathetic stimulation causes the arrector pili muscles attached to the hair follicles to contract, which brings the hairs to an upright stance. This is not important in human beings, but in lower animals, upright projection of the hairs allows them to entrap a thick layer of "insulator air" next to the skin, so that transfer of heat to the surroundings is greatly depressed.

3. Increase in thermogenesis (heat production). Heat production by the metabolic systems is increased by promoting shivering, sympathetic excitation of heat production, and thyroxine secretion. Let's discuss details of these methods.

Hypothalamic stimulation of shivering. ***Shivering*** is caused by ***primary motor center for shivering*** which is located in the *dorsomedial portion of posterior hypothalamus*. This center is excited by cold signals from skin and spinal cord. This center becomes activated when the body temperature falls even a fraction of a degree below a critical temperature level. It then transmits signals that cause shivering through *bilateral tracts down the brain stem*, into the *lateral columns of the spinal cord*, and finally to the *anterior motor neurons*. These signals are nonrhythmical and do not cause the actual muscle shaking. Instead, they increase the tone of the skeletal muscles throughout the body by facilitating the activity of the anterior motor neurons. When the tone rises above a certain critical level, shivering begins. This probably results from feedback oscillation of the muscle spindle stretch reflex mechanism. During maximum shivering, body heat production can rise to *four to five times normal*.

Increased Thyroxine Output is a Long-Term Cause of Increased Heat Production. Cooling the anterior hypothalamic preoptic area also increases production

of the neurosecretory hormone thyrotropin-releasing hormone by the hypothalamus. This hormone is carried by way of the hypothalamic portal veins to the anterior pituitary gland, where it stimulates secretion of thyroid-stimulating hormone. Thyroid-stimulating hormone in turn stimulates increased output of thyroxine by the thyroid gland. The increased thyroxine increases the rate of cellular metabolism throughout the body, which is yet another mechanism of chemical thermogenesis. This increase in metabolism does not occur immediately but requires several weeks' exposure to cold to make the thyroid gland hypertrophy and reach its new level of thyroxine secretion.

Behavioral control of body temperature. Aside from the subconscious mechanisms for body temperature control, the body has another temperature-control mechanism that is even more potent. This is behavioral control of temperature, which can be explained as follows: whenever the internal body temperature becomes too high, signals from the temperature-controlling areas in the brain give the person a psychic sensation of being overheated. Conversely, whenever the body becomes too cold, signals from the skin and probably also from some deep body receptors elicit the feeling of cold discomfort. Therefore, the person makes appropriate environmental adjustments to re-establish comfort, such as moving into a heated room or wearing well-insulated clothing in freezing weather. This is a much more powerful system of body temperature control than most physiologists have acknowledged in the past. Indeed, this is the only really effective mechanism to prevent body heat control breakdown in severely cold environments.

Abnormalities of body temperature regulation

Hyperthermia is the state of the organism when its temperature rises above 37єC. It easy develops when the surrounding temperature is too hot and air humidity is near 100 %. As we discussed earlier these conditions result in the impossibility of evaporation. Long-term hyperthermia can cause "heat stroke" which symptoms are as following: redness of skin because of peripheral vessels dilation, absence of sweating, disorders of central nervous system (disorientation, delirium, convulsions). Injured person can loose the consciousness because of peripheral vessels dilation and sudden drop of arterial pressure.

During evolution warm-blooded animals have elaborated the specific reaction in response to intervention of foreign pathogens into their internal environment – ***fever***. Fever, which means a body temperature above the usual range of normal, is caused by abnormal activity of temperature-regulating center when it stimulates temperature rising.

Some causes of fever (and also of subnormal body temperatures) are presented in *Figure 8.*6.They include bacterial diseases, brain tumors, and environmental conditions that may terminate in heatstroke.

Many proteins, breakdown products of proteins, and certain other substances, especially lipopolysaccharide toxins released from bacterial cell membranes, can cause ***the set-point of the hypothalamic thermostat to rise***. Substances that cause this effect

are called ***pyrogens***. Pyrogens released from toxic bacteria or those released from degenerating body tissues cause fever during disease conditions. When the set-point of the hypothalamic temperature-regulating center becomes higher than normal, all the mechanisms for raising the body temperature are brought into play, including heat conservation and increased heat production. Within a few hours after the set-point has been increased, the body temperature also approaches this level.

Mechanism of pyrogens action. Some pyrogens are able to act directly and immediately on the hypothalamic temperature-regulating center to increase its set-point. Other pyrogens function indirectly and may require several hours of latency before causing their effects. This is true of many of the bacterial pyrogens, especially the *endotoxins from gram-negative bacteria*. When bacteria or breakdown products of bacteria are present in the tissues or in the blood, they are phagocytized by the blood leukocytes, by tissue macrophages, and by large granular killer lymphocytes. All these cells digest the bacterial products and then release the substance ***interleukin-1*** – also called *leukocyte pyrogen* or *endogenous pyrogen* – into the body fluids. The interleukin-1, reaching the hypothalamus, immediately activates the processes to produce fever, sometimes increasing the body temperature a noticeable amount in only 8 to 10 minutes. As little as one ten-millionth of a gram of endotoxin lipopolysaccharide from bacteria, acting in concert with the blood leukocytes, tissue macrophages, and killer lymphocytes, can cause fever. The amount of interleukin-1 that is formed in response to lipopolysaccharide to cause fever is only a few nanograms. Several experiments have suggested that interleukin-1 causes fever by first inducing the formation of one of the prostaglandins, mainly prostaglandin E_2, or a similar substance, which acts in the hypothalamus to elicit the fever reaction. When prostaglandin formation is blocked by drugs, the fever is either completely abrogated or at least reduced. In fact, this may be the explanation for the manner in which *aspirin* reduces fever, because aspirin impedes the formation of prostaglandins from arachidonic acid. Drugs such as aspirin that reduce fever are called ***antipyretics***.

Hypothermia is the state of the organism when its temperature decreases below 35єC. Unless treated immediately, a person exposed to ice water for 20 to 30 minutes ordinarily dies because of heart standstill or heart fibrillation. By that time, the internal body temperature will have fallen to about 25 °C (77 °F). If warmed rapidly by the application of external heat, the person's life can often be saved. Once the body temperature has fallen below about 28–29 °C (85 °F), the ability of the hypothalamus to regulate temperature is lost; it is greatly impaired even when the body temperature falls below about 94 °F. Part of the reason for this diminished temperature regulation is that the rate of chemical heat production in each cell is depressed almost twofold for each 10 °F decrease in body temperature. Also, sleepiness develops (later followed by coma), which depresses the activity of the central nervous system heat control mechanisms and prevents shivering.

6. METABOLISM AND ENERGY EXCHANGE

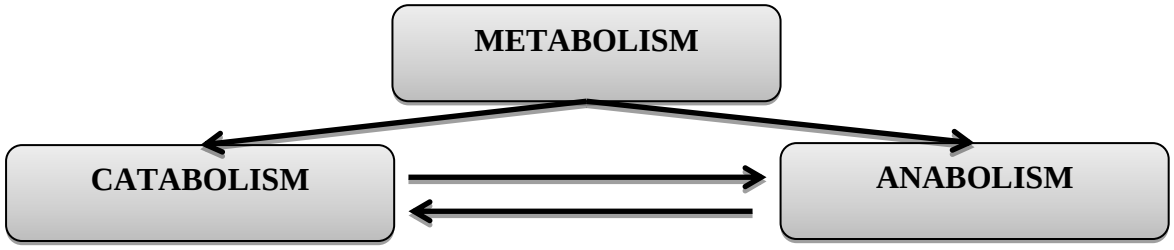
Task 6.1. *Give definition of metabolism and energy exchange.*

_____
_____
_____
_____

Task 6.2. *Define importance of these processes.*

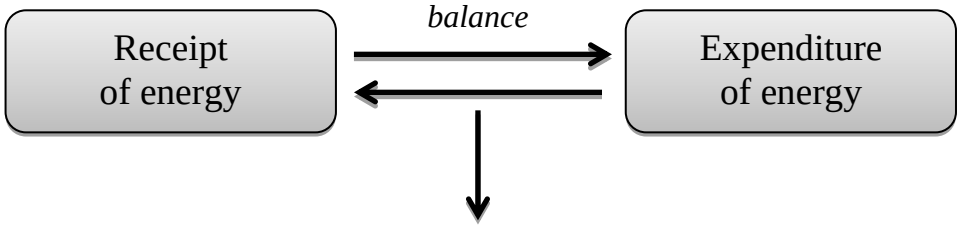
_____
_____
_____
_____

Task 6.3. *Complete the following scheme.*



_____ _____
_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

Task 6.4. *Complete the following scheme.*



They characterize: _____
_____
_____
_____
_____
_____

Task 6.5. *Define the sources of energy in organism.*

_____
_____
_____
_____
_____
_____
_____

Task 6.6. *Define the importance of ATP.*

_____
_____
_____
_____

Task 6.7. *Define how many ATP molecules are used to supply different mechanisms and systems activities.*

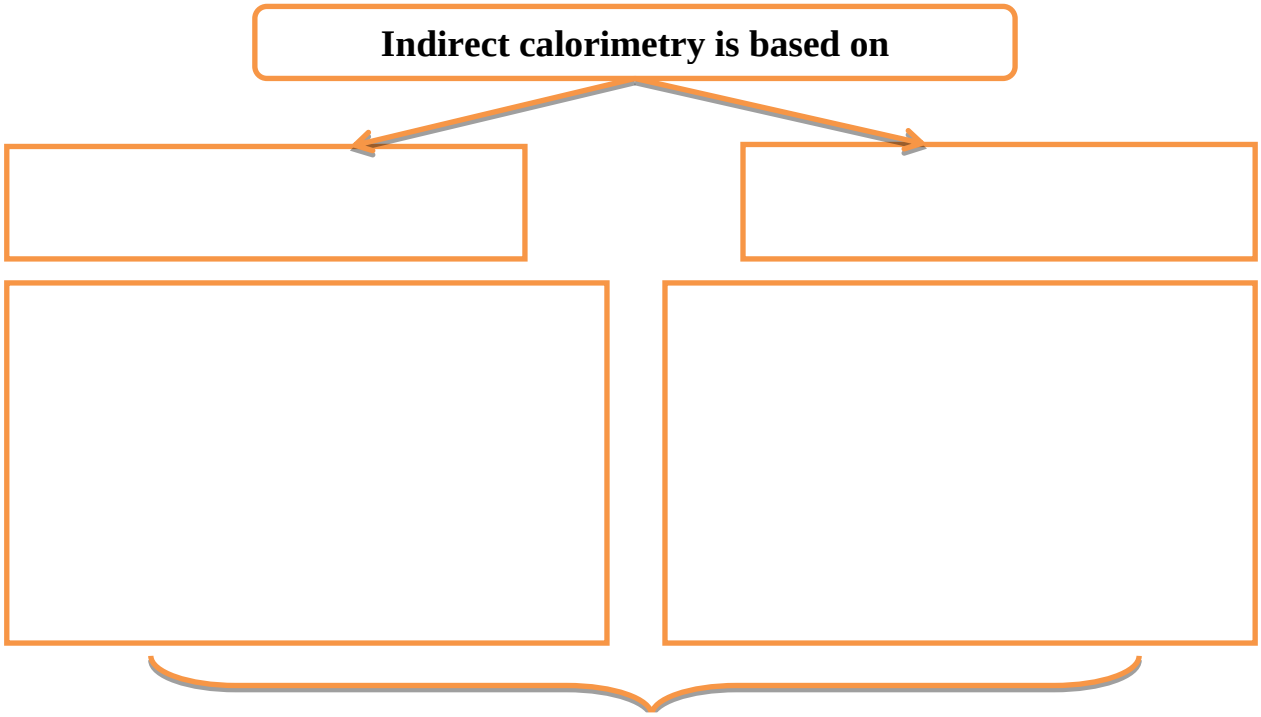
Secondary heat production which can be measured by methods of calorimetry

Task 6.8. *Define the methods of energy and total metabolism measurement.*

1. _____
   _____
2. _____
   _____

Task 6.9. *Complete the following statements.*
Direct calorimetry is _____
_____
_____

Task 6.10. *Complete the following statements.*



Significance: _____
_____
_____
_____

Task 6.11. Metabolic rate can be calculated from the rate of O_2 utilization, because 95 % of energy expended in the body is derived from reactions of oxidation with different foods. *Complete the following statements.*

- ✓ *If 1 L of O_2 is metabolized with starch, as a result _____ calories of energy are released*
- ✓ *If 1 L of O_2 is metabolized with fat, as a result _____ calories of energy are released*
- ✓ *If 1 L of O_2 is metabolized with proteins, as a result _____ calories of energy are released*

Task 6.12. *Give definition of* ***oxygen calorific equivalent***

_____
_____
_____
_____
_____

Task 6.13. *Give definition of RQ and complete the formula*

_____

_____

$$RQ = \frac{\qquad\qquad}{\qquad\qquad}$$

Task 6.14. *Complete the formulae and calculate the RQ for glucose, fats and proteins*

1) *Oxidation of glucose:*

$$C_6H_{12}O_6 + 6O_2 \rightarrow$$

so $RQ_{glucose}$ = _____ = _____

2) *Oxidation of fats (on example of triglycero-palmitate – glycerol ether of saturated palmitic acid)*

$$2C_3H_5(C_{15}H_{31}COO)_3 + 145O_2 \rightarrow 102CO_2 + 98H_2O$$

so RQ_{fats} = _____ = _____

3) *RQ for proteins can be measured by the same way*

so $RQ_{proteins}$ = _____

Task 6.15. *Energy expenditure is divided on two types: basal metabolism and working metabolism. Complete the following table to characterize both.*

Basal metabolism	***Working metabolism***

Task 6.16. *Define the conditions to determine Basal Metabolic Rate (BMR)*

1. _____
2. _____
3. _____
4. _____

Task 6.17. *Complete the following statements:*

BMR is about _____ cal/hour in man with the weight _____ kg.

BMR depends on:

1. _____

2. _____

3. _____

4. _____

5. _____

Task 6.18. *Complete the table to define the factors regulating the BMR.*

Increasing factors	***Decreasing factors***
1.	*1.*
2.	*2.*
3.	*3.*
4.	*4.*
5.	*5.*

Task 6.19. *Complete the following statements*

The highest BMR is typical for 6 month children; then it gradually decreases and in puberty is about equal to adults. After 40 years old it gradually decreases. BMR in man 70 kg is _____ Cal/day, in woman _____. Energy expenditure is _____ in mental work than in _____ exertion. Emotional excitement causes acceleration of MR in _____ % from BMR due to involving of muscles contraction. Children's cry increases MR in 3 times. After food intake MR and energy expenditure increases in 1 hour, reach maximal level in 3 hours, and remain in that level for several hours. So, effect of food intake leading to increase of MR and EC is called _____.

Task 6.20. *Give definition and explain phenomenon of specific dynamic food effect*

_____

_____

_____

_____

_____

Task 6.21. *Define main physiological principles of adequate nutrition*

1)_____

2)_____

3)_____

Task 6.22. *Complete the following statements*

Organic components of food – proteins, carbohydrates and fats – contain chemical energy necessary for synthesis of ATP. Energy intensity of diet has to correspond to the needs of an organism. It depends on:

1._____

(caloric content of diet for men has to be in _____ % higher than for women).

2._____

(for male from _____ to _____ ; students: men _____ , women _____

Task 6.23. *The most important criterion of optimal diet is the body weight (BW); normal BW differs from ideal in 10 % (±10 %)*

1) *Broca's method for calculation of ideal BW:*
   IBM_m=height (cm) – 100 (for men)
   IBM_m=height (cm) – 105–110 (for women)
2) *Index of Ketle =* $\frac{m}{h^2}$

Calculate your ideal BW and compare with the normal one (normal index is 22–30 units)

_____

_____

Task 6.24. *Define the optimal ratio of proteins, fats and carbohydrates in balanced diet*

Proteins	***Fats***	***Carbohydrates***

Proteins minimum is _____gram per day.
Proteins optimum is _____gram per day, or _____ to 1 kg/body weight.
Protein optimum id diet for children is _____ gram/kg/day,
for pregnant women – _____ gram/kg/day.
Fats can be synthesized from carbohydrates in organism. Daily diet content of fats has to be about _____ %. Carbohydrates may be synthesized from _____ and _____. Daily diet content of carbohydrates has to be minimum _____ g.

Task 6.25.

The adequate daily distribution of food ration is _____ meals with time interval in _____ hours

Complete percentage content of daily food intake (ration)

1st breakfast –	%	Breakfast –	%
2nd breakfast –	%	Dinner –	%
Dinner –	%	Supper –	%
Supper –	%		

7. BODY TEMPERATURE REGULATION

Task 7.1. *Give definitions of "core temperature" and "shell temperature" and describe their peculiarities*

Core temperature is _____.

_____

_____

Shell temperature is _____.

_____

_____

_____

_____

Task 7.2. *Complete following statements*

Comfort temperature in case of humidity _____ % is _____ ºC for easy dressed men and _____ ºC for stripped one.

Task 7.3. *Give definition*

Endogenous thermoregulation is _____

_____

_____

_____

Task 7.4. *Define main ways of heat production*

1)_____

- ✓ _____
- ✓ _____

_____

2)_____

_____

Task 7.5. *Define the most important factors affecting metabolic rate*

*1)*_____

_____

2)_____

_____

3)_____

_____

4)_____

_____

5)_____

_____

Task 7.6. *Define the importance of brown fat in infants to maintain normal body temperature:*

_____
_____
_____
_____
_____
_____

Task 7.7. *Define each way of heat loss and its importance for thermoregulation:*
Radiation is _____
_____
_____
_____
_____
_____

Conduction is _____
_____
_____
_____
_____
_____

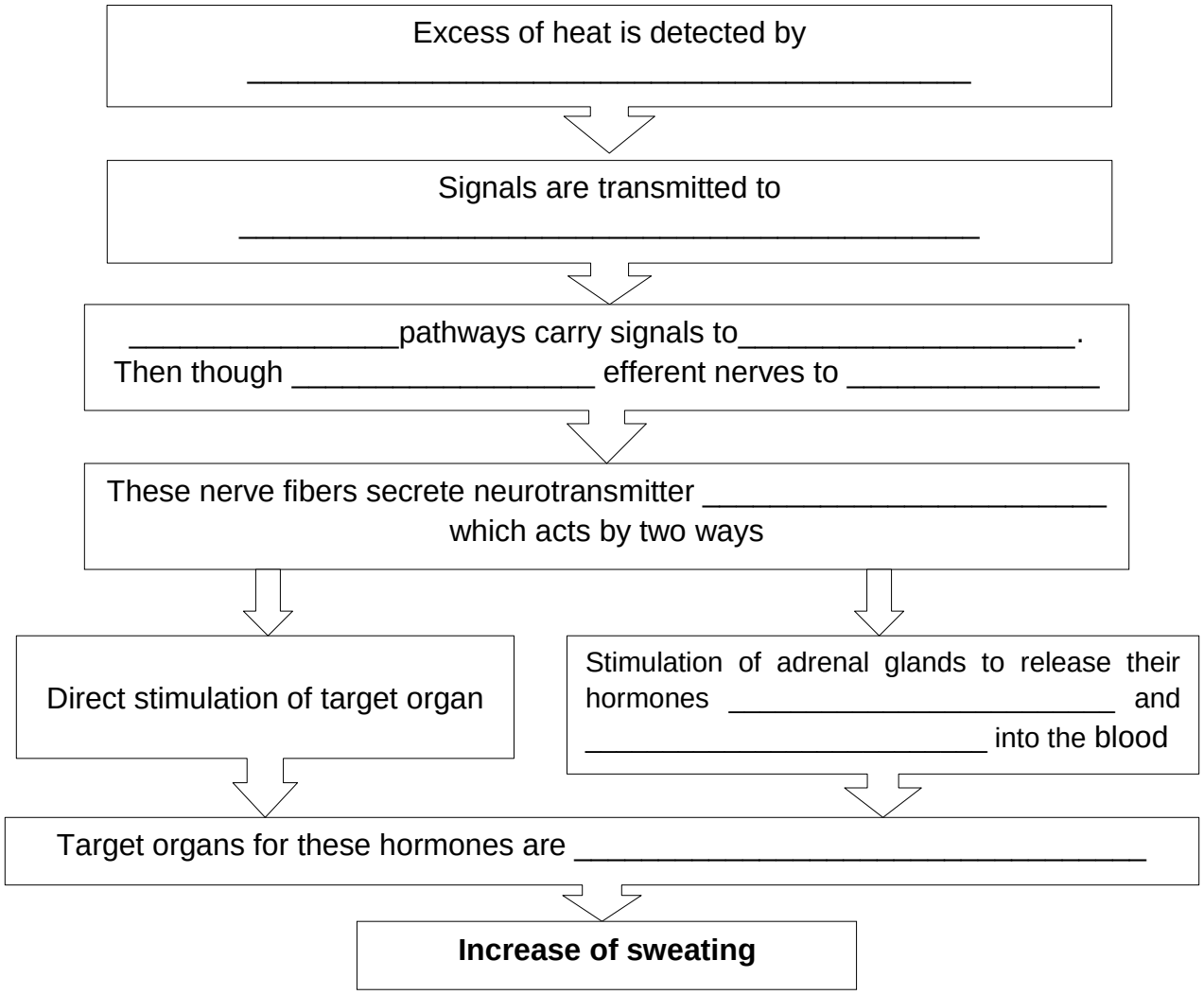
Convection is _____
_____
_____
_____
_____
_____

Evaporation is _____
_____
_____
_____
_____
_____

Task 7.8. Evaporation is the most important mechanism of adaptation to the hot climate. During adaptation the content of electrolytes in sweat decreases. *Explain the mechanism of this phenomenon.*

_____
_____
_____
_____
_____
_____

Task 7.9. *Complete the scheme* ***"Regulation of sweating by Autonomic Nervous System"***



Task 7.10. *Complete the following statements. Define types of thermoreceptors and describe their peculiarities*

Receptors which are adapted to detect temperature are _____ of afferent nerve fibers of _____ and _____ types. Depending on their localization thermoreceptors are of two types:

1)_____

_____

_____

_____

_____

2)_____

_____

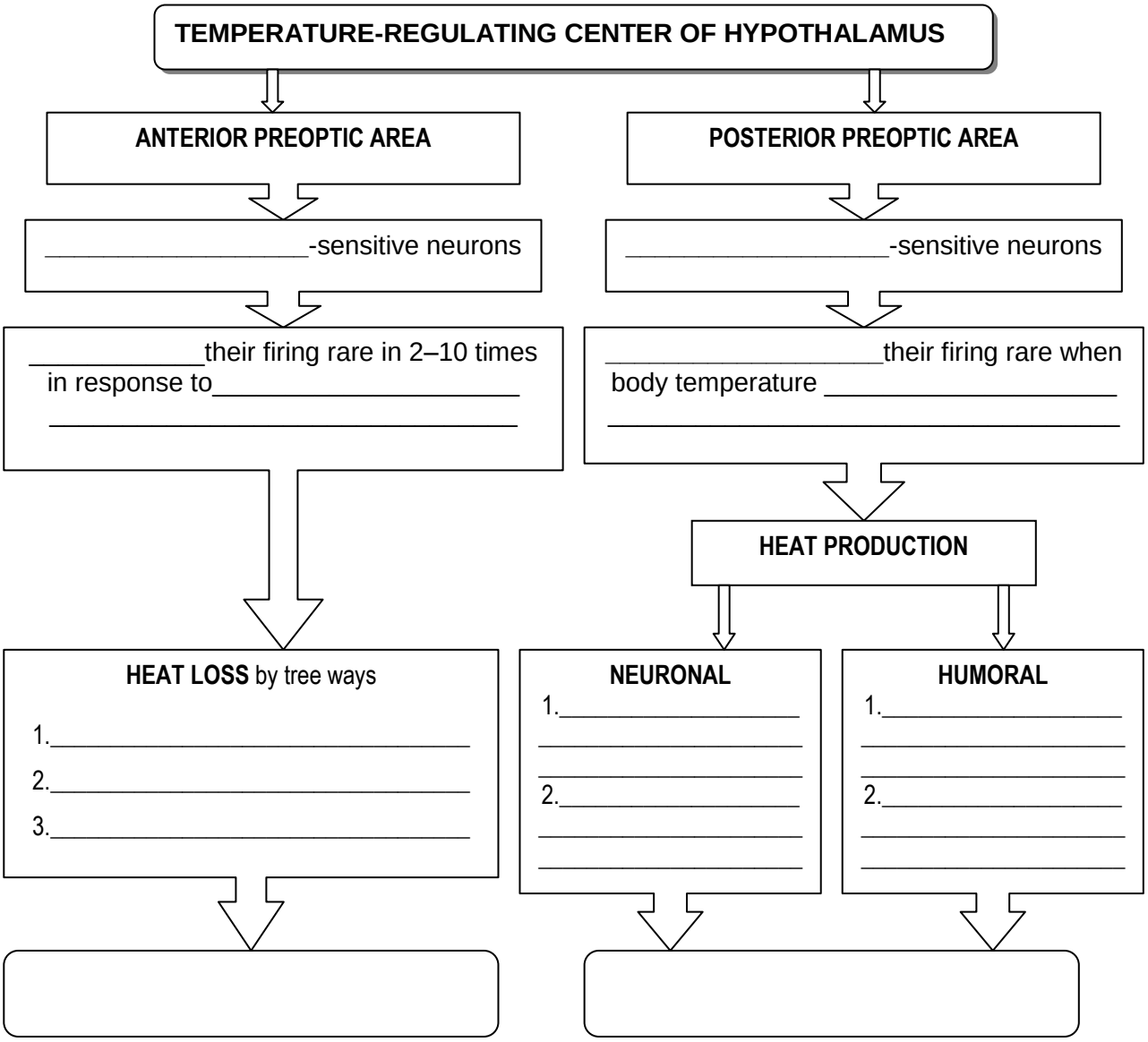
_____

_____

_____

_____

Task 7.11. *Complete the scheme* ***"Role of Hypothalamus in body temperature regulation"***



Task 7.12. *Define the temperature-increasing mechanisms when the body is too cold.*

1._____
2._____
3._____
_____

Task 7.13. *Define mechanism of shivering.*

1. _____ signals from _____ and _____ are detected by _____ receptors.
2. They are transmitted to primary motor center of shivering which is located _____
3. Then impulses are transmitted from _____ to_____
4. Target organs are _____
5. Tone of _____
6. It results in _____

Task 7.14. *Define temperature-decreasing mechanisms.*

1._____

_____

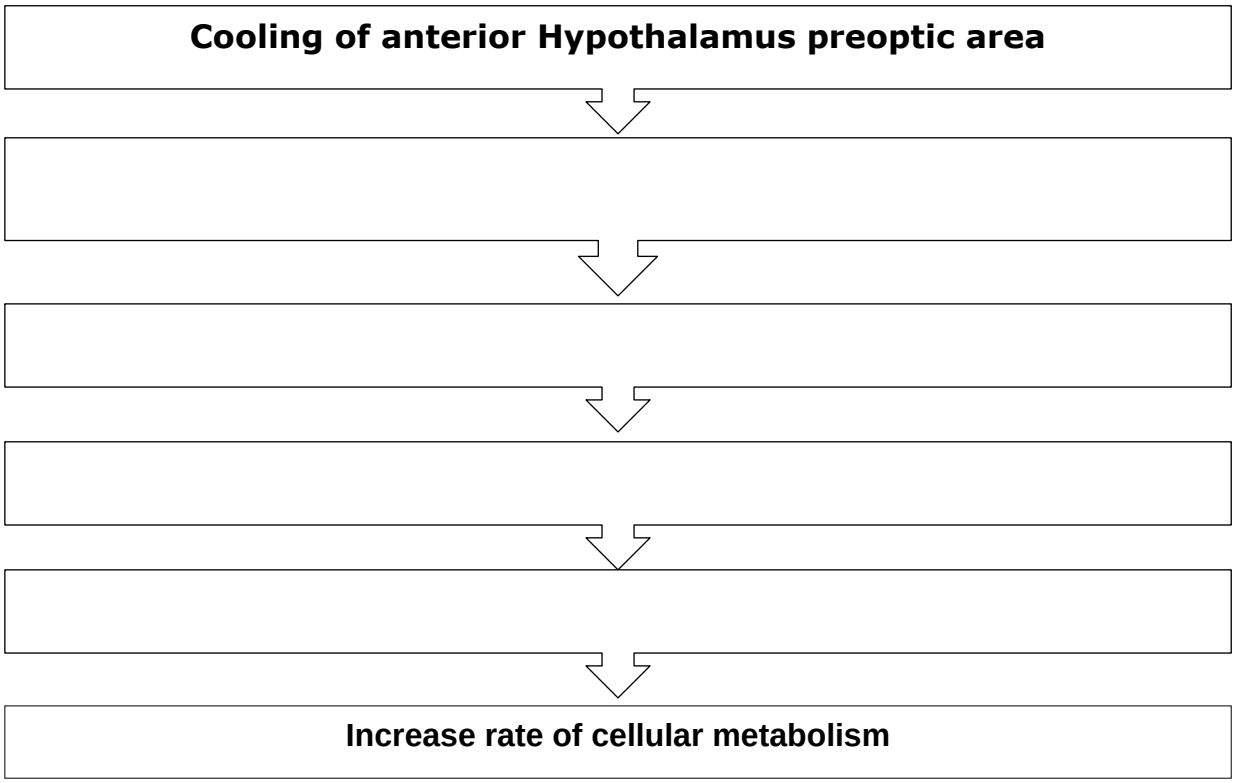
2._____

_____

3._____

_____

Task 7.15. *Complete the following scheme to define the role of thyroxin in thermoregulation*



Task 7.16. *Describe mechanisms of behavioral control of thermoregulation*

When temperature is too high _____

_____

_____

_____

_____

_____

When temperature is too low _____

_____

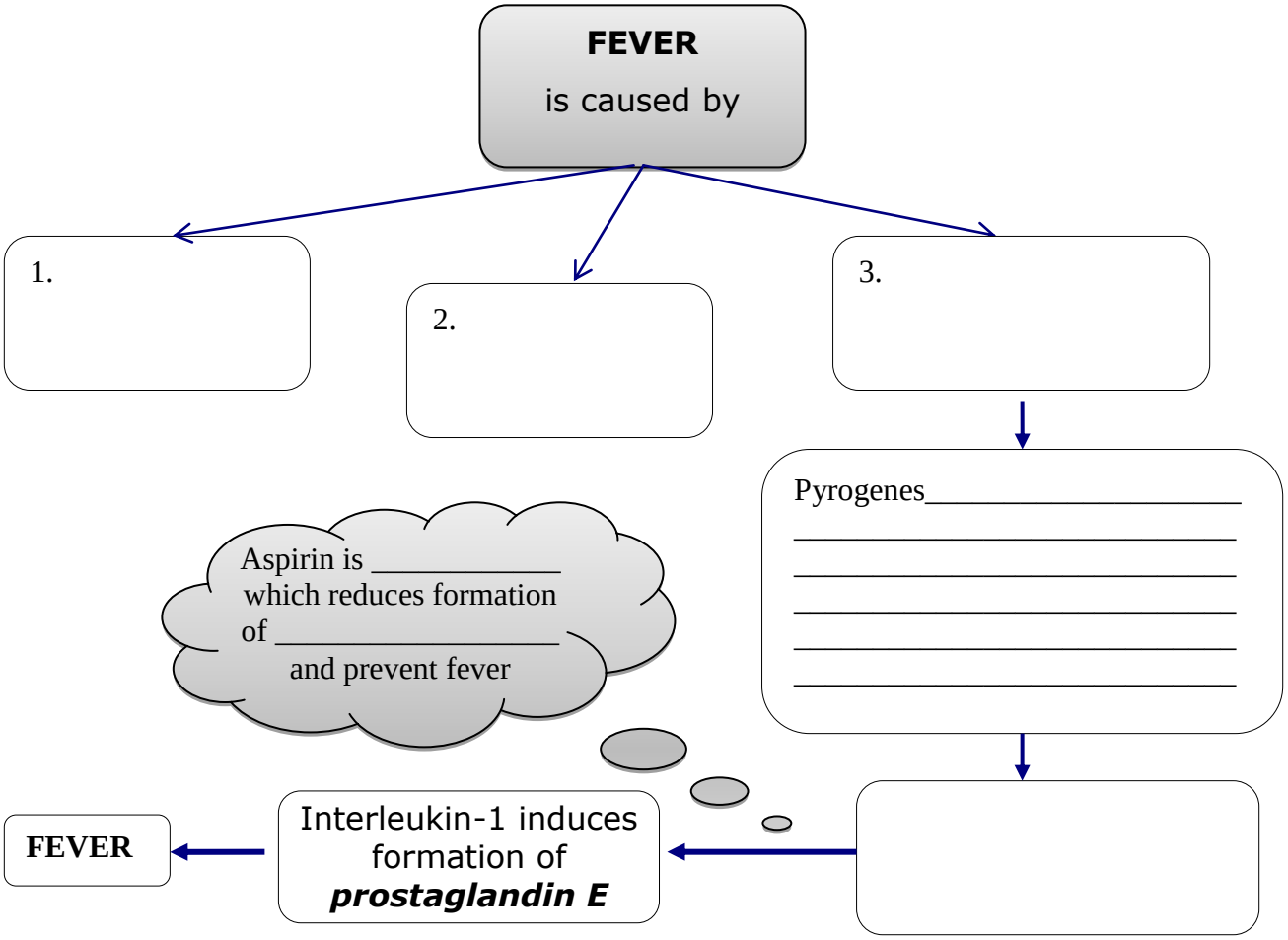
_____

_____

_____

_____

Task 7.17. *Complete the scheme* ***"Mechanisms of hyperthermia"***



PHYSIOLOGY OF EXCRETION

8. MECHANISM OF URINE FORMATION BY KIDNEY

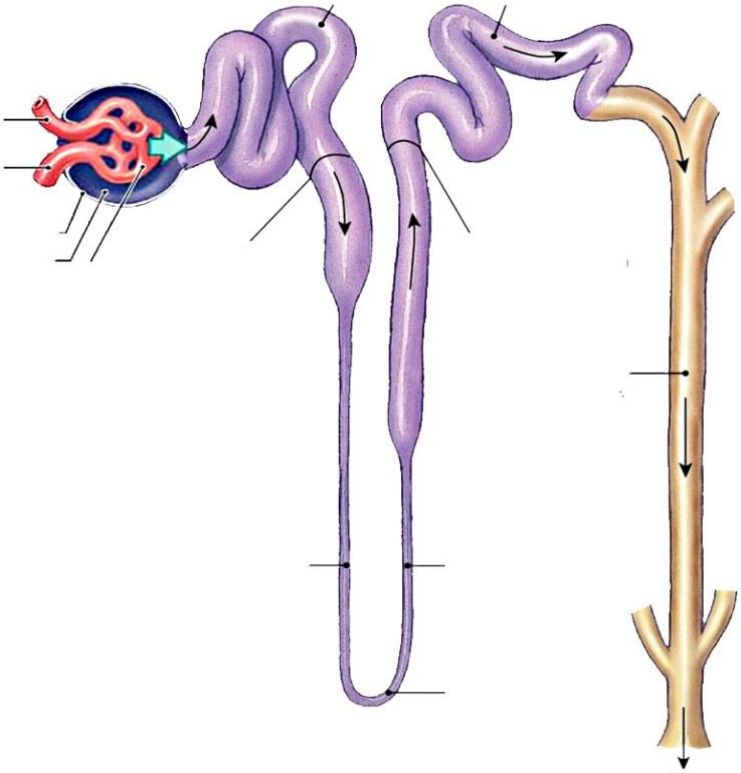
Task 8.1. *Functional system of excretion includes several organs. Define them and their role in excretory function of the organism.*

1. _____
   _____
2. _____
   _____
3. _____
   _____
4. _____
   _____
5. _____
   _____
6. _____

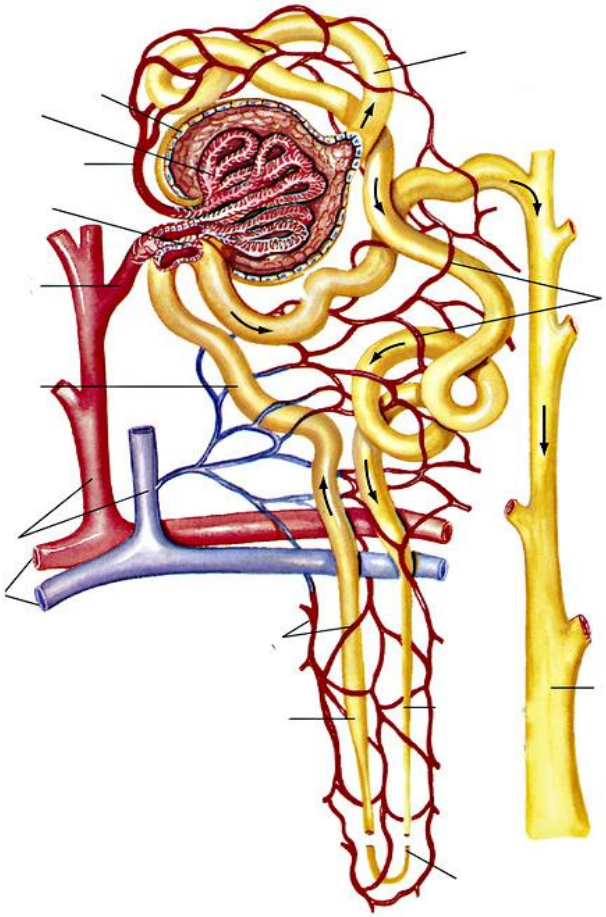
Task 8.2. *Define the role of kidneys in human organism by filling the following table.*

Function	Explanation
1.	
2.	
3.	
4.	
5.	
6.	
7.	

Task 8.3. *Label the illustration* ***"Nephron as a structural and functional unit of kidneys"***



Task 8.4. *Label the picture "Renal blood supply"*



Task 8.5. *Define the peculiarities of renal circulation by filling the following table.*

Peculiarity	Explanation
1.	
2.	
3.	
4.	
5.	
6.	

Task 8.6. *List the processes of urine formation and give the definition of them by filling the following table.*

Process	Type of transport	Definition
1.		
2.		
3.		

Task 8.7. *List the layers of renal filter and define peculiarities of each of them.*

Layer	Peculiarities

Task 8.8. *Define GFR and write its formula.*

GFR is _____
_____
_____

GFR = _____ × _____

Task 8.9. *List the factors influencing NFP.*

Factor	Value	Explanation
1.		
2.		
3.		
4.		

Task 8.10. *Define the factors that influence K_f (filtration coefficient).*

Factor	Conditions that lead to its change
1.	
2.	

Task 8.11. *Define the factors that regulate the tone of afferent and efferent arterioles.*

Factor	Response
Afferent arteriole	
1.	
2.	
3.	
4.	
Efferent arteriole	

Task 8.12. *Draw the scheme of RAAS activity and list its effects.*

Effects of RAAS:

- _____
- _____
- _____
- _____
- _____

Task 8.13. *Complete the following table "Influence of afferent and efferent arterioles resistance on GFR".*

Mechanism	Hydrostatic pressure in capsule	GFR
Afferent arteriole dilation		
Afferent arteriole constriction		
Efferent arteriole dilation		
Moderate constriction of efferent arteriole		
Severe constriction of efferent arteriole		

Task 8.14. *Fill the table "Reabsorption in nephron"*

Part of nephron	Type of reabsorption	Mechanism of reabsorption	Substances which are reabsorbed	Hormones that regulate reabsorption
Proximal tubule				
Descending limb of Henle's loop				
Ascending limb of Henle's loop				
Distal tubule				
Collecting duct				

Task 8.15. *List the steps of countercurrent multiplier.*

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

Task 8.16. *Define the role of vasa recta in maintenance of osmolarity of renal medulla.*

_____
_____
_____
_____

Task 8.17. *Describe the process of secretion and define the substances that are excreted by urine by this way.*

_____
_____
_____
_____
_____

Task 8.18. Define significance of Renal autoregulation and mechanisms.

_____
_____
_____
_____

Task 8.19. *Explain the significance of tubuloglomerular feedback.*

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Task 8.20. *Fill the table "Reflex of urination"*

Stimulus	Receptors	Afferent nerve	Nerve center	Efferent nerve	Target organ	Response

Task 8.21. *Complete the table "Role of kidneys in homeostasis maintenance"*

Regulation of water-ion balance		
Aldosterone	***ADH***	***ANP***
Regulation of blood pressure		
Regulation of acid-base balance		

SUPPLEMENT

You should collect values of important physiological parameters in the table below

NORMAAL VALUES OF HOMEOSTATIC PARAMETERS

Parameter	***Units of measure***

Parameter	*Units of measure*

For your notes

For your notes

Навчальне видання

Фізіологія вісцеральных систем: Травлення. Енергетичний обмін та терморегуляція. Виділення

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