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Features of Mechanisms of Adaptation and Homeostasis in a Functional System

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Abstract: The review considers the issues of adaptation of functional systems and regulation of homeostasis, which are characterized by their genetic determinism and phenotypic variability, universality and specificity. It has been established that, on the one hand, these processes determine, on the one hand, the complexity of the structure and meaning of a functional system, and, on the other hand, the unity of the structural and functional levels of the organization of a living being during adaptation and regulation of homeostasis.

Key words: functional systems, compensatory processes, genetic determinism, adaptation.

Relevance. The problem of adaptation and homeostasis occupy a special place in biology. Biochemists, biophysicists, morphologists, physiologists and other specialists are studying their mechanisms, which have been formed in evolution and provide optimal vital activity at all levels of living organization. This is explained by the fact that adaptation to continuously changing conditions of external and internal environments is ensured by genetically determined transformations of the structure and its function at the molecular, subcellular, cellular organ and organism levels [1, 3, 26]. This knowledge of their universal and specific features requires adequate models and study methods.

To date, the most complete understanding of adaptation and mechanisms of homeostasis regulation has been obtained in the study of blood circulation and respiration. The mechanisms of regulation of the relative constancy of the concentrations of ions and nutrients in the internal environment of the body are much less studied [25–27].

The main objective of this article is to consider the hierarchical organization of the functional systems of a living organism, the structural foundations of the processes of adaptation and homeostasis. Both when considering the literature data and when presenting the results of experiments, attention was focused on the existence of a dialectical unity of structure and function, genetic determinism of the dynamics of adaptation, regulation of homeostasis, universality and specificity in the study of functional systems that are different in nature and level. For this, structures of any level of complexity, ranging from molecules to the whole organism, need regulation systems. These systems ensure the interaction of various structures already in a state of physiological rest. They are especially important in the active state when the organism interacts with a changing external environment, since any changes require an adequate response of the organism. In this case, one of the obligatory conditions for self-organization and self-regulation is the preservation of the constant conditions of the internal environment inherent in the body, which is homeostasis (H) [3, 37, 54].

H is a self-regulating process in which all biological systems strive to maintain stability during the period of adaptation to certain conditions that are optimal for survival. Any system, being in dynamic equilibrium, strives to achieve a stable state that resists external factors and stimuli.

H is a term that is used both to describe the existence of organisms in an ecosystem and to describe the successful functioning of cells within an organism. Organisms and populations can maintain homeostasis while maintaining stable birth and death rates.

The state of a biological system of any structural and functional level depends on a complex of influences. This complex consists of the interaction of many factors, both external in relation to it, and those that are inside or are formed as a result of the processes occurring in it. The level of influence of external factors is determined by the corresponding state of the environment: temperature, humidity, illumination, pressure, gas composition, magnetic fields, and the like. However, the body can and should maintain the degree of influence of far from all external and internal factors at a constant level. Evolution has selected those of them that are more necessary for the preservation of life, or those for the maintenance of which the corresponding mechanisms have been found [26, 29, 30].

The great importance of blood in maintaining homeostasis has become the basis for. formation of a special system of homeostasis of many parameters of the blood itself, its volume. For their preservation, there are complex mechanisms included in a single system of regulation of body homeostasis [23, 25].

All body systems must work together to maintain proper homeostasis within the body. G is the regulation in the body of such indicators as temperature, water content and carbon dioxide levels. Maintaining the body's internal balance homeostasis can be defined as a property of an organism or system that helps it maintain its set parameters within the normal range of values. This is the key to life, and the wrong balance in maintaining homeostasis can lead to diseases such as hypertension and diabetes, pyelonephritis and other diseases. D is a key element in understanding how the human body works. Such a formal definition characterizes a system that regulates its internal environment and seeks to maintain the stability and regularity of all processes occurring in the body [1, 3, 5].

A change in G can occur under the influence of any external factors, as well as be of endogenous origin: the intensification of metabolic processes tends to change the parameters of homeostasis. At the same time, the activation of regulatory systems easily ensures their return to a stable level. But, if at rest in a healthy person these processes are balanced and the recovery mechanisms function with a reserve of power, then in the event of a sharp change in the conditions of existence, in case of diseases, they turn on with maximum activity. If one of the prerequisites for the existence of a living organism is nutrition, then proteins, being one of the ingredients of food, are of the greatest importance, since without them body tissues cannot be built. In turn, each person has individual functional capabilities of the homeostasis regulation systems themselves. This largely determines the severity of the body's reaction to any impact, and ultimately affects life expectancy [4].

Maintaining homeostasis is incredibly important for the body. The human body contains a certain amount of chemicals known as acids and bases, and their proper balance is essential for the optimal functioning of all organs and body systems. The level of calcium in the blood must be maintained at the proper level. Because breathing is involuntary, the nervous system provides the body with much-needed oxygen. When toxins enter your bloodstream, they disrupt the body's homeostasis. The human body responds to this disturbance with the help of the urinary system. It

is important to emphasize that the body's homeostasis works automatically if the system functions normally. G is not a set of organs, but the synthesis and balance of bodily functions. Together, this allows you to maintain the entire body in a stable state.

The modern period of development of biomedical science is characterized by the intensive development of molecular genetic, biochemical, biophysical, physiological and morphological studies. This, of course, makes it possible to deepen the existing ideas about the unity of structure and function, to reveal the essence of continuously occurring adapted processes in living systems, the regulation of homeostasis. However, in view of the fact that structural and functional rearrangements are considered at different levels of organization of living matter, it becomes necessary to establish a relationship on the scale of the whole organism, the role and place of molecularly - genetically - continuously occurring adaptive processes under the influence of external and internal environments. The study of the patterns of evolution and individual development makes it possible to determine the universality of molecular genetic mechanisms in the formation of hierarchical levels of a living organism. Adaptation is a continuously ongoing process, the reorganization of structure and function, which does not stop for a single moment from the moment of the birth of a living organism to the moment of death. This is due to the continuous variability of both endogenous and exogenous factors (internal and external environments of the body. In a living organism, elementary chemical, biochemical reactions occur in the structure of membranes, the nucleus and cytoplasm constantly with different intensities. As a result, every moment the body changes its structure and function "However, both activation and inhibition, according to the general biological law, is a deviation from some average statistical perimeter (abscissa), the norm. Evolutionary genetically determined "switching on" of mechanisms (structures) that return structural - functional, adaptive changes to the initial level. If factor has a long-term effect, then the elements of the system of a living organism, interactions according to the feedback principle, move to the level of genetically programmed evolution. adaptation occurs at a new, different from the original level [23, 26, 54].

According to the teachings of C. Bernard on homeostasis, the cells of highly organized animals are constantly surrounded by a constantly circulating aquatic environment, which delivers substances of various chemical structures necessary for the ongoing processes of assimilation and dissimilation. At the same time, it receives and removes the excretions formed as a result of dissimilation. It is a circulating fluid and is the environment of the body. In terms of its physicochemical properties, ion concentration, partial pressure of oxygen and carbon dioxide, nutrients, it is relatively constant and ensures optimal functioning of the structures of the corresponding level of organization of the functional system of the body. In the process of deepening ongoing and the function of cells and subcellular physico-chemical, biochemical and biophysical processes. As a result, each cell of organs has a constant composition of the nucleus and cytoplasm. Even with short-term or long-term changes in the homeostasis of the interstitium (within the permissible range), adaptive rearrangements of constancy inside the cell, its cytoplasm and nucleus. The presence in highly organized animals of evolutionally formed mechanisms that ensure the maintenance of the constancy of the internal environment was the main property of adaptation and regulation of homeostasis.

The concept of Claude Bernard was further successfully developed in the works of Cannon. Having established that the maintenance of a relatively stable state of the internal environment is carried out due to the expression and repression of mechanisms in response to the variation of individual indicators (the concentration of ions, amino acids, biologically active substances, etc.). Keeping relatively constant, the main parameters of the internal environment

(blood, intestia, cerebrospinal fluid, p CO2, p O2) as a result of the dynamism of metabolic processes, structural and functional rearrangements continuously vary within the narrow limits of the physiological norm. Feedback in the functional system that regulates homeostasis, in accordance with the change in one or another of its parameters under the influence of factors of external and internal environments. It is also genetically determined and ensures the correspondence between changes in the homeostasis parameter and correction mechanisms. Considering the organism as an open system, composed of variable elements and continuously subjected to perturbing external and internal influences, Kennom believed that a living organism as a system can be preserved only sometimes, when the perturbing influence automatically "turns on" effects stabilizing the internal environment [7, 8 , 10].

Based on the analysis of the extensive material of his own research, as well as the data of other authors, Kennon came to the conclusion that in a complex organism, homeostasis is maintained due to the coordinated action of self-regulation mechanisms. In the implementation of this process, he distinguishes 2 mechanisms: 1. Signaling devices that are sensitive to fluctuations in the parameters of the internal environment; 2. Corrective devices regulate the intensity of physiological reactions aimed at restoring the equilibrium state of the system. Under physiological conditions, without extreme effects of external and internal factors, the main parameters of the internal environment of the body or its constituent levels (from molecular and above) | deviate insignificantly and the correction is carried out (achieved) by the minimum direction of the available structure and function. However, under extreme impacts, the parameters of the internal environment do not reach the extreme limits that threaten the structural and functional state of cells, subcellular formations. Almost simultaneously with the deviation of the parameters of the internal environment from a certain value, corrective mechanisms (signal devices) are activated, which are aimed at restoring and stabilizing these parameters, i.e. maintaining homeostasis. Turning on simultaneously or in a certain sequence, this mechanism provides internal homeostasis [11–13].

Analyzing the basic views of Cannon on homeostasis, its essence, it can be noted that he acted as a particular expression of the general process of self-regulation of the internal environment of the body. According to Cannon, the internal environment (regardless of the considered level of organization of a living system) is the main organ, the preservation of the structure and function of which is achieved by an evolutionarily established system of organization of complex physiological processes that ensure the existence of the organism as a whole as an open self-regulating system.

Thus, according to the concept of Cannon, homeostasis is a state of the internal environment of the body, which continuously varies, but remains relatively constant due to the integration of physiological processes, carried out on the basis of the unity and self-regulation of the structure and functions of individual organs and systems. In modern definitions, as well as in the definition of Cannon, homeostasis is the constancy of the internal environment, the stability of structural and functional transformations that ensure this state, adaptation to the continuously changing conditions of the external and internal environments of the body, including mechanisms on the subcellular, cellular, tissue, organ and organism levels [37, 38, 54].

Despite the fact that in recent years, with the development of new technologies, the mechanisms of homeostasis regulation are covered at the physicochemical, molecular and cellular levels. It is important to obtain a sufficiently complete description of the correction features in constantly changing environmental conditions. It is precisely this problem with respect to the numerous parameters interpreted by the functional system that still remains an

unresolved problem. The foregoing applies primarily to the processes of digestion and absorption of qualitatively and quantitatively unpredictable food that are dynamically occurring in the stomach and small intestine. Regulation of homeostasis and structural and functional adaptation, starting from the cell level, is possible under the condition of a constant concentration of electrolytes, biologically active substances (hormones, cytonins, etc.), which are the basis for the optimal course of numerous intracellular reactions. Moreover, changes in a narrow range of values: critical decreases or decreases can lead to disruption of the evolutionary homeostasis established in the evolution, not only in the interstitium, but also inside the cells with the ensuing consequences.

With the accumulation of knowledge about the mechanical breakdown of food ingredients along the digestive tube (digestive conveyor), parietal and membrane digestion, endocrine, nervous and immune regulation of them and each stage of absorption (absorption cycle), the idea remains unchanged that a prerequisite for the optimal functioning of systems of all hierarchical body levels is to maintain a constant concentration of electrons and nutrients. This is possible only if (if at each moment of time the rate of their entry into the blood of the intestinal lumen and from the so-called depots (i.e., tissues where they were previously deposited) corresponds to the rate of consumption during metabolism, the implementation of specific functions (synthesis, secretion, transmission, nerve impulse, etc.). The idea of deposition of excess nutrients in their mobilization from the "depot" as a mechanism that ensures homeostasis was formulated by C. Bernard. its gradual movement in the small intestine in the direction and to the surface of the mucous membrane of the suction cells of the villi.For this, the gastric contents are digested sequentially in the lumen of the intestine, the surface mucus of the values obtained by us during electron microscopic examination.At the final stage, in the membrane digestion, the process of absorption is carried out.Process absorption multi-stage also regulates the flow of split nutrients into the internal environment - blood or lymph. For example, at the stage of their transfer through the plasmolemma to the cytoplasm, amino acids are transported actively, with the participation of special carriers and ATP, glycerol and fatty acids are passively transported, uncleaved peptides are dosed, in accordance with the number of receptors on the membrane of endocytic formations [29, 30, 52, 54].

Thus, when studying the mechanisms of regulation of homeostasis during digestion and absorption, the qualitative and quantitative composition, the physicochemical properties of the food taken, the evolutionary and ontogenetically established features of the functioning of the digestive-absorptive conveyor, including, in addition to the organs of the digestive system, the state of endoecology (microbiocenosis), endocrine , immune and nervous status, gender, age, etc. With the seeming imperfection of the structure and function of the stomach, pancreas and small intestine, the digestive transport conveyor in newborns and children under 1 year old is also perfect with breast (natural) feeding (evolutionarily formed type of nutrition of mammals) ensures the harmonious development and formation of organs, functional systems of the body of all hierarchical levels [8–13].

Natural and perfect, from the point of view of evolution and individual development of mammals, should be considered the development and formation of all organs and systems of the body in accordance with the principles of the theory of functional, consolidation and minimization of function. The development and structural and functional formation of functional systems in the close unity of space and time, taking into account hereditary, environmental, climatic and other factors, is the main mechanism for adaptation and regulation of homeostasis.

Without dwelling in detail on these and other clinical and experimental data (they are given below in separate chapters), we only note that the mechanism that has developed in evolution in conditions of full health of parents, and when breastfeeding is improved for at least one year [14–17]. On the contrary, if, for example, the technology of natural feeding is violated, discoordination occurs, the development and formation of regulatory systems (nervous, endocrine, immune) and, as a result, the mechanisms of homeostasis regulation become imperfect [31–36]. Artificial feeding is the cause of a violation of the formation of microbiocenosis of the gastrointestinal tract, the activity of organs that carry out both digestion and absorption. As a result, the absorption of antigen-significant proteins in the small intestine increases, which, due to a violation of the homeostasis of the internal environment, not only sensitizes the body, but also causes the development of allergic dermatosis, anemic diseases, kidney damage, etc. Thus, the formation of structural and functional features of the digestive organs, their evolutionary and ontogenetic features have a significant impact on the mechanisms of functioning of the digestive-absorption conveyor, activation of the adaptation processes of the body.

Clinical and experimental studies on the correction of the mechanisms of disturbance and absorption to a certain extent restore the mechanisms of regulation of homeostasis of the internal environment, contribute to the prevention of effective treatment and remission of the noted diseases. Mechanisms of homeostasis and the process of digestion - absorption is violated with the same type of nutrition, intestinal dysbacteriosis, stress, immunodeficiency, etc. [2, 32, 33]. These and other data indicate the leading role of the functional system of digestion and absorption, which is closely integrated with all regulatory formations of the body [41–51].

When proteins enter the internal environment (blood and lymph) from the intestine for known or unknown reasons, the mechanisms that provide homeostasis are instantly “turned on”, then the mechanisms that ensure homeostasis are instantly “turned off”. The endothelium of the capillaries of all organs, transporting them to macrophages, which are part of the loose connective tissue. The endothelium of the capillaries of the vascular glomeruli of the kidneys filters them along with the primary urine. And in the lysosomes of macrophages and the epithelium of the proximal tubules of the nephron, after reabsorption (discovery No. 332), the exogenous protein absorbed by the enterocytes of the villi of the jejunum is cleaved to amino acids. If the homeostasis of the internal environment is disturbed for a long time due to protein absorption, then this can lead to various diseases of the internal organs and kidneys, including excretion as part of the final urine. It should be noted that this occurs simultaneously with active digestion and absorption in the small intestine [9, 41, 42, 53, 55, 56].

Thus, in the evolution of mammals, along with the formed mechanisms of digestion and absorption that regulate homeostasis, there is also an endogenous mechanism in the body, in which lysosomes take part, numerous macrophages and the epithelium of the proximal tubules are formed during protein digestion, amino acids are transported to the interstitium and blood without disturbing them. homeostasis [6, 18, 19, 20–29, 40].

The fundamental importance of the previously unknown properties of macrophages in the kidneys that digest exogenous food protein, as well as simultaneous transport and digestion in macrophages and the epithelium of the tubules of the kidneys, is that the functional systems of the body interact with each other when regulating homeostasis. It has evolved, is genetically determined, and can change phenotypically [9, 13, 55]. It has been clinically and experimentally established that the mechanisms of regulation of homeostasis of the internal environment during digestion are violated the more, the earlier artificial nutrition is carried out in ontogenesis, and

secondary immunodeficiency, dysbacteriosis develops. The organs of the digestive system, being on the border of the external and internal environments of the body, experiencing the most powerful “disturbing” effect from microorganisms, with the structural and functional perfection of the processes carried out in it, can ensure the optimal structure and function of all organs and systems and the body as a whole. When damaged, on the contrary, they cause numerous acute and chronic diseases [3, 53, 54, 56].

The results of studies conducted by Academician K. A. Zufarov and his students made it possible to establish the unity of structure and function in the dynamics of adaptation and regulation of homeostasis in the study of numerous processes occurring at various hierarchical levels of body organization [7–9, 55].

The literature data presented in this paper are necessary for considering, as a rule, the structure of functional systems at various levels of organization. The goal is the same: when considering the adaptation of functional systems and the regulation of homeostasis, to establish their genetic determinism, phenotypic variability, universality and specificity. The next very important thing is that due to this, on the one hand, the complexity of the structure and meaning of the functional system is determined, on the other hand, the unity of the structural and functional levels of the organization of the living organism during adaptation and regulation of homeostasis.

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