 ISSN NO: 2771-8840
Date of Publication: 11-10-2023

Subject and Tasks of Biophysics

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Annotation. The article deals with the formation of basic competencies when teaching a biophysics course. The types, functions, pedagogical and psychological qualities of the basic competencies on which they are based are substantiated.

Key words: formation of competencies, profession, pedagogical qualities, practical context, degree of universality, key competencies, educational practice, learning activities

Biophysics as a medical and biological science that studies the mechanisms of physical and physicochemical processes in biological systems. The place of biophysics among fundamental biological and medical disciplines, connections with biological and medical sciences. A brief historical sketch of the development of biophysics. Methods and directions of modern biophysics.

The subject of biophysics is the study of the physical and physicochemical processes underlying life. There are also more comprehensive definitions of biophysics. For example, Nobel Prize laureate A. Szent-Gyorgyi argued that biophysics is “everything that is interesting.” The term “biophysics” has been entrenched in scientific literature since 1892, when Karl Pearson, author of the book “The Grammar of Science,” stated in its pages: “... a science that tries to show that the facts of biology - morphology, embryology and physiology form special cases application of general physical laws, was called etiology... Perhaps it would be better to call it biophysics.” A. Fick and after him other German scientists called this field of knowledge medical physics, but the French physiologist J. A. d'Arsonval, even before K. Pearson's proposal, preferred the phrase "biological physics" to the term "medical physics."

Modern biophysics studies the mechanisms of physical and physicochemical processes in biological systems at the submolecular, molecular, supramolecular, cellular, tissue, organ and organism levels.

By the nature of the objects of research, biophysics is a typical biological science. According to the methods of studying biological objects and analyzing research results, biophysics is a unique branch of physics (according to M.V. Volkenshtein, “biophysics is the physics of life phenomena”). She is at the forefront of those areas of biology that transform this ancient field of human knowledge from the humanities into an exact science. The introduction of physical principles of analysis of biological phenomena into medicine allows it to become not only an art, but also a science. This is the special role of biophysics among other medical theoretical disciplines.

Biophysics is often spoken of as a new, young science. So, on November 9, 1934 P.L. Kapitsa wrote: “Biophysics is a completely new field; it came along with biochemistry to replace the old classical physiology. Instead of studying physiological processes as a whole...biophysics and biochemistry study the individual elements of a living being and try to explain its function through the laws of physics and chemistry.” Indeed, biophysics emerged as a separate scientific discipline relatively recently, but the beginnings of biophysics arose immediately after the appearance of work in the field of experimental physics. Thus, some of G. Galileo’s research (measuring body temperature, determining the work done by a person, etc.) can be attributed to biophysical research.

The desire to explain the life processes of humans and animals by physical laws was very characteristic of the work of many scientists of the 17th and 18th centuries. (R. Boyle, R. Hooke, I. Newton, P.S. Laplace, A.L. Lavoisier, M.V. Lomonosov and many others). XIX century became the century of triumph of analytical methods in the study of biological phenomena. These methods were most developed in physiology, in the depths of which modern biophysics was born. Many physiological processes, including nervous activity, were tried to be explained on the basis of physical laws. Unlike similar attempts by predecessors, such explanations were largely confirmed experimentally. Hermann Helmholtz measured the speed of propagation of a nerve impulse. Emile Dubois-Reymond studied the bioelectrogenesis of almost all organs and tissues of the body.

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Ernst Weber explained some properties of hemodynamics based on physical laws. Outstanding discoveries have been made in the field of biophysics of the senses - just mention the Weber-Fechner law.

At the same time, the 19th century. determined a very characteristic trend in the subsequent development of biophysics. One of the first scientists to notice and approve this trend was Ivan Mikhailovich Sechenov, the father of Russian physiology. With no less reason, he can be called the founder of Russian biophysics. He used the methods of mathematics and physical chemistry to study respiration and established quantitative patterns of dissolution of gases in biological fluids. In the works of I.M. Sechenov traces the most promising path of development of physiology and biophysics, associated primarily with physical chemistry. In his doctoral dissertation (1860) I.M. Sechenov stated: “A physiologist is a physical chemist who deals with the phenomena of an animal organism.”

However, only in the 20th century. biophysics became an independent science. From then on, she began to study fundamental problems of biology: heredity and variability, ontogenesis and phylogeny, metabolism and bioenergetics.

Most researchers (biophysicists) of the 17th–19th centuries. considered a living organism as a physical system, and the main method of such study of biological phenomena was the search for external analogies. Note that even now a similar technique is used in biophysics, not without success. For example, muscle contraction can be modeled by the inverse piezoelectric effect, the amoeboid movement of cells by the movement of a mercury drop in an acid solution, the conduction of a nerve impulse by the migration of a scratch along an iron wire treated with nitric acid (Lilli’s model), etc.

The cognitive value of such models is quite limited. Often, when modeling the same biological phenomenon, they replace one another following the emergence of new technical devices. For example, reflex activity was considered in the time of R. Descartes by analogy with the work of a steam engine, at the beginning of the last century - a telephone exchange, now - an electronic computer. However, similar (phenomenological) models are also needed. They make it possible to clarify some details of phenomena already understood in principle, and to create bionic systems that use the laws of biological organization to build complex technical devices, such as robots. And yet, this useful area of physical modeling is not the main one in solving fundamental biophysical problems.

The main goal of biophysical research is to elucidate the intimate (internal) mechanisms of biological processes, and not to consider external analogies. It is generally accepted that living organisms are complex physicochemical systems. Therefore, not physical, but physicochemical modeling turned out to be the most fruitful. It led to the creation of the ion theory of excitation, the discovery of the nature of bioelectrogenesis, the elucidation of the properties of biological membranes, etc. The achievements of biophysics in recent years have been especially significant along this path.

Essentially, modern biophysics is physical chemistry and chemical physics of biological systems. This is the leading direction in the work of the world’s two largest institutes of biophysics of the Russian Academy of Sciences, which are located in the city of Pushchino near Moscow. Many research institutions of the Academy of Sciences, the Academy of Medical Sciences, and the Russian Ministry of Health are now working on the problems of biophysics. Among them are the Institutes of Physical Chemistry and Chemical Physics of the Russian Academy of Sciences, the Institute of Biophysics of the Russian Ministry of Health. University departments of biological physics are also involved in the development of biophysics in our country.

Biophysics is a borderline field of knowledge, and the boundaries between it and a number of other biological sciences are rather arbitrary. When drawing these boundaries, they proceed from the very definition of the subject of biophysics - biophysical includes studies that reveal the physical, as well as physicochemical mechanisms of biological processes. In biophysical research, the basic principle of experimental study of nature is applied - a quantitative analysis of the body's reactions to certain stimuli with the construction of functional dependencies between them. Life processes receive a strict interpretation in the form of quantitative patterns, which are an abstract form of expressing the functional dependence of the reaction on the stimulus.

Physiology has been studying the functions of the body since time immemorial. At different times, the content of physiology changed. Now she considers a function as a form of activity with a certain final result, the manifestation of which is physiological properties (Shidlovsky, 1981). Their internal mechanisms cannot be penetrated using traditional physiological approaches to studying function. These mechanisms, since they are of a physical and chemical nature, are studied by biophysics and biochemistry. The difference between the

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tasks of biophysics and physiology in the study of body functions can be illustrated with the following example. When studying biopotentials, a biophysicist is interested, first of all, in the mechanism of the occurrence of electromagnetic processes in living tissues, the physicochemical basis of this phenomenon, and its energy supply, while for a physiologist biopotentials are indicators of the vital activity of the organism and serve as a quantitative characteristic of the most important physiological properties (primarily excitability) . Thus, using an electrocardiogram, a physiologist judges the properties of the heart muscle (automaticity, excitability, conductivity). He is less interested in the physicochemical nature of electrogenesis in the myocardium; this constitutes the main task of the biophysical study of electrical processes in the heart.

Biochemistry, like biophysics, also seeks to penetrate into the mechanisms of physiological phenomena, but studies their chemical nature. The difficulties in distinguishing between biophysical and biochemical research are understandable, but it must be done. “There is no doubt,” said academician G.M. Frank (1974) - that any manifestations of life and living organisms in general are ultimately “chemical machines.” However, despite the primacy of chemistry, chemical language and chemical concepts are insufficient to reveal the material essence of life phenomena. This primarily relates to the paths of energy transformation, the nature of interaction forces and various physical processes, such as, for example, the generation of electrical potentials, the occurrence of mechanical energy, control and regulation mechanisms.”

Biophysical methods are created on the basis of physical and physicochemical methods of studying nature. They must combine difficult to compatible properties: high sensitivity and greater accuracy. This condition is met, first of all, by the achievements of modern electronics. The use of optical methods is very fruitful. Various spectroscopy methods are widely used, including radio spectroscopy (electronic paramagnetic resonance (EPR) and nuclear magnetic resonance (NMR) methods). Radioisotope techniques have long come into use.

Any research requires that recording instruments do not introduce distortions into the process being studied. For a biophysical experiment, compliance with this requirement is especially important. The famous Soviet biophysicist B.N. Tarusov believed that this requirement contained the most important feature of biophysical methods, distinguishing them from the use of similar methodological techniques in other areas of physics. This somewhat exaggerated formulation of the specifics of biophysical methods has certain grounds. It is difficult to compare any physical system with a living organism due to the latter’s unusually high sensitivity to any influences on it. They do not simply disrupt the normal course of biological processes, but cause complex adaptive reactions that vary in different organs and under different conditions. The distortion of the meaning of true phenomena may turn out to be so significant that it becomes impossible to make corrections to artifacts (phenomena that are not characteristic of the object under natural conditions and arise during its research), since correction methods used successfully in physics and technology are often fruitless in biophysics .

To better understand the areas of application of biophysical methods, let us consider the main directions of scientific research in biophysics. According to the decision of the International Association of General and Applied Biophysics, these include research at the molecular and cellular levels, as well as the biophysical study of sensory organs and complex systems.

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