INFLUENCE OF ELECTROMAGNETIC RADIATION ON BIOLOGICAL OBJECTS OF DIFFERENT LEVEL OF ORGANIZATION

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ABSTRACT

This article will consider the effects of electromagnetic radiation at the molecular and cellular levels. The very possibility of biological effects of electromagnetic radiation with a frequency of 10^{11} and below is determined by the fact whether there is a primary reception of electromagnetic waves, that is, whether there is any physical mechanism for the interaction of biological structures with an electromagnetic field of non-thermal intensity, leading to a change in the functional activity of these structures. In this regard, it is important to understand what can happen in such an interaction at the microscopic level.

Keywords: electromagnetic radiation, biological effects, conformational states, spectrum of natural frequencies

1. Introduction.

Analyzing the results of studies of the impact of electromagnetic radiation on biological objects of various levels of organization, it is easy to see that most, if not all, of the effects can be explained by a change in the functional activity of proteins. This also applies to transport proteins and enzymes that determine biochemical processes, as well as bio-macromolecules embedded in membranes. The structure of protein molecules allows the possibility of many conformational states, and the functional activity of a protein molecule depends to a large extent on which of these conformational states exist in these states. Transitions between conformational states in protein molecules occur continuously, but their dynamics and direction are determined by the conditions of the environment surrounding the protein molecule.

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One of these external factors is electromagnetic radiation, which can shift the dynamic balance in one direction or another.

The possibility of accumulation in biological molecules of energy sufficient to overcome the potential barrier between conformational states is associated with the excitation of acoustic vibrations in biological structures. An important condition for the implementation of such an accumulation process is the dissipation of bonds between internal oscillators, the role of which can be played by side groups of amino acid residues in a protein chain or polar water molecules in the hydration shell of a protein molecule. An example of such a protein chain is shown in Figure 1.

2. **Proteins as possible receptors for electromagnetic radiation**

Electric charges or dipoles in these oscillators interact with the electric component of the incident electromagnetic wave. This interaction can cause fluctuations in the individual components of the protein chain. The dissipative coupling between the oscillators ensures the synchronization of these oscillations and, due to this, an increase in the amplitude [1] even in the case of a low intensity of the exciting electromagnetic radiation. To a certain extent, we can say that an external action does not pump up the energy necessary for a conformational transition, but organizes for this the energy of internal vibrations of a bio-molecule by synchronizing them.

A significant increase in the amplitude of a certain type of internal vibrations leads to a conformational transition in the protein molecule. Synchronization occurs when the excitation frequency is close to or a multiple of the natural frequency of the oscillatory system. Since the side groups of a protein molecule have different lengths, masses, and bond systems, as can be seen from Figure 1, the spectrum of natural frequencies and, accordingly, interaction frequencies will be wide.

A similar model of the interaction of biological systems with electromagnetic radiation was studied in [2]. A linear chain of monomers linked by a dipole-dipole interaction was considered.

The role of monomers can be performed by nucleotide pairs containing nitrogen bases of DNA, or peptide residues in a protein chain. Interaction with the electric component of the electromagnetic field will lead to the excitation of oscillations in monomers with the participation of dipoles. The solution found by the matrix algebra method for forced vibrations shows the presence of resonant frequencies at which the effect of an electromagnetic wave on a protein molecule is the strongest. The hemoglobin molecule is a convenient model for experimental studies of the interaction of electromagnetic radiation with protein molecules. In one of the first experiments [3], Mössbauer spectroscopy was used to study the fast dynamics in the rabbit hemoglobin molecule with and without exposure to millimeter waves. Mössbauer spectroscopy makes it possible to observe the dynamic behavior of the side groups of this protein, located near the heme, with characteristic times of ~ 10^{-7} s, obtaining information by measuring the parameters of the so-called "quasi-elastic" line of the Mössbauer spectrum. The results of the experiment showed that electromagnetic radiation does not affect the average values of the parameters of the "quasi-elastic" line, but this effect significantly changes the distribution of the amplitudes of this line. The interpretation of these results in terms of the model of a damped Brownian oscillator allows us to speak of an increase in the amplitudes of low-frequency oscillations in the hemoglobin molecule under the influence of electromagnetic radiation.

Structural changes in protein molecules are closely related to their functional activity. This aspect was first touched upon in the “protein-machine” hypothesis [4], put forward to consider the interaction of protein molecules with an electromagnetic field. The structure of protein molecules is determined both by the system of bonds between peptide residues in the protein chain and by the bonds of peptides with water molecules in the hydration shell. An example of such a structure is the main component of the skin - collagen. This protein is highly hydrated [5]. The greatest hydration of collagen is typical for skin areas near the joints, where the concentration of mechanoreceptors (Ruffini bodies) is increased. Hydrated collagen has electrical and piezoelectric properties, and its structure and therefore dimensional changes under the influence of electromagnetic radiation can cause spontaneous activity of Ruffini corpuscles, forming a signal to the central nervous system.

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3. Effect of electromagnetic radiation on conformational states in proteins

Models of the interaction of electromagnetic radiation with protein molecules show the possibility of synchronizing the internal oscillations of some chains and, due to this, the concentration of energy sufficient to change the conformation in macromolecules. Experimental confirmation of the existence of conformational transitions under the action of electromagnetic radiation was obtained in a number of works. First of all, these include Mössbauer measurements performed on hemoglobin molecules. The results of these measurements are given in [6]. Mössbauer spectroscopy provides very precise information about the distribution of the electric field and hence the structure of the molecule near the Mössbauer isotope. In hemoglobin, ^{57}Fe is such an isotope , and it is located in the center of the heme complex, surrounded by the protein part of the globule. The transition of a hemoglobin molecule to a new conformational state is accompanied by a change in the electric field on the nucleus of the ^{57}Fe isotope , and this manifests itself in a change in the parameters of the Mössbauer spectrum of the protein. The measurement results are shown in Figure 2. In the range of 44.50 - 50.36 GHz, 10 frequency values were found, at which the interaction of electromagnetic radiation with hemoglobin molecules was observed. This interaction manifested itself in the Mössbauer spectra as the appearance of an additional doublet of lines corresponding to the new conformational state. The parameters of these doublets, which appeared during the interaction at resonant frequencies, are shown in Figure 2. It should be noted that the response of hemoglobin molecules to electromagnetic radiation at different frequencies is not the same. Probably, each resonant frequency corresponds to a transition to its own conformational state associated with this frequency. This indicates a large amount of conformational space, but this fact seems surprising, since the iron atom in hemoglobin has simultaneous bonds with only a few parts of the globule.

This conclusion is confirmed by the results of Mössbauer studies of the interaction of the hemoglobin molecule with electromagnetic radiation at helium temperatures [7]. In this case, the Mössbauer spectrum of hemoglobin contains two subspectra. One of them is a well resolved doublet of lines corresponding to the low spin component of hemoglobin. The other subspectrum had the form of an asymmetric doublet of broadened lines. It belongs to the high-spin component of methemoglobin with an intermediate relaxation time insufficient for full resolution of the hyperfine magnetic structure.

During resonant interaction of a hemoglobin molecule with electromagnetic radiation, the parameters of the first doublet practically do not change, while the parameters of the high-spin subspectrum. The parameters of additional doublets in the Mössbauer spectra of hemoglobin at resonant frequencies of interaction with

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millimeter waves change significantly, which indicates conformational transitions in this particular component of methemoglobin. Moreover, the area ratios of the lines corresponding to both components remain unchanged in magnitude, which means that the induced transitions do not have a spin character. Thus, the measurement results indicate that the transition of a globular bio-macromolecule from one conformational state to another under the action of electromagnetic radiation is accompanied by a rearrangement of the system of internal bonds in the protein tertiary structure.

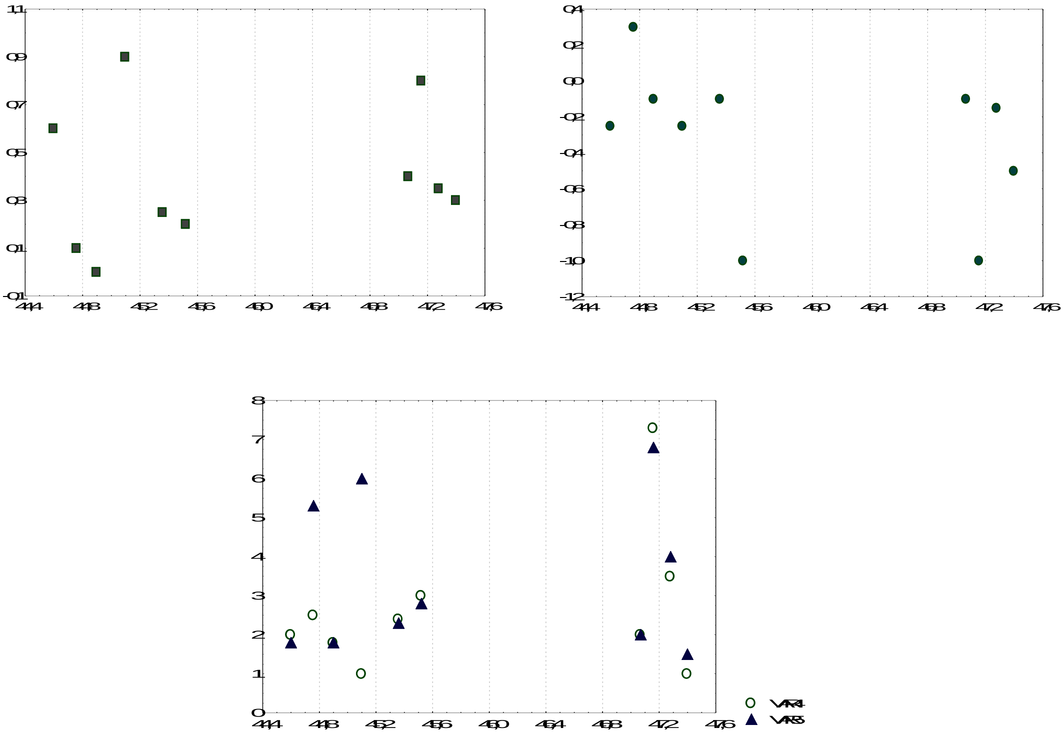

Fig. 2. Parameters of additional doublets in the Mössbauer spectra of hemoglobin at resonant frequencies of interaction with millimeter

Conformational transitions in protein molecules are closely related to the structure of internal movements in bio-macromolecules. Mössbauer measurements of the effect of electromagnetic waves on the dynamics of hemoglobin [8] showed that the interaction at resonant frequencies increases the intensity of transitions in a certain conformational subspace. Mössbauer spectra testify to the general stabilization of the molecular structure under the influence of electromagnetic radiation, and this

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indicates the synchronization of internal movements in the protein molecule by the electromagnetic field. Consequently, electromagnetic radiation acts most effectively on those conformational states that have natural frequencies close to the frequency of the external generator. An increase in the amplitude of these oscillations leads to a conformational transition.

Changes in the structure of the bonds of protein molecules were also recorded using infrared spectroscopy. In [9], this method was used to study the effect of electromagnetic radiation on blood plasma. It was found that irradiation with electromagnetic waves leads to changes in the infrared spectra associated with the destruction of hydrogen bonds. In another work [10], the infrared spectra of lecithin and human serum albumin were measured under irradiation with electromagnetic radiation with a wavelength 8,6 mm and an incident power flux density of 50 mW/cm^2. These spectra showed that millimeter waves do not cause irreversible changes in the secondary structure of protein molecules, including phase transitions in lipids and transitions from α - helices to β - bends. However, electromagnetic radiation modified the dynamics of proteins, which manifested itself in an increase in hydrogen exchange in human serum albumin. This effect was completely reversible.

Conclusion

Thus, the considered examples of the interaction of protein molecules with electromagnetic radiation allow us to consider these macromolecules as one of the main contenders for the role of recipients of electromagnetic waves. Thus, electromagnetic radiation affects biological objects even at very low intensity, and the range of effective frequencies is very wide.

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