Biophysical mechanisms of the therapeutic action of bioresonance therapy. Modern concepts and probabilistic models

M.Yu. Gotovsky[1], Yu.F. Perov[1], L.V. Chernetsova[2]
([1]Center for Intelligent Medical Systems "IMEDIS", Moscow, [2]GOU VPO "Izhevsk State Medical Academy", Izhevsk)

In the previous publication, the existing concepts of biophysical mechanisms of bioresonance therapy (BRT), based on the empirical concepts expressed by F. Morel, were considered from a critical standpoint [1]. The analysis showed that, despite some critical remarks that have appeared in the literature recently, there are currently no ideas about the mechanisms of the therapeutic action of BRT, even in the most general form. In this regard, a more in-depth consideration of the biophysical mechanisms of the therapeutic action of BRT becomes urgent, which is the subject of this article.

The functioning of the human body is associated with the emergence of excitation processes in organs and tissues, accompanied by electrical phenomena, all of which, with the exception of currents or resting potentials, have an oscillatory character. Due to the fact that BRT is a method of treatment using natural electrical oscillations and human electromagnetic fields, it is necessary to dwell in more detail on the analysis of their characteristics.

The human body is a source of bioelectric fields, which is accompanied by the formation on the surface of the body of a complex pattern of electrical potentials and the creation of external electric and magnetic fields [2]. Simultaneously with the registration of bioelectric activity, studies of the electric field of the human body began to be carried out. The first attempt to register the electric field of the human brain and transfer it to another person was made in 1928 by M. von Ardenne [3]. In these experiments, a recording metal plate was placed over the head of one person, the signal from which, through inductive or capacitive coupling, was then transmitted to the head of another. Probably, from a historical point of view, these studies can be considered the first attempts to use a person's own electric fields for medical purposes.

The electric field measured near a person is due to bioelectric processes occurring in the body and contains several components - constant and variable. As a result of the research, it was shown that it is in principle possible to register low-frequency bioelectric potentials from the body surface and at a certain distance from it, reflecting the functional activity of individual organs and systems of the human body [4]. Thus, any part of the human body is a source of electrical vibrations that carry information about the current state of the body.

The study of human magnetic fields, in comparison with electric fields, significantly lagged behind due to methodological difficulties and low sensitivity of the recording equipment. Only with the advent of a supersensitive meter, the operation of which is based on the Josephson effect - a superconducting quantum interference sensor (SQUID) - did it become possible to register external human magnetic fields. The first was recorded the magnetic field of the heart, somewhat later - the magnetic field of the brain, which, like electric ones, are an informative indicator in assessing the functional state of these organs [5].

Thus, at present, two classes of electrical and electromagnetic signals have been identified, recorded on the surface of the human body and at a distance from it. The first of them is the result of the functioning of the bioelectric "generators" of the body and is recorded by the contact method using the electrode technique. The second type can be considered as a natural continuation in the surrounding person space of fields of the first class. All these processes are the result of the simultaneous activity of several sources in the human body, including those that have not yet been thoroughly studied.

Electrical processes in the form of bioelectric potentials of excitable organs and tissues are recorded as electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG), etc., which are well studied and widely used in medical practice [1, 6]. The magnetic fields inherent in the human body are recorded as a magnetocardiogram (MCG), a magnetoencephalogram (MEG), a magnetomyogram (MMG), etc. [5]. All these electric and magnetic fields, the frequency range of which lies mainly in the range from tenths of a Hz to a few kHz, are characterized by very low intensity. Comparative characteristics of a person's own electric and magnetic fields are given in table. 1.

Table 1

The main low-frequency electric and magnetic fields of a person. According to [5], with rev.

Электрические поля	Амплитуда, мкВ	Магнитные поля	Амплитуда, пкТл	Полоса частот, Гц
Сердечная мышца				
Электрокардиограмма	0,3–3000	Магнитокардиограмма	50	0,5–100
Электрокардиограмма плода	5–50	Магнитокардиограмма плода	1–10	0,5–100
Скелетные мышцы				
Электромиограмма	1–500	Магнитомиограмма	10	0–2000
Головной мозг				
Электроэнцефалограмма	1–300	Магнитоэнцефалограмма	1	0,5–30
Вызванные потенциалы	1–100	Вызванные магнитные поля	0,1	0–60

The study of the nature of the spectra of bioelectric potentials made it possible to state that their intensity is most represented in the infra- and low-frequency range and with an increase in frequency, the amplitude of the spectral components decreases. In this regard, for a long time there was an assumption that there are no frequencies above units of kHz in the spectra of biopotentials, however, in further studies, electrical signals with a frequency of up to 150 kHz and above were recorded. Subsequently, the entire complex of external electric fields began to be regarded as an "electric portrait" of a person, reflecting his functional state in health and in various pathologies [7].

The current ideas indicate the important role of internal electric fields in the life processes of the human body, which allows us to conclude that they are highly informative and can be used for diagnostics and treatment. In addition to participating in autoregulatory processes in the body, these fields can play a certain role in the functioning of all internal organs and systems. In a first approximation, the work of this mechanism can be represented in the form of functional connections between organs and systems of the whole organism, which are carried out due to electric and electromagnetic fields carrying biologically important information, thereby providing, according to the apt definition of V.G. Zilov "information homeostasis" [8]. Such communication channels can be not only nerve pathways, but also electromagnetic fields and the electric currents generated by them, contributing to the unification of all organs and systems of the body into a single self-regulating complex. That is why their own electromagnetic signals are used in the BRT method, however, it was their application that caused critical remarks from the opponents of this method of treatment.

The essence of this part of the critical statements, the analysis of which is given in the previous publication, comes down to the question of the existence in the human body of "physiological" and "pathological" oscillations, their identification and the subsequent decrease in the proportion of "pathological" by inverting them. It is not superfluous to emphasize that the criticism is based on purely theoretical conclusions, which have not received experimental substantiation. At present, the only one, according to our information, is the publication by H. Klima et al., In which an attempt was made to experimentally prove or disprove one of the basic principles of BRT [9]. Running a little ahead, it should be noted that, judging by the results published in the article, it was not possible to fully confirm or refute one of the most controversial provisions of the BRT method, despite the modern instrumentation of the experiment.

Biological systems are open, dynamically stable, non-equilibrium systems with spatial and temporal organization aimed at self-preservation and self-reproduction. The organization of biological systems is characterized by a certain order in the functional (energetic), structural and informational sense. Biological systems, in comparison with others, are extremely complex in their organization, but, at the same time, they are distinguished by high efficiency and reliability. Such systems arose as a result of a long evolutionary process and are capable of highly efficiently supporting life processes due to homeostasis. In the classical sense, homeostasis is the relative constancy of factors of the internal environment, such as, for example, the content of sugar, gases and electrolytes in the blood, osmotic and arterial pressure and the like. [ten]. The physiological concept of homeostasis means the body's desire to maintain the relative constancy of the internal environment under changing external conditions. In its evolution, the human brain has reached a stage at which the brain stem structures are responsible for the nervous homeostatic control of the state of the internal environment of the organism. As a result of this, the cerebral cortex was freed for the implementation of higher functions and gives a person what Claude Bernard in his famous phrase called "the condition of a free life" [11]. on which the brain stem structures are responsible for the nervous homeostatic control of the state of the internal environment of the organism. As a result of this, the cerebral cortex was freed for the implementation of higher functions and gives a person what Claude Bernard in his famous phrase called "the condition of a free life" [11]. on which the brain stem structures are responsible for the nervous homeostatic control of the state of the internal environment of the organism. As a result of this, the cerebral cortex was freed for the implementation of higher functions and gives a person what Claude Bernard in his famous phrase called "the condition of a free life" [11].

Homeostasis can be associated with the concept of stable stationary states in mathematics, although this interpretation is not used in biology and medicine. A stationary state (also called an equilibrium point) is characterized by a set of values of variables at which the state of the system does not change over time. At the same time, despite the fact that homeostasis means a certain dynamic constancy of the internal environment, it retains its absolute meaning only in rather limited and, strictly speaking, tending to zero time intervals. The whole system of homeostasis, as was formulated by E. Bauer, works to maintain a stable imbalance of the organism with the environment and against equilibrium, i.e. all biological systems are non-equilibrium [12].

Regulation processes in the body function with feedback (positive or negative), which coincides with the principles of the theory of automatic regulation in technology. In this case, the only caveat that should be made is that control theories are mainly developed for linear systems, while biological ones refer to dynamic nonlinear systems. This is due to the peculiarity of their regulation, which determines the nonlinear nature of the body's response to external influences. The difference between biological systems and technical automatic control systems lies in the fact that they are able to change not only the response when interacting with the environment, but also self-organize their internal structure in such a way, so that it is most consistent with the optimal conditions for their existence. The processes occurring in all dynamic nonlinear systems, both in physical, technical, chemical and biological ones, are studied by nonlinear dynamics [13]. In a system with negative feedback, the deviation of a variable state from a stationary value is minimized by using feedback. In a system with positive feedback due to the connection, the deviations from the stationary state tend to increase to a certain value. In functioning biological systems, feedback is a combination of positive and negative feedback, i.e. combined feedback. As a result, when approaching its stationary value, oscillations arise in the system, reflecting some inaccuracy in maintaining the parameters of the internal environment of the body, which is biologically justified. As a temporary reaction, these fluctuations of parameters represent a kind of mechanism of "self-adjustment" and adaptation of the organism to changing environmental conditions. In addition, there are multiple interactions of such vibrations with each other, as well as their influence on other physiological processes, thereby causing changes in their rhythm. An example of such an effect is respiratory arrhythmia, in which the heart rate increases during inhalation and decreases during exhalation. Thus, biological systems do not always tend to approach stationary states and they are mostly in an oscillatory mode.

Most physiological parameters are usually measured as a function of time, and they are recorded as continuous oscillations that cover a very wide frequency range. The periods of oscillations accompanying, for example, the processes of excitation in neurons or nerve fibers, are measured in seconds or their fractions, while at the other end of the time scale, the periods can be years. Between them are circadian (circadian) rhythms, for example, in the biological clock, and fluctuations in biochemical reactions with periods of the order of minutes [14]. Despite the large amount of research on biological rhythms, there is no general theory of oscillatory reactions. But even if such a theory did exist, it would in any case be very complex and have limited practical applicability. As theoretical,

Relatively recently, the idea that many nonlinear systems, not only physical and chemical, but also biological, are capable of chaotic behavior has been recognized [15]. Chaos means time-varying, unpredictable, random processes, which are similar in complexity to such a classical phenomenon as the Brownian motion of molecules. In the mid-1990s. E.L. Goldberger (AL Goldberger) made a hypothesis, which received further confirmation that in healthy individuals, the dynamics of rhythms is of a chaotic nature, while the disease is associated with their periodic behavior [16]. It is well known, for example, that chaotic heart rhythm decreases or disappears altogether with myocardial infarction, heart failure, burns, massive blood loss, extreme physical exertion, etc. Similar patterns can be traced for other processes, for example, the EEG of a healthy person demonstrates a high degree of randomness, but when an epileptic seizure occurs in the bioelectrical activity of the brain, there is a transition to an almost periodic process [17]. Thus, the existing concept that, due to illness or external disturbing influences, the human body cannot maintain the rhythm unchanged, as a result of which its amplitude is constantly changing, has been significantly revised. Modern concepts are that the randomness in the rhythm of many biological processes is an indicator of health, while their frequency but when an attack of epilepsy occurs in the bioelectrical activity of the brain, there is a transition to an almost periodic process [17]. Thus, the existing concept that, due to illness or external disturbing influences, the human body cannot maintain the rhythm unchanged, as a result of which its amplitude is constantly changing, has been significantly revised. Modern concepts are that the randomness in the rhythm of many biological processes is an indicator of health, while their frequency but when an attack of epilepsy occurs in the bioelectrical activity of the brain, there is a transition to an almost periodic process [17]. Thus, the existing concept that, due to illness or external disturbing influences, the human body cannot maintain the rhythm unchanged, as a result of which its amplitude is constantly changing, has been significantly revised. Modern concepts are that the randomness in the rhythm of many biological processes is an indicator of health, while their frequency has been substantially revised. Modern concepts are that the randomness in the rhythm of many biological processes is an indicator of health, while their frequency has been substantially revised. Modern concepts are that the randomness in the rhythm of many biological processes is an indicator of health, while their frequency
- evidence of illness [18]. This approach to the dynamics of rhythms in the human body allows a fundamentally different consideration of the existence of "physiological" and "pathological" oscillations in the human body in relation to the mechanisms of the therapeutic action of BRT. The processing of electrical oscillations in the BRT apparatus is carried out by inverting the signals in real time. Inverting (from lat.inverto - turn over, change) whenBRT represents a change in the phase of the signal compared to the original by 180 °. The phase is one of the main characteristics of the oscillatory process, which determines its state

at a given moment in time. The addition of two signals - input (non-inverted) and output (inverted) - leads to their mutual compensation [19]. In the mode of continuous inversion in real time, such a position can be realized in the case of relatively constant frequency and phase of the recorded (input) signal, i.e. its periodicity. Returning to the ideas about the periodicity in the rhythm of oscillatory processes, as evidence of the disease, it can be assumed that the “pathological” oscillations in the human body are precisely those that are close to sinusoidal in their form, contain few harmonic components, are characterized by a relatively constant frequency and amplitude ... On the contrary, "physiological" fluctuations are characterized by inconstancy of frequency, amplitude,stochasis - random, probabilistic) character. Such signals, as noted by E.Goldberger, are more "information-rich", which, most likely, predetermined their use in the BRT method [16]. In this regard, we can assume that F. Morel, theoretically substantiating his intuitive assumption about "physiological" fluctuations, had in mind the signals "harmonious" to the human body, that is, those that are in a kind of harmony with it, and not "harmonic" , interpreted as sinusoidal or close to them in shape [20].

One of the best known and most frequently used statistical characteristics of signal time sequences is the power spectrum, which allows a complex time series to be represented as superimposed sinusoidal oscillations of different frequencies. Power spectra using fast Fourier transform were obtained for many electrophysiological indicators, such as, for example, ECG, EEG, EMG, etc. [21]. In such a power spectrum, for example, the ECG has one or more maxima (peaks) that correspond to the fundamental frequencies present in the signal. In a sense, the human body is a system subordinate to the rhythm of the heart, since it is the source of the most powerful electrical activity in terms of the amplitude of generated potentials, reaching up to 3 mV [22]. In addition to these main maxima of bioelectric activity, there may be other sources, for example, EMG, the signal amplitude of which is much less and does not exceed 0.5 mV. Similar ratios are observed for MCG, MEG, and MMG (Table 1).

However, in the signal spectra at amplitudes lower than those of the ECG and EMG, the power is distributed over a wider frequency band and is characterized by a large number of peaks. The emergence of such low-amplitude non-decaying signals is due to an ensemble of cellular or tissue oscillators or pacemakers with different frequencies, which often do not remain constant and their change does not have a regular periodic character. Since such ensembles are a source of noise, it is very difficult to predict their behavior in time and to identify its own individual rhythm for each of them. In terms of their statistical characteristics, such signals are noise and are characterized by broadband power spectra, which in most cases are associated with overlapping maxima.

Noise, which in this case is considered as a random fluctuation (from lat.fluctuation - fluctuation, random deviation from the mean), is used here in the sense ofdirectly opposite to that in which this term is defined in technology. It is important here to distinguish this type of biological noise from interference, which are also aperiodic (inharmonic) and are considered in technology as noise. The main difference is that such biological noise contains information embedded in small fluctuations in the amplitudes of many frequencies [23]. Since the coding and transmission of information in biological systems is carried out according to the frequency principle, the electrical signals (bioelectric potentials and electromagnetic fields) of a person are considered as a noise signal, which is a source of important information [24].

Signals of any nature are of significant interest from the point of view of the useful information that they can carry. Information of this kind can be contained in sinusoidal oscillations in the form of amplitude, frequency or phase of oscillations, while a noise-like signal with a complex (non-sinusoidal) structure is capable of transferring a significantly larger amount of information [25]. First of all, this refers to white noise, which is used in the analysis of the state of physiological systems [26]. In this regard, one should again refer to the previously cited article by G. Klim et al., In which the authors, reproducing, if possible, the BRT conditions, by registering electrical oscillations through hand electrodes, tried to isolate “electromagnetic bioinformation” (“Elektromagnetische Bioinformation ») In the frequency range 100 Hz - 100 kHz [9]. The experiments were carried out in a double-blind manner on three healthy, according to the anamnesis, volunteer subjects. The obtained measurement results and their spectral analysis using the fast Fourier transform showed that well-known EMG spectra were recorded. It is quite understandable that as a result of limiting the band of recorded frequencies to 100 Hz, the spectrum of the ECG signal could not be detected, since its main frequencies are located in a lower frequency region. It should be noted that no conclusions about the presence or presence of "electromagnetic bioinformation" in the recorded signals were made during the imitation of the BRT method. It is noteworthy that no attention was paid to electrical noises of biological origin, the presence of which is clearly traced in the spectra of registered signals given in the article.

Stochastic synchronous and resonant processes play an important role in the systemic regulation of the functions of organisms and imply the temporal consistency of dynamic processes or the amplification of periodic signals when their phase-frequency characteristics coincide [27, 28]. An external noise-like signal evokes a response in the biological system, the mechanism of which cannot always be unambiguously interpreted. Changes in the frequency and amplitude of such a signal can form various types of connections between the signal itself and spontaneously oscillating physiological processes in the body. In some cases, there is a stochastic capture of the frequency and phase of the rhythm by an external signal (synchronization), which can have a significant effect on the endogenous rhythm. It is noteworthy that such an effect on the rhythms of biochemical reactions, occurring in the body in the course of metabolism using alternating electric or magnetic fields of low frequency, is considered as "metabolic resonance" [29, 30]. However, the details of behavior during external periodic exposure using electric or magnetic fields are so unpredictable that it seems unlikely that they will ever be fully discovered, especially in such a complex system as a biological one. In addition, it must be borne in mind that such an effect cannot be arbitrary: it is impossible to impose on the body dynamics unusual for it, for example, oscillations with frequencies that are sharply different from natural frequencies. Therefore, for exogenous BRT, we can only talk about choosing within a certain set of natural frequencies, which, as a rule, in its entirety remains very extensive. In this regard, there is only one way - experimental determination of such frequencies together with a systematic comparison with clinical results in the course of treatment.

Recently, the concept of stochastic resonance has gained recognition, which is one of the most important approaches in relation to the interaction of low-intensity electric and electromagnetic fields with the body [31, 32]. It is based on the principle of amplification of small impacts by the flow of energy into the system from the body's own broadband noise under the influence of an external source. This situation looks, at first glance, somewhat unusual, since the concept of noise has long been associated with the concept of an interference that can impair the functioning of any systems. However, recent studies carried out on biological objects - from isolated cells to the whole organism - show that the presence of noise can be beneficial.

The environment and internal environment of the body are a source of noise, which, being a random variable, interferes with the processes of transmission and reception of information in the body, thereby disrupting information homeostasis. If noise is considered as random signals that interfere with the perception of information, then the functioning of all protective systems of the body is aimed at increasing the value of the signal-to-noise ratio. There are several ways to improve this ratio due to the mechanisms of spatial or temporal summation of transmitted signals, which are quite realizable in biological objects [32].

Spatial summation becomes possible if information signals are simultaneously perceived N by the number of elementary independent "receivers", aswhich, for example, can be cells or other structures of the body. Temporary summation is carried out whenN-fold repeating informationalsignals. In both cases, the total signal-to-noise ratio increases by several times, which for a sufficiently large numberN will allow the "reception" of information signals that haveintensity below the level of thermal noise. With the joint interaction of spatial and temporal summation, the signal amplification can reach tens and even hundreds of times.

However, noise, which was previously considered an unwanted interference, can also play a positive role, increasing the signal-to-noise ratio, which is realized in such an effect as stochastic resonance. The phenomenon of stochastic resonance consists in the amplification process as a result of the input (pumping) of energy from the broadband internal noise of the object, and at a certain optimal noise level, the maximum effect is observed [31]. The term "resonance" in this case is also used not in the generally accepted sense, but reflects the non-monotonic (resonant) dependence of the object's response on the intensity of internal noise. The role of noise oscillations necessary for the implementation of stochastic resonance can be played by both external and internal thermal noise of the body. The main properties of stochastic resonance depend on both the characteristics of the noise (spectral composition) and the informational significance of the external signal for the organism. The general principle of stochastic resonance as applied to threshold systems is that in the absence of noise, the signal magnitude is insufficient to reach the threshold and implement the response of the body. With the appearance of noise, this threshold is overcome, and this happens in a random (stochastic) manner.

Stochastic resonance can, for example, be involved in the activation of ion channels in the membrane of neurons, which increases their sensitivity to low-intensity electrical signals that cannot overcome the excitability threshold. In this form, the amplification factor of the response in response to an external signal can reach 103 and more [33]. Stochastic resonance when exposed to external electromagnetic fields can occur at one frequency or at several frequencies of the acting signals. In this sense, the use of the term "resonance" should be considered quite acceptable, which, in particular, concerns the BRT method, in which a resonance proceeding according to a stochastic mechanism can occur both at one and at many frequencies, which is essentially a multiresonance [34]. However, the situation can sometimes be completely different, when the obtained effect disappears some time after exposure, i.e. if the rhythm is restored, then it becomes stable. Thus, in such systems, oscillations can exist that are restored to their original form after a small perturbation applied to any phase of the oscillations. Such oscillations are called stable limit cycles [15].

The local stability of a stationary state or limit cycle is determined using a small perturbation. If the stationary state or limit cycle is capable of recovery, they are stable. If, on the other hand, a small perturbation causes such changes in the dynamics that the initial state is not restored, then the stationary state or the limit cycle are unstable. In real situations, there are always small disturbances in the environment, constantly affecting any biological system, therefore, any observed stationary state or fluctuations are locally stable. When the parameters change, the local stability of stationary states and cycles can change. Any value of the parameter at which the number and / or stability of stationary states and cycles changes is called a bifurcation point, and the system is said to have undergone a bifurcation (from lat.bifurcus -bifurcated). At the bifurcation point, the system loses its stability in the state and goes over to a new regime, as a result of which two new branches appear, characterized by stability. Thus, at the point of bifurcation, the system reaches a certain critical state and passes into a new stable state, which is characterized by a higher level of order compared to the previous one.

The bifurcation diagram can be considered as the state of the system from the standpoint of "health-disease", where the disease or its onset is regarded as a loss of stability at the bifurcation point [35, 36]. In order to transfer the system to a new stable state, it is necessary to change the mode of natural oscillations of the system with the help of external influences. In the vicinity of the bifurcation point, the system exhibits maximum sensitivity to small influences, including noise signals. Thus, the noise signal, despite its low intensity and broadband, acting at the bifurcation point, can induce the transition of the system from an unstable state (pre-illness or disease) to a stable (health) one. Noise-induced transitions have been known for a relatively long time and have been well studied for both physical, chemical,

From the standpoint of stochastic resonance, the mechanism of the therapeutic effect of BRT may consist in action at the bifurcation point, which induces the transition of the functional systems / systems of the human body from an unstable state, characterized as a pre-illness or disease, to a stable one, regarded as health. Such a mechanism is acceptable for endogenous BRT, while in the case of using exogenous BRT using external electromagnetic fields and radiation, it is necessary to indicate other ways of realizing the therapeutic effect. For the exogenous BRT method, the therapeutic effect can be realized through other mechanisms, among which the leading role belongs to ion cyclotron and magnetoacoustic resonances.

In an alternating magnetic field, the movement of ions occurs along a cycloidal trajectory in a plane perpendicular to it and with a certain circular (cyclotron) frequency, the value of which depends on the charge, ion mass and magnetic field strength. This phenomenon is well known in physics as ion cyclotron resonance. For the first time, A. Liboff drew attention to the role of ion cyclotron resonance for biological objects located in the Earth's magnetic field, as one of the mechanisms of action of alternating magnetic fields. A. Liboff proposed the theory of ion cyclotron resonance, according to which the resonant frequencyf of an ion depends on its mass m, charge q andmagnetic field strength B [38]. Based on the established ratios for any of the ions contained in biological objects, it is possible to determine its cyclotron frequency in relation to the real intensity of the geomagnetic field in a given area (Table 2). According to the theory of A. Liboff, an external low-intensity alternating magnetic field in the presence of a geomagnetic (47–50 μT) can change the rate of ion transport through ion channels in the membrane, and these effects are observed only at certain cyclotron frequencies [39].

table 2

The calculated values of the cyclotron resonance frequency ν for some unhydrated ions in the geomagnetic field at B ≈ 50 μT. According to [38]

Вид иона	Отношение заряда к массе иона, q/m	Циклотронная резонансная частота, f
H^+	0,99	760 Гц
Mg^{2+}	0,082	110 Гц
Ca^{2+}	0,05	61,5 Гц
Na^+	0,043	33,3 Гц
Fe^{2+}	0,036	27,9 Гц
K^+	0,026	19,6 Гц

As a result of the research, it was experimentally shown that the effects of the biological action of variable low-frequency magnetic fields in the presence of a constant geomagnetic field are observed at certain theoretically predictable frequencies corresponding to the cyclotron frequencies of K ions+, Ca2+ and Mg2+ [40]. The discovered biological effects consisted in a change in the transport of these ions across the cell membrane, which manifested itself as a change in the extracellular and intracellular concentration, and the resonant frequency of the alternating magnetic field for the effect to be observed must be very accurate - up to ± 0.1 Hz. Quite naturally, great interest was shown to ion cyclotron resonance, since it opened up the possibility of influencing, for example, the processes of initiation and conduct of excitation with the help of a low-intensity alternating magnetic field. Dozens of publications have appeared in which the results of experimentally discovered effects under the action of magnetic fields of cyclotron frequencies K+, Ca2+ and Mg2+ to various biological objects - from cells under conditions in vitro beforethe whole organism. However, research results were also published in which, although these effects were confirmed, the mechanism of ion cyclotron resonance proposed by A. Liboff was questioned. It was suggested that the effects obtained in the experiments of A. Liboff and his followers can be explained on the basis of the concept of the action of alternating magnetic fields on bound ions (first of all, Ca2+). This model was proposed by V.V. Lednev and became known as the hypothesis of magnetic parametric resonance, in which the strength of the alternating magnetic field is not a key factor [41]. The response of a biological object to the impact depends on the ratio between the strengths of the constant (geomagnetic field) and variable components, as well as their frequencies, which explains the higher sensitivity of biological objects to alternating magnetic fields of certain frequencies.

Within the framework of this concept, the exogenous BRT method can be considered as the action of an alternating magnetic field of a certain frequency or set of frequencies, against the background of a relatively constant magnetic component - the geomagnetic field. In the resonance mechanisms proposed for exogenous BRT, the empirically found frequency value can be substantiated using the concepts of ion cyclotron or magnetic parametric resonances.

The interactions of electromagnetic fields with biological objects, as studies have shown, are not limited only to the electrical polarization of the medium, since there is another way - transformation into mechanical vibrations.

The mechanical effect of pulsed electromagnetic fields of the radio frequency range in the form of converting their energy through thermal into acoustic has been studied in sufficient detail, since it manifests itself in a person in the form of auditory effects ("radio sound") when his head is irradiated [42]. The emergence of mechanical vibrations in the brain tissues in the range from 50 to 200 Hz, having a resonant character, was experimentally discovered in the case of exposure to an alternating electric field [43]. The effect of the formation of acoustic waves propagating in tissues when exposed to pulsed magnetic fields was further confirmed in experiments on animals and was then used for non-invasive measurements, as well as for visualization of internal tissues and organs [44, 45].

environments of electrostriction processes arising under the action of sinusoidal electric and magnetic fields, and low intensities. All vital processes are accompanied by mechanical manifestations that occur both at the level of the whole organism and in organs, tissues, cells and subcellular components. In 1955, the existence of mechanical vibrations in a nerve fiber during the passage of an excitation pulse was discovered [46]. Subsequently, such mechanical vibrations began to be considered as conformational changes in proteins, accompanied by the generation of elastic mechanical waves propagating in the environment [47]. Conformational vibrations of macromolecules in the process of enzymatic catalysis, according to some information, are accompanied by the appearance of acoustic waves that form the cell's own acoustic field.

Table 3

Frequencies (number of revolutions) for some enzymes. According to [47]

Фермент	Число оборотов, Гц
Пепсин	0,001
Пируват-карбоксилаза	13
Альдолаза	33
АТФ-аза миозина	104
Миокиназа	166
Энолаза	150
Дегидрогеназа триозофосфата	166
ДПН-цитохромредуктаза	183
Гексокиназа	215
Фосфоглюкомутаза	280
Конденсирующий фермент (цикл Кребса)	450
Фосфорилаза	676
Дегидрогеназа молочной кислоты	1215
Фосфорилаза	1600
Фумараза	1660
Уреаза	77000
Каталаза	8,0Ч10^5
Карбоангидраза	1,6Ч10^6
Ацетилхолинэстераза	3,0Ч10^6

Should Mark, what mechanosensitivity characteristic not only for specialized receptor structures (mechanoreceptors), and is a universal property that applies to almost all cells of the body. This mechanism of transformation of mechanical vibrations into electrical signals is realized through mechanosensitive ion channels of cell membranes, and not only excitable ones [48]. Mechanosensitive properties were found in the myocardium, capillary endothelium, osteoblasts, lens, and even in plant cells.

It is also impossible to exclude the possibility of participation in the magnetoacoustic effects of crystals of biogenic magnetite (Fe2O3), which, as shown by J.L. Kirschvink (JL Kirschvink) in the form of inclusions are found in the adrenal glands, cerebellum, midbrain, corpus callosum and human brain [49]. Crystals of magnetite in tissues are, in principle, capable of responding in a resonant manner to an alternating magnetic field through magnetoacoustic resonance. The energy of the alternating magnetic field absorbed in this case is converted into mechanical vibrations in the same frequency range [50].

The possibility of such transformation of a low-frequency magnetic field in the form of a magnetoacoustic effect in the BRT (MORA-therapy) mechanism was analyzed by V.

W. Ludwig. In model experiments under conditionsin vitro they were shownthe possibility of the existence of electromagnetic-acoustic resonances under the action of a low-frequency magnetic field [51].

The basic general principles of the BRT method are based on the provisions characteristic of adaptive biofeedback. In the modern interpretation, biocontrol is considered as any change in the state of an object, system or process leading to the achievement of a certain goal. The general task of management in medicine is reduced to achieving the necessary (desired, predetermined) therapeutic or prophylactic effect [52].

The biofeedback system in general includes a control object (patient) and a control (therapeutic) system, which interact with each other through positive and negative feedback. In the course of control (treatment), the controlled object (person) is continuously influenced by both control and disturbing influences. Biofeedback is usually built using an external feedback system, the principle of which is based on closed bioelectronic systems that allow matching the time and / or characteristics of external (signaling, informational) impact with the dynamics of certain patterns and parameters of bioelectric activity of functional systems of the body.

Adaptation plays an important role in the implementation of adaptive processes, since any state of the organism is a consequence of adaptation, in the process of which it is formed and actively transformed with the opposite effect, aimed at achieving the optimal level of functioning. Adaptive biofeedback is based on the continuous use of current information to optimize the selected indicator (indicators) as control of the state of the body in conditions of insufficient a priori information.

Despite the large number of studies in the field of biofeedback, the principles and methods of dynamic control over the functional state of the body, especially during treatment, have not been sufficiently developed. Among the external manifestations of physiological processes occurring in the human body, objectively recorded physiological indicators of the activity of various body systems are widely used in biocontrol systems. Biofeedback is put in software dependence on the available a priori information about the functional significance of the recorded parameters of physiological processes. The bioelectric activity of organs and systems is also used as signals of the functional state, along with blood pressure, heart rate, respiratory rate, etc. In these cases, biopotentials play the role of command signals,

For a long time, when using many, both fairly well-known and relatively new methods of treatment with physical factors, not enough attention was paid to the maximum individualization of the treatment process, due to the indispensable requirement of its therapeutic adequacy, and, consequently, practical effectiveness. Such an approach can be implemented using computerized diagnostic and treatment complexes with feedback channels, thanks to which, at any time of treatment, the most optimal form of exposure for each patient is selected. This idea of an automated biologically controlled diagnostic and treatment equipment was first expressed back in the 1960s. K. D. Gruzdev and M.P. Spichenkov in relation to controlled electrical stimulation [54]. Remarkably

Considering BRT as an adaptive biocontrol system, its active dynamically controlled link is the functional systems or the body system intended for action, and information (signal) disturbance is a function parametric changes of these systems or systems. In this case, biocontrol in the BRT is built and, which is very important, depending not only on a priori, but also on-line information current. The feedback loop contains an additional loop, implemented using a computer and introducing additional corrective actions into the operation of the biological (main) control loop [55]. The peculiarity of adaptive control in BRT is determined by the specifics of the accumulation of current (additional) information about the state and dynamic characteristics of the functional systems of the body, necessary to achieve the optimal therapeutic effect. Concluding a brief discussion of the biophysical mechanisms underlying BRT, it should be emphasized that that a distinctive feature of this integrated approach is the desire to determine the main pathogenetic mechanism of the disease in order to establish a therapeutic effect, strictly aimed at its elimination. The BRT method allows tuning external electrical signals to activate mechanisms aimed at eliminating pathological processes in the body.

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