Modern biophysical view of electromagnetic processes of the phenomenon of life of living biological systems as a promising basis for the development of complex medicine: the role of cell membranes

Ganna Nevoit[1], Inga Arune Bumblyte[2], Maksim Potyazhenko[3], Ozar Minser[4]
[1, 2]Lithuanian University of Health Sciences, Kaunas, Lithuania
[1, 3]Poltava State Medical University, Poltava, Ukraine
[4]Shupyk National Healthcare University of Ukraine, Kyiv, Ukraine
[1]Corresponding author
E-mail: [1]*anevoit@gmail.com*, [2]*ingabumblyte@gmail.com*, [3]*umsainua@ukr.net*, [4]*o.mintser@gmail.com*

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Abstract. The results of a theoretical study of the role of cell membranes in electromagnetic generation and in the process of realizing the phenomenon of life are presented in the article. The aim of the theoretical study was to summarize the existing scientific physical and biological knowledge of modern science about the electromagnetic processes of the phenomenon of life at the cellular level in order to deepen the fundamental knowledge of complex medicine. This study is a fragment of research work on "The development of algorithms and technologies for implementing a Healthy Lifestyle in patients with Noncommunicable Diseases based on the study of functional status" (state registration number 0121U108237: UDC 613 616-056-06: 616.1/9-03). General scientific methods and theoretical methods were used in this theoretical study. The main conclusions of the theoretical study were made as follows: 1) Cell membranes can be considered one of the main morphological structures of electromagnetic generation at the cellular level. 2) Cell viability is ensured by electromagnetic generation and electromagnetic generation of cells can be considered as a separate important function of membranes in addition to those already defined, as it provides signaling. 3) The end result of electromagnetic generation of cell membranes and all molecules of the cell is its own electromagnetic fields, which have a millimeter wavelength range with a frequency of 1010-1011 Hz and they are a quantum mechanical result of electromagnetic generations, perform the information-energy function in intercellular interaction in vivo.

Keywords: magnetoelectrochemical theory of metabolism, cell membrane, electromagnetic field, the phenomenon of life, complex medicine.

How does energy control life? We don't know that. We often even forget to ask such questions blinded by our successes.
A. Saint-György
We cannot hope for the completeness and perfection of our knowledge. Science exists momentarily and moves forward every minute.
K. Tsiolkovsky

1. Introduction

The question of deepening the fundamental ideas of the course of physiological and metabolic processes in the cells of living biological systems is relevant because they substantiate the theoretical foundations for medicine as a scientific field. What processes make biological molecules alive? The search for an answer to this fundamental question continues to be relevant for modern science and complex medicine.

It is generally known that the biopolymer molecule has the same structure in vivo and in vitro.

However, biopolymer molecules are alive in a living organism - in vivo and cease to be alive in vitro. Why is this so? What changes occur in a molecule if its molecular composition remains the same? We believe that the answer to this question can be based on the ideas of modern biophysics. It is important that the quantum mechanical (energy) characteristics of atoms change in the molecules that have entered the state in vitro. Energy from other biopolymers of the body has ceased to flow to them. This changed their energy state and energy levels gradually began to fail to meet the life support needs of the molecule in vitro. This led to the cessation of the phenomenon of life in the biological polymer and the molecule became dead, although its structure remained unchanged. Thus, it becomes clear that the basis of the phenomenon of life at the level of cells and tissues must be related to the peculiarities of the energy processes between atoms in biopolymers and the life of a living biological system is an electromagnetic process. However, many questions remain unanswered. For example, what generates energy at the micro-level? Where exactly is energy formed? How exactly is energy formed? What processes occur in the formation of energy? How exactly is the transfer of energy in molecules? What models can describe this? These issues are constantly discussed by scientists, and they remain unexplored by basic science until the end. The answers to these questions can help to create a holistic model of the theoretical idea of the phenomenon of life in a living biological system and the human body. This can contribute to the further progress of modern medicine. Therefore, the study of this problem is relevant.

The cell is a generally accepted structural unit of living complex biological systems and it can be an independent unicellular organism that has all the properties of living things. Therefore, the aim of the theoretical study was to summarize the existing scientific physical and biological knowledge of modern science about the electromagnetic processes of the phenomenon of life at the cellular level in order to deepen the fundamental knowledge of complex medicine.

2. Materials and methods

The analysis of the presented data is a fragment of research work of the Department of Internal Medicine and Emergency Medicine of Poltava State Medical University (23, Shevchenko St., 36011, Poltava, Ukraine) on “Development of algorithms and technologies for implementing a Healthy Lifestyle in patients with Noncommunicable Diseases based on the study of functional status” (state registration number 0121U108237: UDC 613 616-056-06: 616.1 / 9-03).

Scientific work is carried out in conjunction with the following scientific institutions: 1) Lithuanian University of Health Sciences (9, A. Mickevičius St., LT-44307, Kaunas, Lithuania), the cooperation coordinator is Head of Nephrology Department, Prof., DM I. A. Bumblyte; 2) Shupyk National Healthcare University of Ukraine (9, Dorogozhytska St., 04112, Kyiv, Ukraine), the cooperation coordinator is the Head of the Department of Informatics, Information Technologies and Transdisciplinary Education, Prof., DM O. P. Mintser.

General scientific methods (dismemberment and integration of elements of the studied system, imaginary experiment, logical, historical research, analysis, induction, deduction, and synthesis of knowledge) and theoretical methods (method of constructing theory, logical methods, and rules of normative nature) were used in this theoretical study.

3. Results and discussion

We determined in the course of theoretical research that all biological molecules of the cell play a role in the implementation of electromagnetic processes and in ensuring the phenomenon of life at the cellular level of the hierarchical structure of living biological systems. Cell membranes were recognized as the main morphological substrate of electromagnetic generation at the cellular level in a theoretical study. The results of the theoretical study describe the role of cell membranes in this theoretical review.

Living biological systems must owe their activity to cell membranes. And this is not due to the

shaping or barrier function of the membranes. The ability of cell membranes to generate electromagnetic radiation in accordance with the laws of electrochemistry is their main function [1-5].

Cell membranes play an important role in the mechanisms of magnetoelectrochemical generation of electric current, the electromagnetic field of the cell, and the realization of the phenomenon of biological life at the micro-level of the organism. All metabolic processes of living organisms are due to the peculiarities of magnetoelectrochemical processes that occur in them at the cellular level and lead to magnetoelectrochemical excitation of the membranes of their cells and the appearance of biocurrents in them. That is, cell membranes are involved in the direct energy supply of the cell. Thus, all types of physiological activity and biochemical activity of the cell depend on the functions of biological membranes directly. Therefore, electromagnetic generation can be defined as another important separate function of the membrane and added to all previously known functions of cell membranes.

The total mass of intracellular membranes is 2/3 of the mass of the dehydrated cell. This confirms the key role of membranes in cell life. The total area of cell membranes depends in direct proportion on the intensity of energy metabolism in the cell. For example, the total area of the membranes of the rat liver reaches thousands of square meters with an organ mass of about 6 g. The cell dies with a significant violation of the integrity of the cell membrane, as electromagnetic generation has become impossible. Dysfunction of the cell membrane is manifested by a metastable condition/disease of the cell and the whole organism. For example, it is the pathology of the receptor apparatus of the membrane that leads to type 2 diabetes mellitus, violation of the structure and integrity of the hepatocyte membrane leads to cytolysis syndrome; excessive intake of phospholipase A2 in humans and animals in the bites of some venomous snakes leads to severe destruction of cell membranes, which may be incompatible with life, etc. [6-9].

The membrane is a structural dynamic formation with characteristic electromagnetochemical features of the organization. It was established by electron microscopy that all biomembranes of living biological systems have a three-layer structure with asymmetry of the three-layer organization (layers have different thickness and density depending on the type of cell and membrane). The bimolecular layer of lipids was on the edges and the protein layer is localized in the middle of the cell membrane. The total thickness of the membrane is 7-15 nm. The components of the membrane are in the liquid crystalline state, are semiconductor heterostructures, and have an external positive charge, which is formed by the heads of phospholipids. Membranes have an electrical surface potential of 75-200 mV, and they have an increased concentration of Na^+ ions outside the membrane and K^+ inside the cell (selective permeability property for Na^+ and K^+ ions) [10-14].

All properties of biological membranes are based on quantum-mechanical features of their structure. It is fundamentally important that the qualitative, quantitative composition and structural localization of membrane components ensure the presence of the properties of semiconductor heterostructures in all biological membranes. It is established that [2, 4, 15-26]:

1) liquid crystal structure is characteristic of all membranes; features of the liquid crystal structure are as follows:

– a bimolecular layer of phospholipids forms biomembranes and is a liquid crystal under physiological conditions (at body temperature, normal pH and ionic composition of the interstitium and cytosol);

– combination of high ordering is combined with high mobility of molecular components in membranes and it causes uniqueness of a liquid crystalline state of membranes;

– the lability of liquid crystals of membranes ensures the maintenance of the stability of the structures formed by them in an open system under changing conditions of its existence; this is manifested in the significant mobility of their molecular components and in the high rate of recovery of membrane damage (for example, the half-life of membrane structures in the plasmalemma and endoplasmic reticulum membranes is 50 hours, the half-life of membrane structures in mitochondrial membranes is 110 hours, the half-life of membrane structures in the

nuclear membrane is 120 hours, the half-life of membrane lipids is 15 hours Membrane structures of membrane cholesterol are 24-140 hours);

– the fluidity of biological membranes decreases with increasing content of cholesterol, calcium, and magnesium ions in physiological conditions;

– divalent ions, depending on the concentration, neutralize to some extent the negative charge on the heads of phospholipids and weaken their mutual repulsion, and this leads to a denser packing of molecules in the biomembrane;

– local anesthetics (novocaine and related compounds) increase the fluidity of cell membranes because they affect their liquid crystal state;

– the liquid crystal state of the membranes changes during cell growth and development, as well as in some pathological conditions (cancer, dystrophy, etc.);

– liquid crystals are capable of phase transitions, i.e. they can turn into solid crystals and return to their previous state again; this process can occur in physiological conditions in vivo under the action of a number of chemical agents and be in certain locations of membranes;

2) asymmetry in the composition of lipid layers is characteristic of all cell membranes:

– the outer side of the plasmalemma of all mammalian cells is saturated with choline phosphatides (phosphatidylcholine, sphingomyelin), and the inner side of the plasmalemma of all mammalian cells is saturated with aminophosphatides (phosphatidylethanolamine, phosphatidylserine);

– the outer and inner surfaces of biological membranes undergo various deformations with temperature changes and under the influence of chemical agents due to lipid asymmetry;

– lipid asymmetry can determine the curvature of the cell membrane and its properties as a semiconductor;

3) asymmetry in the composition of membrane proteins and carbohydrates is characteristic of all cell membranes:

– the inner side of biological membranes is free of carbohydrates; glycoproteins are concentrated mainly on the outer side of the plasmalemma and provide receptor function;

– the main part of enzymes-proteins of plasma membranes of the majority of cells is built in an internal half of a lipid bilayer;

– asymmetric orientation of proteins and lipids determines the vector properties of the biomembrane, i.e. it determines the possibility of unidirectional transfer of substances through it, and also affects the properties of membranes as semiconductors;

4) all membranes are characterized by high dynamics of existence and structure:

– data on the variability of physicochemical properties of cell membranes allow us to consider cell membranes as very dynamic structures;

– cell membranes can move, disappear, reappear in the cell;

– membrane exchange occurs in the cell continuously;

5) surface electric charge is characteristic of all biological membranes:

– the surface charge is created by polar heads of phospholipids, glycoproteins (mainly carboxyl groups of sialic acid and amino acid residues), glycolipids; they form a negative charge on the surface of biological membranes;

– the existence of charged groups on biological membranes leads to the formation of a diffusion double electric layer, in which a negative charge of the cell surface is recorded; this negative charge is balanced by the positive charge created by the intercellular environment due to ions;

– the potential difference between parts of the double electric layer (difference of the potential of the outer surface relative to the interstitium) - this is the electrokinetic potential/zeta potential;

– zeta potential depends on the nature of the electrolyte and the concentration of ions;

– the thickness of the double layer of the membrane increases 5 times with a decrease in the concentration of sodium chloride in the intercellular medium by 200 times; the zeta potential is related to the thickness of the double layer by an exponential dependence;

– the zeta potential decreases to zero at high electrolyte concentrations;

– the excess of positive charges can become so significant that the zeta potential will change its sign when divalent cations are present in the intercellular environment;

– decrease in zeta potential and change of a sign of zeta potential on the opposite is followed by sticking of plasma membranes of the next cells (for example, change of zeta potential happens at excess Ca2 + in the intercellular environment, and also at rearrangements of cell membranes);

– zeta potential in blood cells (e.g., erythrocytes) may be reduced due to disorders of the salt, and protein composition of blood plasma; this is the basis of the principle of changing the sedimentation rate of erythrocytes;

– zeta potential on the surface of the membranes of different cells varies from –10 to –30 mV;

– zeta potential decreases in the interstitium and cytosol exponentially with increasing distance from the outer to the inner surface of biomembranes;

– Debye shielding radius – the distance used to estimate the decrement/attenuation of the zeta potential at which the potential falls in "e" times;

– the Debye shielding radius is 0.8 nm in the interstitium, ie it is approximately one-tenth of the thickness of the biomembrane;

– zeta potential acts at a very limited distance, but it has a significant effect on the size of the intercellular spaces, counteracting the forces of gravity of van der Waals;

– the smallest distance between cells is 10-20 nm and the energy well in the interaction of Coulomb and van der Waals forces exists at this distance;

– tissues whose cells are characterized by high zeta potential have longer (up to 10 μm) intercellular spaces;

6) membranes are characterized by electrostriction and flexoelectric effect (the ability to generate electric potentials on the membrane during its deformation) also.

Quantum-mechanical features of the structure of membranes cause the appearance of their electrical properties. In this case, the surface charge of the plasmalemma plays an important role in intercellular interactions, promoting the stability of membrane structures, the binding of ions that are in the intercellular environment. The ionic composition of the premembrane layers of the intercellular medium depends on the surface charge of the plasmalemma. The surface charge of the plasmalemma affects a significant number of intracellular metabolic processes.

Biological membranes are characterized by unique magnetoelectrochemical properties. This is undoubtedly due to the fact that they are semiconductor heterostructures and exhibit the properties of semiconductors due to the quantum-mechanical parameters of their structure. The conceptual apparatus of semiconductor physics is valid for biological membranes. The semiconductor structure is a certain boundary in which there is a semiconductor material according to modern ideas. The interface between the areas of electronic conductivity inside the semiconductor crystal (pn junction), and the interface between the layers of the semiconductor with different band gaps (heterojunction) are related to this. Heterostructure denotes the existing "layered pie" of different semiconductors. This is a multilayer of biological membranes, i.e. in the case of living biological systems. A heterojunction is a contact between two different substances or between a substance and a vacuum. A heterostructure is an object that must have at least one heterojunction. A semiconductor heterojunction is a contact between two semiconductors of different types and different types of conductivity. Different materials are used in heterojunctions. It is necessary that these parameters have the same accuracy as two parameters: the temperature coefficient of expansion and the lattice constant. The electron-hole junction or p-n junction is the interface between semiconductors with electronic and hole conductivity. Given the above, it was found that the term heterostructure is quite valid for biological membranes. As it turned out, cell membranes can be attributed to layered semiconductor materials in structure (alternation of lipid and protein layers). They are characterized by a heterojunction as well [27-30].

Membranes of all cells of the human body (including tissues, bones, fats, fluids, etc.) are different types of semiconductors depending on their structure and the corresponding quantum mechanical characteristics [26, 30]:

– nerve and muscle cell membranes are narrow-band semiconductors that conduct current well

in the form of semimetals;

– membranes of various lipids and bone cells are broadband semiconductors that are different insulators, including ionic (usually proton) conductivity;

– membranes of other cells and various aqueous media of an organism carry to semiconductors with mixed conductivity.

The mechanisms of membrane electromagnetic generation of biocurrents in living biological systems continue to be studied and discussed. Membrane Theory describes a generally accepted model of membrane operation due to Na^+/K^+-pumps. However, a number of scientists continue to actively criticize this theory. For example, a weak point of the membrane theory was the calculated energy consumption of ion diaphragm pumps, which is incompatible with common sense. Scientists have estimated that membranes need 3,600 times more energy to maintain Na^+ and K^+ gradients through Na^+/K^+-ATPase than a cell can actually store. Thus, fundamental natural science has studied and modeled in detail the structural components of cell organization, but it has not been able to explain the universal mechanism of cellular energy supply and the emergence of magnetoelectric phenomena in cells from the standpoint of classical electrochemistry. The electrochemical paradigm of metabolism cannot give an adequate description of the mechanism of alternating current production by cells due to environmental resources. It cannot definitively explain exactly how the rhythm and adaptive energy response of the cell to the influence are ensured. It cannot explain exactly how and by what mechanisms cells are organized into a single morphoenergetic structural system of functioning of living tissues and the whole organism. This information makes us think about the existence of as-yet undiscovered by science methods of regulation and energy supply of cellular metabolism and the need to continue the search for truth as well [14, 31-38].

The model of the circuit of membrane magnetoelectrochemical generation of biocurrents can be considered a promising option for a possible solution to the "crisis of energy supply of membranes". This model describes a universal mechanism for explaining the phenomenon of electromagnetism in living biological systems. This mechanism is a consequence of the occurrence of alternating current in the membranes. This model describes the mechanism of current occurrence in membranes on the basis of the laws of electrochemistry of semiconductors and the laws of self-organization of electrode reactions. The process of magnetoelectrochemical generation of electric current occurs on biological membranes. This is due to the organization of unidirectional motion of protons in the biomembrane in the so-called self-organized cathode-anode circuit/circuit of membrane magnetoelectrochemical generation of biocurrents. This circuit is a combination of two oppositely directed processes – the current-forming anodic motion of protons and the cathodic reaction, which are controlled by proton field effects (ionic processes). The mechanism of membrane electrochemical generation of biocurrents in living biological systems is based on the principles of semiconductor electrochemistry and allows anodic oxidation of digested food in mammals, fish, and birds. After that, the products of the acidified medium excite the cathodic reduction of the oxidant. It is oxygen in mammals, fish, and birds and it is photons of the Sun and carbon monoxide in plants. Difficulty in assimilating any of these reagents and excretion of metabolic products complicates the work of the corresponding electrochemical boundary of the site of viability at first. This can lead to the death of a living biological system in severe disorders due to energy deficiency, respectively. Biological membranes as semiconductors are characterized by a variety of properties due to the presence of the so-called "forbidden energy zone", which must be overcome by electrons to carry out metabolic processes in living things. The concentration of free electrons (current carriers) is low in biological membranes as in semiconductors. This concentration is less than the wider "forbidden zone". Any energy effects on the membranes greatly change the concentration of free electrons and the associated reactivity of those parts of the membranes that currently perform the function of the electrode. Reactions to the energizing effects of the areas of the membranes that perform the functions of the electrodes are nonspecific. Their result is a change in the rate of electrode reactions. [7, 26, 39-43].

The mechanism of proton field effects in biological membranes can be described as follows:

in contrast to metals in the energy structure of semiconductors (all condensed substances and media except pure metals belong to them, organic matter of membranes of living biological systems including) is a forbidden energy zone states that electrons must overcome to participate in electrode processes. Electrons increase their own energy under the action of an external energy factor. They move from the more electropositive (valence) zone of the semiconductor to the more electronegative ego zone (conductivity) and then accelerate the cathodic reactions. The "holes"/electropositive states left by them in the valence band accelerate the anodic reactions. Theoretically, many electron-proton circuits of cells are able to self-organize and combine through their proton layers of spatial charge into larger functional structures to perform certain or collective functions of the tissue of the organ to which they belong (e.g., pacemaker cells in heart tissue, etc.). Self-assembly from many different magnetoelectrochemical contours of cells can create different structures of living biological systems with hierarchical connections and fractal laws of their work according to universal mechanisms of ontogenesis and phylogeny [7, 26, 39-43].

This promising model of biological magnetoelectrochemical membrane generator is able to solve the so-called "energy supply crisis of membranes and diaphragm pumps" and adequately explain the possible path of energy supply. It does not contradict the presence of diaphragm pumps and it is able to adequately supplement the existing Membrane Theory [7, 26].

The biological role of electromagnetic generation of cell membranes is also that the membranes create electromagnetic radiation of cells and thus determine the information and energy contact of cells with each other. Electromagnetic generation of cells determines the implementation of information and energy processes of cellular phenomenology of life. This is a signaling mechanism. It was found that areas of membranes with protein molecules included in them oscillate with a frequency of $0.5 \cdot 10^{11}$ Hz. This is due to the fact that the molecules of biological membranes, which are composed of anharmonic groups Amide 1, are able to transfer the hydrolysis energy of the molecule of adenosine triphosphate along the biopolymers due to the soliton mechanism. Solitons can decompose into rapidly relaxing excitons and local deformation of the protein molecule under the influence of electromagnetic radiation. This will cause oscillations with a wavelength of 4.6 to 8.8 mm. Electromagnetic radiation of cell membranes and, accordingly, cells are in the ultrahigh-frequency range. The ultra-high frequency range refers to the so-called biological range (from 10^{14} Hz and below). It is represented photons / by Davidov solitons with a wavelengt > 1 μm to 0 and an energy < 0.5 eV and up to 0. The ultrahigh-frequency range coincides with this region of the solar electromagnetic spectrum and is much lower than the ionization and excitation energy levels of atoms and molecules [22, 44-52].

It is established that cell membranes have a potential difference of 60-80 mV at a thickness of 70 A. This determines the value of the field strength $E = 107$ V/m and this is an indicator of a fairly high voltage level. Single cells generate a high-frequency electromagnetic field in the millimeter wavelength range with a frequency of 1-100 GHz with a radiation level of $1 \cdot 10^{-20}$-$1 \cdot 10^{-22}$ W/HCm^2. Cell membranes are deformed by the propagation of mechanical or acoustic waves and electrical oscillations with a frequency that will be equal to the frequency of mechanical oscillations that may occur in the system. Resonant frequencies of influence of electromagnetic radiation of ultrahigh-frequency of millimeter range on water structures and biological objects make 50-100 GHz and have discrete character. This is probably due to the quantum nature of radiation, and possibly the existence of areas in the system (presumably hexagonal fragments of water), energy transitions are discrete in which and those that are in the specified range. The mechanism of propagation of information signals at the cellular level is associated by some scientists with the existence of acoustoelectric waves precisely because their frequencies may coincide with the frequencies of individual organs, disrupting their work [26, 47, 53-60].

The formation of the cells' own electromagnetic fields is the end result of the electromagnetic generation of cell membranes and all cell molecules. The electromagnetic fields of cells of all living biological organisms have a millimeter wavelength range with a frequency of 10^{10}-10^{11} Hz and are a quantum-mechanical result of the electromagnetic energy interaction of all

electromagnetic generations. These fields can serve as an electromagnetic "model/framework" of a living biological system, according to some scientists. This electromagnetic "framework" can determine the morphological features of a biological organism according to the ideas of the quantum-mechanical theory of the phenomenon of life of Prof. S. P. Sitko. This can ensure the realization of the phenomenon of life as well. Each self-functioning cell [and any living object - tissue, organ, organism] is an integral quantum-mechanical system due to the presence of its own generated electromagnetic field. The macroscopic self-consistent potential of a cell can be formed according to the genome by laser type in the millimeter range of electromagnetic waves due to the electromagnetic activity of cell membranes [13, 45, 61-73].

The results of the theoretical study had a long epistemological development:

1923 – biologist A. G. Gurvich (1874-1954, Russia-Soviet Union) discovered the fact that living cells have mitotic radiation [26, 63-65, 74-76];

1944 – A. G. Gurvich formulated the general concept of the biological field on the basis of ideas about the vector of biological processes, like those that characterize all life processes [26, 63-65, 74-76];

The 60s of the XX century – were created generators of electromagnetic radiation in the millimeter wavelength range [26, 77, 78];

1968 – P. Mitchell found that cells expend most of the energy of metabolism to create and maintain a field strength of 10^5 V/cm on plasma membranes [26, 63-65, 79, 80];

80-90s of the twentieth century – N. Zalyubovska, (Soviet Union) proved the dependence of the vital activity of living things on the frequency and power of electromagnetic radiation in the millimeter range. I. Cherkasov and S. Nedzvetsky (Soviet Union) accidentally discovered the possibility of treatment of gastric ulcers in the treatment of the visual organ with a millimeter radiation generator. E. Andreev, M. Biliy, S. Sitko (Soviet Union) discovered the therapeutic effect of exposure to individual quanta (~ 10-21 W/Hz cm^2) of electromagnetic radiation in the millimeter range at a very low intensity of exposure to certain biologically active points number. These discoveries became the basis for further research in this area [26, 53].

1986 – H. Frohlich proved that the natural oscillations of the plasma membranes of cells are in the millimeter wavelength range with frequency 10^{10}-10^{11} Hz [22, 26, 49, 63-65].

1986 – S. P. Sitko (1936-2020, Soviet Union – Ukraine) laid the foundations of the so-called "physics of living things". A group of physicists led by S. P. Sitko became an employee of the research center of quantum medicine "Response" of the Ministry of Health of Ukraine. Branches of the Quantum Medicine Center "Response" operated throughout the Soviet Union. Scientists of the research center of quantum medicine "Response" have formulated a quantum-mechanical hypothesis of the realization of the phenomenon of life at the macro level. They declared that "quantum-mechanical principles of identity and discreteness can be applied to living organisms provided that there is a self-consistent potential of structures that form this object and have identical spectral characteristics" and "self-organized potentials of living objects that provide a quantum -mechanical scenario of life, are realized according to the genome as their own coherent fields in the millimeter wavelength range. These fields are electromagnetic models of living things. They are extremely stable due to the power of coherence, which allows you to constantly monitor, implement and adjust the retransmission of the genome to the body by standard mechanisms of biochemical heredity" [13, 26, 28, 61, 62, 81-84].

1997 – the team of the research center of quantum medicine "Response" led by SP The grid was proved for the first time in a direct experiment to have the presence of the human body's own electromagnetic field from the millimeter range of electromagnetic waves of the coherent field of the body, which is formed as a result of the activity of each cell of the body. They were the first to register the nonequilibrium component of human electromagnetic radiation in the millimeter range using equipment, and once again proved the correctness of the hypothesis about the physics of living things [13, 26, 28, 61, 62, 81-84].

In the second half of the XX century - the beginning of the XXI century – the rapid development of basic sciences is taking place and the latest fundamental knowledge about

electromagnetic phenomenology and the study of the nanoscale structure of matter are accumulating. Science has proved the fact of the field structure of matter and the subordination of all processes on Earth to the universal laws of the universe. This created the preconditions for the analysis and development of the latest concepts of knowledge at the present stage [85-90].

2019-2022 – a team of scientists led by O. P. Mintser made an attempt to generalize the existing latest material within the system of complex medicine and made a conceptualization of the Magnetoelectrochemical Theory of Metabolism. Further work on this continues now [26, 30, 90].

4. Conclusions

The following conclusions can be drawn on the basis of the results of the theoretical study:

1) Cell membranes can be considered one of the main morphological structures of electromagnetic generation at the cellular level.

2) Cell viability is ensured by electromagnetic generation and electromagnetic generation of cells can be considered as a separate important function of membranes in addition to those already defined, as it provides signaling.

3) The end result of electromagnetic generation of cell membranes and all molecules of the cell is its own electromagnetic fields, which have a millimeter wavelength range with a frequency of 10^{10}-10^{11} Hz and they are a quantum mechanical result of electromagnetic generations, perform the information-energy function in intercellular interaction in vivo.

The practical significance of the results is that knowledge and understanding of the quantum-mechanical features of the human body and the role of electromagnetic components is the next step toward deepening the fundamental knowledge of the pathogenesis of diseases of internal organs. Modern deepening of fundamental knowledge to the level of magnetoelectric processes of molecular level in living biological systems is expedient to integrate into medical science with the change of electrochemical paradigm of metabolism to magnetoelectrochemical paradigm of metabolism.

Further development of concepts of magnetoelectrochemical theory with in-depth analysis of theoretical ideas about the course of electromagnetic processes at the level of organs and the whole human body is promising. Electromagnetic processes in the heart, brain, and muscles remain relevant and continue to be studied. The electromagnetic phenomenology of renal function remains interesting and little studied. It is already clear that the kidneys are one of the key organs for regulation and maintenance of electromagnetic processes in the human body. This is because the kidneys regulate the electrolyte composition of the body's fluids, thus providing an ionic basis for the excitation of current in the cell membranes of living biological systems.

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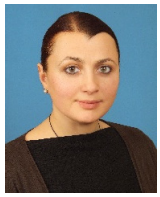

Ganna Nevoit, Ph.D., Associate Professor, Physician-therapist in the specialty "Therapy", Associate Professor of the Department of Internal Medicine and Emergency Medicine of the Poltava State Medical University (Ukraine), Assistant of Nephrology Department of the Lithuanian University of Health Sciences (Lithuania).

Inga Arune Bumblyte, MD, Professor, Physician-therapist in the specialty "Nephrology", Head of Nephrology Department of the Lithuanian University of Health Sciences (Lithuania), President of Lithuanian Association of Nephrology, Dialysis and Transplantation.

Maksim M. Potyazhenko, MD, Professor, Physician-therapist in the specialty "Therapy", Head of the Department of Internal Medicine and Emergency Medicine of the Poltava State Medical University (Ukraine).

Ozar P. Mintser, MD, Professor, Honored Worker of Science and Technology of Ukraine, Honored Innovator of the Ukrainian SSR, Head of the Department of Informatics, Information Technologies and Transdisciplinary Education of the Shupyk National Healthcare University of Ukraine.