Conceptual Fundamentals of Physics of the Alive

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"We must be prepared to find a new type of physical law prevailing in living matter. Or are we to term it nonphysical, not to say a superphysical, law?

No, I do not think that, for the new principle involved is a genuinely physical one: it is, I think, nothing else than the principle of quantum over."

Erwin Schrödinger
"What is the life?" 1943

The conceptual basis of Physics of the Alive is the perception of the fact that any independently functioning living system is simultaneously a macroscopic quantum object and maser (laser of the mm-range) whose pumping out is provided by metabolism due to the mechanism called "hierarchy of dissipative structures." It is precisely this approach that provides understanding of the macroscopic entire of organism in accordance with the gene information (origination due to the coherence of the effective long-range forces) and its diverse differential stability (difference and stability of species and specimens) that is based on the principles of identity and discreteness of quantum mechanics.

(Received May 20, 1993)

Physics of the alive is a new notion coined with the appearance and recognition of a basically new approach to the problem of formation and multiform differential stability of living systems. This approach embodies the latest advances of natural science and is substantiated by multitargeted experimental and clinical researches.

Today, 50 years later than the lines in the epigraph were written, we can only be astonished at a brilliant foresight of the creator of quantum mechanics that, as is known, is a theoretical basis of fundamental science studying its objects on three (viz. nuclear, atomic and molecular) levels of quantum organization of nature. The idea of the alive as the next, fourth step of this "quantum ladder of nature" (Weisskopf) enables us to unite the life and non-life methodologically and creates the prerequisites to form a fundamental theory of the alive [1].

In that sense, it is a matter of principle that the trends in this field would not be restricted by an obsolescent methodological nomenclature.

Not out of place is to remind that the Western civilization has been holding to the atomistic doctrine in learning to apprehend the laws of nature for many centuries. Originally, it was purely speculative considerations of the Ancient Greek Thinkers (Democritus and his school, 5th C.B.C.) on the existence of an indivisible primary basis (i.e., the atom) of the whole being. Later, the correctness of the atomistic concept was shown by the entire progress of science and engineering. One think that the whole experience of the mankind (at least, of its Western part) witnesses that when studying components of the complex we get to know it

more thoroughly. In other words, it is correct for the last centuries and up to now. The statement that the basic knowledge of nature can be obtained from studying the microscopic structure of objects was generally accepted. It is in this standpoint that the advance of spectral analysis in nuclear, atomic and molecular physics has been interpreted. Introduced by quantum mechanics (through its basic principles of identify and discreteness), the idea of the characteristic (eigen) frequencies make it possible to obtain universal "certificates" for each type of nuclei, atoms and molecules. In fact, this means an unambiguous quantitative definition of all microscopic entities, composing the world around, in terms of their energy spectrums.

Due to the thermal motion of molecules, supramolecular structures placed in a condensed medium do not possess, as a rule, discrete far IR, sub-mm, or mm spectra that could be referred to the next step (i.e., that following the molecular one) of the quantum ladder. Therefore, the molecular step was considered the last. On the other hand, out of the four (viz. strong, weak, electromagnetic and gravitational) fundamental interactions known to natural science only the last two are long-distance in character. However, the gravitational interactions are in comparison extremely weak; as to the electromagnetic interactions, in condensed media they also become effectively short-distance due to screening. Thus, we again arrive at the same conclusion: all qualitatively substantial events run high on a microscopic level within the distances comparable with the dimensions of molecules and under. It is for these reasons (whether we realize it), which in biology and medicine the part of fundamental science is played by biochemistry, molecular biology and genetics.

However, while in the realm of inanimate nature such atomistic decomposition of a whole has led, as mentioned above, to the outstanding discovery of three fundamental steps of the quantum ladder of nature (the "crisis of elementariness," arises only on a subnuclear level), in the realm of living nature studying the systems on the cellular, subcellular, or supracellular levels leads to a sort of anthropomorphism. This in fact imparts consciousness and psychics to all known structures of the alive such as DNA, lysosomes, cellular membranes, cytoskeleton, immune system, etc. As applied to these structures the following expressions are coined: they "are taught to distinguish between their own and strange genes," "control the sequence of events," "regulate the cellular cycle"; or "the replication mechanism is triggered," "the necessary amino-acids and proteins are being manufactured," "the formation of internal organs goes," "the membrane channel opens (closes)," and so on, and so forth. Though each time we can find a biochemical reagent ("morphogene") which initiates a particular process, on the whole, painted microscopically, the picture of the vital activity on a cellular level (also on adjacent levels) looks like science fiction when each cell or aggregate of cells should have structures inherent in a developed state, with its schools, universities, hospitals, army, informers, factories and plants, and so on. It is in such a picture that we perceive a crisis of "atomism" as applied to living matter.

The situation seemed to look hopeless, so even prominent scientists hardly believed that it was possible to give a mere outline of the understanding of living nature. While, reviewing the problem from a physical standpoint, we immediately realize that subject of our interest,

the alive, has those features that radically differ it from all standard physical objects. The very phenomenon of the development of the alive, from a seed or zygote to a grown-up plant or organism, is the first and most striking examples. Moreover, both in the development of an individual (ontogenesis) and in the development of everything alive or separate taxonomic groups (philogenesis) we observe the complication of the structures accompanied by the reduction of symmetry. Intuitively, it is obvious that such a picture is in a complete contrast to the one that is met with in ordinary situations in inanimate nature when the ordered structures, being on their own, convert into the disordered ones.

In physics (more precisely, in thermodynamics) such an asymmetry of time is expressed by the second law of thermodynamics that says that a certain measure of such a disorder, the entropy S, in a closed system ever increase to its maximal value. The entropy increasing law $dS \geq 0$ holds in all inanimate closed systems whose behavior is described by linear relations.

Recall that originally the notion of entropy was introduced to describe the behavior of identical objects (molecules of gas, liquid, so on) in a state of thermal equilibrium at temperature T:

$$dS = \frac{dQ_{rev}}{T} \tag{1}$$

where T is the absolute temperature, and dQ_{rev} is the quantity of heat reversibly supplied to the system or withdrawn from it.

It is obvious that being applied to complex, even mechanical systems (to say nothing of living ones), such an approach meets some difficulties. So, the notion of the "information entropy" [2] has been introduced. It is

$$S_{\text{inf}} = -\int_0^\infty f(U)\ln f(U)dU, \tag{2}$$

where $f(U)$ is the distribution function, which depends on coordinates of the phase space of a system.

Treating the transition from the nonalive to the alive as a nonequilibrium phase transition, synergetics deals with the equation for the order parameter in the form $\dot{\xi} = \varphi(\xi) + F(t)$, with a nonlinear function $\varphi(\xi)$ and a fluctuating force $F(t)$. For the simplest nonlinearity we have

$$\dot{\xi} = \lambda\xi - \beta\xi^3 + F(t). \tag{3}$$

One can readily show that in a stationary state the Fokker-Planck equation with the parabolic potential $U=r^2$ gives the following probability distribution

$$f(U)dU = N\exp\left\{\left(\lambda U - \frac{1}{2}\beta U^2\right)Q^{-1}\right\}dU \tag{4}$$

where Q is the noise intensity, and the constant N is given by the normalization condition $\int_0^\infty f(U)dU = 1$. The parameter λ is known under the name of control parameter. It determines the transition from the state "no life" ($\lambda<0$) to the state "life" ($\lambda>0$). If we now make use of Klimontovich's S-theorem, according to which the variation of the information entropy of a system that undergoes a phase transition should be examined with the average energy

$$\langle U \rangle = \int_0^\infty U f(U) dU, \tag{5}$$

being kept constant (i.e., by normalizing the entropy before and after the transition with respect to the noise intensity Q), we find for the energy of phase transition

$$S_{before} = \ln \frac{\lambda}{\beta} + 1. \tag{6}$$

After the transition, in the reasonable limit $\frac{Q\beta}{\lambda^2} << 1$, when the distribution function is properly approximated by the expression

$$f_{after}(U) = N \exp\left[-\frac{\beta}{2Q}\left(U - \frac{\lambda}{\beta} \right)^2 \right], \tag{7}$$

the normalization factor is found equal to $N = \sqrt{\frac{2\beta}{\pi Q}}$, so that

$$S_{after} = \frac{1}{2} \ln \frac{\pi Q}{2\beta} + \frac{1}{2}, \tag{8}$$

I.e.,

$$S_{after\ max} = \frac{1}{2} \ln \frac{\pi}{2} + \ln \frac{\lambda}{\beta} + \frac{1}{2}. \tag{9}$$

Since $\ln \frac{\pi}{2} < 1$,

$$S_{before} > S_{after}. \tag{10}$$

I.e., the entropy of the system after such nonequilibrium phase transition that results in the formation of certain patterns of the most general nature turns out to be less than that before the transition. Our intuition has not betrayed us: equilibrium thermodynamics is not an instrument to cope with living systems, the informational entropy decreases within the "non-life-to-life" phase transition, and, consequently, the application of the same "atomistic" ap-

proaches, which are successfully employed in solid state physics, to living systems cannot be considered justified. So, no wonder that scientists are being nonplused in their attempts to understand the nature of the alive in "solid state physics."

What is the way out of the situation arisen?

Two circumstances have crucially initiated the today's breakthrough in understanding the nature of the alive. First, within recent years radical changes have taken place in the very basis of such seemingly "classical" and settled sciences as physics and chemistry. We mean the realization by scientific community of the role of the "openness" and nonlinearity of the systems under consideration in their functioning. This realization was being formed for more than a century and half, from the first description, made by John Scott Rassel, of solitary waves in testing new shapes of ships to sail in channels of England up to the creation by H. Haken of a new interdisciplinary science called "synergetics" and awarding the Nobel prize to I. Prigogine in 1977 for revealing the part of "dissipative structures" in proceeding from physics of "the being" to that of "the becoming."

Unfortunately, here there is no possibility to dwell upon how the nonlinear thinking has penetrated into the consciousness of naturascientists. These are amazing years in the history of science that have marked the understanding of the fact that the subject of inquiry for the up-to-date physics is not only the world formed a billion years ago within fractions of a second after the Great Explosion, but also a huge variety of surrounding objects and systems (both artificial and natural) for which the laws of equilibrium thermodynamics are insufficient.

It has turned out that in open nonlinear systems far from thermal equilibrium qualitatively new, dynamically stable spatio-temporal structures may arise because of a proper nonequilibrium phase transition. It is the structures that we have mentioned when deriving the inequality $S_{before} > S_{after}$ making it possible to reverse the "time arrow" in dissipative systems owing to the so-called negative increment of the entropy from outside, $dS_{out} < 0$ which neutralizes usually positive production of entropy in closed systems, $dS_{intern} \geq 0$

$$\Delta S = S_{after} - S_{before} < 0 \tag{11}$$

$$dS = dS_{out} + dS_{intern} \approx 0 \tag{12}$$

In other words, in far from thermal equilibrium systems due to their openness and nonlinearity it is possible to create qualitatively new physical objects, namely long-existing, dynamically stable complex structures.

Concurrently, it has been realized that the quantum-mechanical approaches are not obligatory applied solely to microscopic objects whose scales are determined by Planck's constant $\hbar$. The amplitude and phase of the wave function, the spectra of eigenvalues and other features of quantum-mechanical systems have come into general use when describing such "macroscopic" phenomena as superconductivity, superfluidify, Josephson effect.

Taking the attitude of modern ideas of self-organization, I. Prigogine has approached the problem of time in a new fashion, trying to solve a known paradox between time reversibility

in two-particle interactions and its irreversibility in many-particle interactions ("time arrow" of the second law of thermodynamics). This can be clearly imagined in such a way: a film about colliding two balls and another film about getting an ink drop into a glass with water are shot. The first film shown in the mode of reverse time (from end to beginning) will not cause any astonishment, while the "spread" of the ink drop in water during direct demonstration represents a natural physical process (the entropy increases) whereas the reverse film in which the drop forming emerging from the volume of water is unreal, like, by the way, any fiction film displayed in a reverse fashion.

Introducing the notion of internal and external time, I. Prigogine [3] has approached a conclusion, important for us, on the connection of time with the character of the system energy spectrum and the periodicity of the wave function.

An extremely profound vision of the role of spatio-phase coherence of the system in creating effective long-distance interactions was shown by H. Fröhlich [4], the author of theory of superconductivity.

Thus, by the beginning of the 80's fundamental science had already paved the way for trying to understand the crucial experiments called for finding a new vision of the nature of the alive.

The second reason, decisive for me and my colleagues in our passing from conventional biophysics to physics of the alive, was the experimental discovery of the manifestation of eigenfrequencies of a human organism in 1982. Of course, these results were achieved not in a blank space. The first experimental results were published in 1969-1972. They started a series of the works carried out in different laboratories all over the world until the present time under the common title "Effects of resonance interaction of low-intensity mm-band electromagnetic radiation with biological objects."

Generally recognized achievements of scientists of the city of Kharkov (Ukraine) in the development of pilot mm-band equipment (operated by backward tubes) contributed to the fact that namely in this city in 1969-70 biophysicist N.P. Zalyubovskaya using the experimental base of the local State University pioneered in the research [5][1].

We do not think that dozens of other papers and books published on this topic up to 1984 had something radically new. Only, the works by S. Webb are an exception, for he was the only one who managed not only to succeed in extremely complex experiments on direct measurements of the mm-band absorption spectra peculiarities of biological systems [6], but also to make a comparative analysis of such spectra taken on the specimens of healthy and diseased (cancerous) tissues [7].

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[1] "Pronounced biological activity" of the mm-band waves, concerning biological objects of different nature (microorganisms, isolated cells, fruit fly, experimental animals, namely white rats and mice), was shown. The examination was made by using the known microbiological, virusological, biochemical, biophysical and other methods. The radiation power density was 1mW/cm^2, and the band was from 1.7 to 8.0 mm. The action was resonant in character (within the band of 6.5-7.1 mm) and showed itself through the change in the intensity and in the character of the course of life processes. By the author's definition, the resonant character of the effect "consisted in the fact that irradiation of a certain wave length yields a different result than irradiation of another wave length even sufficiently close to the former."

What was the most striking and incomprehensible to current science in those experimental results? Of course, it was the nonthermal and resonant character of the effects. As is already mentioned, the line spectra of eigenfrequencies are inherent in the nuclear, atomic and molecular levels of matter organization. More heavy structures (including "heavy" protein molecules), if left free or, say, in a gaseous state, should oscillate with lower frequencies than those usually related to molecular spectra. With real values of the coefficient of elasticity, for a mass of over 100,000 $f_{osc} = \frac{\omega_{osc}}{2\pi}$ falls with the range $10^{10} \div 10^{11}$ Hz, i.e., just fits the mm band of the electromagnetic spectrum[2]. However, in condensed media due to thermal motion the linewidths exceed, as a rule, the intervals between them. Therefore, the existence of characteristic line spectra in the mm band was considered unreal. For exactly this reason the experiments in which resonances with Q-factors $Q \approx 100$ and more ($Q = \frac{\omega_{res}}{\Delta_{1/2}\omega_{res}}$) are observed suggest that a scientist meets a certain peculiarity inherent only in living systems.

No wonder that after N.P. Zalyubovskaya and S. Webb many scientific centers in different countries started working on the resonant response of living objects to the mm-band electromagnetic radiation. In the Soviet Union the research was headed by academician N.D. Devyatkov, in Germany and Italy it was conducted at the Max Planck Institute and at the Milan University, respectively. A huge contribution to the comprehension of the obtained data was made by H. Fröhlich (see [4]) who extended the idea of coherency (which was assumed earlier as a basis of theory of superconductivity) to biological objects. However, in a short time optimistic expectations, initially reposed in that research, changed into disappointment: scientists were not able to succeed in trying to reproduce the results, even if obtained under seemingly identical conditions, i.e., to satisfy the requirement of reproducibility. In time it has become obvious that nonreproducibility of results is connected with the fundamental unidentity of the objects under study with respect to the features unknown by that time [8].

The discovery of these features was initiated by physicists of the Kiev State University, Ye.A. Andreyev, M.U. Bely and S.P. Sit'ko. In 1982 they informed the scientific community of their discovery of "the manifestation of the characteristic eigenfrequencies of the human organism" [9,10][3]. Then employing the quantum physical terminology in studying the alive was a reflection of authors' emotions excited by the observed phenomenon than a profound comprehension of its place in the knowledge of the world around. Such comprehension came much later.

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[2] The classical expression for the oscillation frequency $\omega_{osc} = \sqrt{k/m}$ where k is the coefficient of elasticity, and m is the mass yields, gives as is known, a proper order of magnitude when joining the quantum and classical considerations.

[3] Their investigations were initiated by uncommonness of the results obtained in 1979-80 by physicians I.S. Cherkasov and S.V. Nedzvetsky [11] when treating diseases of the eye with the aid of the skin-effect. They have discovered the "side" effective medicinal action of some bands of the microwave (5-6 mm) electromagnetic radiation (EMR). For example, duodenal ulcer healed under the action of EMR on the eye or occipital area of the head.

As for 1982, it was established that, if diseased, a human organism found an extremely high sensitivity to the mm-band electromagnetic fields (EMF), which was resonant-dependent on the EMF frequency and localized on the body surface. This sensitivity manifests itself in the fact that during the resonant action upon the organism via biologically active points (BAP) there occurs a steady restoration of the functional state of the organism, i.e., treatment, with the EMF-sensitivity being reduced, so that the complete recovery is characterized by the loss of this sensitivity.

What was the singularity of the described phenomenon? Why was it impossible to explain it in terms of physics, biology and medicine of that time? We may quote several such peculiarities of the phenomenon.

First. It is an extremely low level of the power at which an effective action upon the organism happens.

Originally, in the experiments on protozoa, typical output power of employed EMR sources was up to 10^{-2} W/cm^2. It was almost the threshold of the measurable thermal effects and therefore initiated many and protracted debates whether the action was of a "thermal" or "nonthermal" character. Nowadays, the effective power level becomes many orders of magnitude lower, both in detecting resonances of the action function for bioobjects and in clinical practice. The up-to-date threshold power is 10^{-12} to 10^{-18} W/cm^2 that is billionths as many as not only the level of thermal radiation per unit of the skin surface, but also that of the fluctuations in this radiation.

Second. There are macroscopic distances between an area of the effective action and a subject of treatment (a diseased organ).

It was showed that in the experiments under analysis BAPs coincide with the location of the points usually affected in acupuncture [12]. From existing knowledge of acupuncture it is known that the corporal acupuncture points are located largely along specific trajectories on the human skin surface (Chinese meridians) non-correlated with morphologic structures. It should be also noted that, as a rule, the most pronounced medicinal effect can be achieved when the EMR affects the maximally distal BAPs (i.e., the first or last points of a certain meridian that are located on the fingertips of the hands and feet). Thus, often we may speak about distances of tens and hundreds of centimeters. While, it is known that, on penetrating 1 mm of a water solution, the mm-radiation intensity becomes weaker by a factor of almost a thousand (!).

Third. It is a line character of spectra of the mm-EMR action upon living organisms.

This problem is discussed above about experiments on the more simple biological objects. It has been concluded that, as for solid state physics, in condensed media the transitions in the mm spectral band which corresponds to discrete states of a one-particle type, i.e., to Q-factors>100, cannot be observed.

Forth. It is a striking fact of the one-directed action of the mm EMR, from a state "illness" to a state "health," with no response from a healthy person. This in essence defines the healthy organism (as such that does not perceive the external mm EMR in indicated regime of action).

With this, we can understand bad reproducibility of experimental data on bioobjects of more simple organization than that of the man (see [9]). To be alive is only necessary but not sufficient condition to show a resonant response to the low-intensive mm EMR. In addition, the location of the action and the presence of functional disorder is important. Besides, the "treatment effect" always changes the corresponding EMR-target. For these reasons, to speak about reproducibility on a single living "specimen" is incorrect in principle, excepting only the experiments on some protozoa such as intestinal bacilli E.coli with imbedded λ-prophagues.

The problem of data reproducibility must be treated from another point of view. Namely, we must go from the action function based on statistics of a single object to the action functions statistics of many one-type objects. Concerning the man, the implication involved is that the treatment effects achieved with the aid of the mm EMR must become an experimental basis of the outlined conceptions of the nature of the alive (see paper by S.P. Sit'ko, L.N. Mkrtchian, V.D. Zhukovsky et al.).

The new treatment method, called Microwave Resonance Therapy (MRT), involves many interconnected procedures, viz. fitting a therapeutic ("resonant") frequency, or frequencies; selection of duration of the action upon a given point and of the session as a whole; choice of the action mode and parameters of the beam (its dimensions on the body surface, polarization and orientation about the meridian trajectory, power, spectral composition); choice of the session reiteration mode; studying combinations of the action with drugs; determination of the patient's regime before and after treatment sessions, including the necessary levels of comfort and other conditions within the treatment; choice of EMR devices and their combinations, so on[4].

A theoretical explanation of the listed peculiarities of the MRT treatment phenomenon becomes possible only in the context of quantum mechanics.

We assume that a macroscopic living object is an integral macroscopic quantum mechanical system. With this, the multiform differential stability of the alive (differentiation and stability of the species and individuals) can be explained with the aid of the general principles of quantum mechanics, i.e., principles of identity and discreteness. As it is known, these principles are the basis of a physical explanation of the multiform differential stability on other levels, molecular, atomic and nuclear, of quantum organization of nature.

To be considered as a whole in the quantum mechanical context, the macroscopic system must possess nonlocal self-consistent potential. As to formation of the characteristic (eigen) frequencies of the system, it is determined by certain selection rules that convert the transitions between one-particle levels, formed according to the Schrödinger equation in the potential well, into a discrete spectrum inherent only in a given object.

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[4] By January 1,1993 MRT was successfully applied in treating about 200,000 patients at hundreds of clinics, hospitals and scientific institutes in the FSU and beyond its borders (see Appendix).

MRT was substantiated with satisfying all conventional canons of a medical research: organization of homogeneous groups to perform placebo, double blind control, evaluation of the efficacy of different MRT techniques as compared with drug treatment, acupuncture, laserpuncture, electropuncture, magnetic therapy; performance, apart from clinical research, of biochemical, immunological, biophysical, histological, virological, microbiological and genetic ones.

In addition, the special diagnostic facilities were involved which made it possible to watch the patient's state in real time, i.e., to monitor continuously the measurable parameters in the course of a session.

Unified macroscopic potential, in which the quantum mechanical events may happen, can be created only with the proviso that there exist certain long-distance forces. As shown by H. Fröhlich (see [4]), such forces emerge as a certain effective long-distance interaction in the presence of spatio-temporal coherency of a laser type.

Let us show that existence of stable limit cycles maintains the potential profile of a space in which an open nonequilibrium macroscopic system can be described in a quantum mechanical way.

Most generally, the vibrational motion in a system characterized by the parameter q is described by the following equation

$$m\ddot{q}+\gamma\dot{q}+kq=0 \tag{13}$$

where the second and third terms in the left-hand-side define, respectively, the damping $(-\gamma\dot{q})$ and driving $(-kq)$ force of the oscillator.

In the case with an "overdamped" state, where a strong coupling with the environment suppresses really oscillatory processes, the first term of Eq. (13) is negligible, so that

$$\gamma\dot{q}+kq=0, \tag{14}$$

or, making an appropriate time scale, $t=\gamma\, t'$ we have the general form

$$\dot{q}=F(q). \tag{15}$$

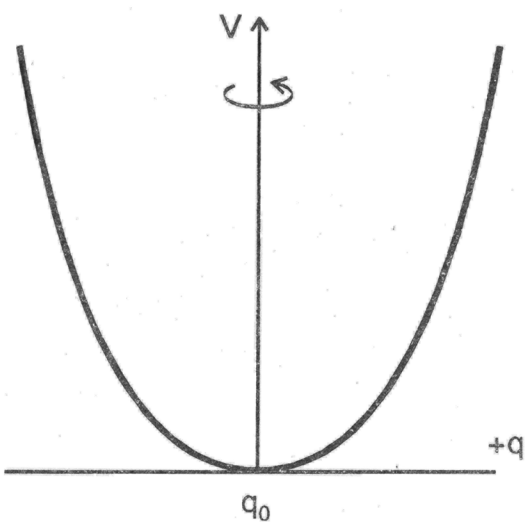

Fig. 1 Visualization of the stable solution of the equation $\dot{q}=-kq$, $(q_0=0)$ by introducing the potential energy $V(q)=kq^2/2$ interpreted as slope of a hill down which the mechanical object moves

Here H. Haken [13] for description employs the potential $V(q)$ related to the force $F(q)$ by $F(q)=-\dfrac{dV}{dq}$.

Indeed, if we take the harmonic oscillator force $F(q)=-kq$ in the capacity of the force, then, besides an additive constant, we obtain $V(q)=\dfrac{kq^2}{2}$. The plot of V as a function of q (Fig. 1) allows the potential curve to be interpreted as the slope of a hill, with a certain body placed on that slope. At the point $q=0$ the driving force vanishes, and Eq. (15) yields $\dot{q}=0$, i.e., in case of deflection from the point q_0 by any value, the body returns to the stable equilibrium state q_0=0.

Even more visual is the two-dimensional case, when the depicted figure is rotated about the y-axis through 360°,

making a vessel like a test-tube, broadening upwards. It is understood that the center of the bottom is a stable equilibrium position for the drops running down by the walls. (The behavior of a drop, wetting glass and running down by the walls, is a more appropriate model of the processes described by Eqs. (14,15) than the behavior of a rigid ball falling back down the hill, since in the latter case the first term in Eq. (13) cannot be omitted, and the ball motion will be of a type of damped oscillations about the point q_0).

As mentioned above, the self-organization processes are conditioned by the medium nonlinearity. This of course must be reflected in nonlinearity of the equation that describes the medium dynamical behavior. The simplest nonlinear addition to the harmonic oscillator driving force is a cubic term, holding the invariance of Eq. (15) under the transformation $q \to -q$ and the axial symmetry of the potential, i.e.,

$$F(q) = -kq - k_1 q^3, \tag{16}$$

and

$$V(q) = \frac{kq^2}{2} + \frac{k_1 q^4}{4}. \tag{17}$$

Therefore,

$$\dot{q} = -kq - k_1 q^3 \tag{18}$$

The equilibrium points are determined by $\dot{q} = 0$. Here we have two qualitatively different situations, corresponding to whether $k > 0$ or $k < 0$:

a) $k > 0$ and $k_1 > 0$

The potential does not qualitatively differ from that depicted in Fig. 1: there exists the only stable equilibrium position, $q = 0$;

b) $k < 0$ and $k_1 > 0$

There exist three solutions of the equation $\dot{q} = 0$: one unstable solution at $q_1 = 0$ and two stable ones, at

$$q_{2,3} = \pm\sqrt{\frac{|k|}{k_1}}, \tag{19}$$

with k passing zero, the potential becomes of the form depicted in Fig. 2. Proceeding from our one-dimensional problem to a two-dimensional problem, we have to rotate that curve about the V-axis. In so doing, we obtain a profile like a bottle bottom. Having been displaced by a random (fluctuating) force from the unstable equilibrium position ($q_1 = 0$), the body spirals down to the domain of the potential energy minimum and then rotates around the valley of the "bottle bottom" according to the following equations given in polar coordinates:

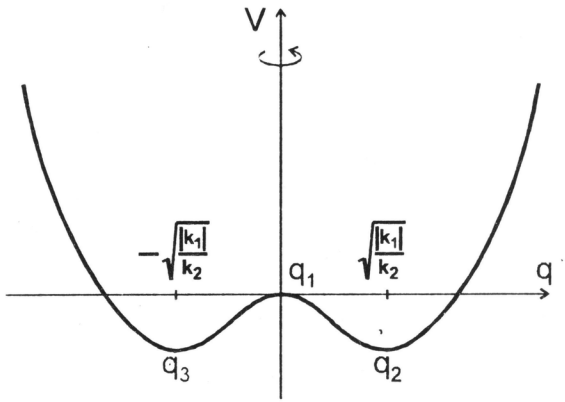

Fig. 2 The Landau-Haken potential whose origin in a self-organizing system accompanies the limit-cycle solution of the nonlinear differential equation $\dot{q} = -kq - k_1 q^3$, $(k < 0, k_1 > 0)$.

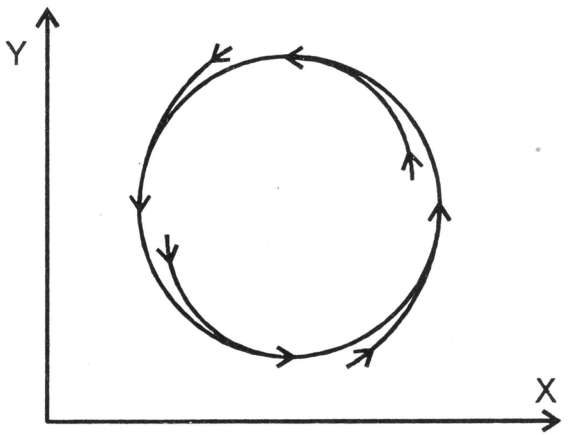

Fig. 3 The limit-cycle solution of the nonlinear differential equation $\dot{q} = -kq - k_1 q^3$, ($k < 0$ and $k_1 > 0$) in phase plane (x,y)

$$\begin{aligned} \dot{q} &= F(q,\varphi) \\ \dot{\varphi} &= \omega \end{aligned}, \tag{20}$$

or, which is equivalent,

$$\begin{aligned} x &= q(\varphi)\cos\varphi \\ y &= q(\varphi)\sin\varphi \end{aligned}. \tag{21}$$

It is for such a periodic motion, executed in general in a phase plane, which the term "limit cycle" is used. Introduced by H. Haken only to illustrate the self-organization process in terms of mechanics, usual for physicists, this mutual correspondence between a potential shape and a character of the system's behavior in a nonlinear medium (i.e., limit cycle) has in fact a profound and fundamental sense.

The fact is that in a dissipative system beyond the threshold of a nonequilibrium phase transition (i.e., with the origin of coherency and, consequently, of the long-distance forces) there may arise very many types of waves of a collective nature. As known, theory of nonlinear differential equations allows the originated patterns to be classified. Usually the corresponding solutions describe the patterns whose phase-plane representations either change in time or are unstable with respect to small perturbations. These are solutions referred to, in view of characteristic behavior of their trajectories near singular points on the phase plane, as focus, node, center, saddle point and others.

However, there exists a particular class of solutions, periodic in time, whose representations in a phase plane are closed curves (in particular, a circumference) and called limit cycles. Therefore, if there has occurred a limit cycle in the coherent system (Fig. 3), then it means that there has arisen a potential similar to that depicted in Fig. 2, i.e., attracting the trajectories from the domains of both smaller and greater radii. It is just the same potential that is necessary for describing the living system as an integral quantum mechanical object.

Can we assume that the biological coherency, observed in the living systems, is based on the existence of the coherent electromagnetic field of the organism over the mm range, corresponding the band 40 to 70 GHz of the observed characteristic (eigen) frequencies?

On the face of it, such a hypothesis is too bold, especially with allowance for real features of the medium in which the oscillations are implied to propagate. Nevertheless, a more detailed analysis of the conditions for the coherent mm-band electromagnetic radiation to occur shows that in water media with the proviso $h\nu >> kT$ such transition are much more favorable those for the usual optical laser band [14] (see also the paper by the same authors in the present issue). At this point it is essential that an inverted population of corresponding active centers is achieved, in the case with the alive, by a metabolic mechanism of the pump, but via a chain of structures embedded to one another (we called this chain "hierarchy of dissipative systems" [15]). Thus, the synergetic description of the alive is a necessary condition for its quantum mechanical description.

Joint analysis of the ordinary formulae of quantum physics and theory of radiation yields that the ratio of the rates of stimulated and spontaneous emission of the resonance frequency $E_2 - E_1 = h\nu$ in a material kept at temperature T reads $\frac{P_{stim}}{P_{spont}} = \frac{1}{e^{h\nu/kT} - 1}$, so that for the mm range and at room temperature, when $\frac{h\nu}{kT} \approx 0.01$, it passes to $\frac{P_{stim}}{P_{spont}} \approx \frac{kT}{h\nu} \approx 100$, that is when keeping the inverted population regime going by way of the metabolic pump on all levels of the dissipative structures in the hierarchical chain of an organism, one appreciably facilitates the transition to a coherent regime. Therefore, in spite of strong absorption of the mm-band radiation by water media of the body, the organism can sustain the maser regime of functioning, even suffering some losses (see [14]).

In the end, the inverted population of the active centers, represented on the organism level by the cells, makes it possible to translate all the variety of hereditary information stored in DNA into the coherent EMR language. According to conceptions of physics of the alive the biochemical reactions in cell during this retranslation as well as the quadradimentional dynamics of its structures take the most direct participation in ruling the "maser" chemical pumping and frequency selectivity of membrane resonators.

It is worthy to put emphasis on the mechanism of the self-consistent electromagnetic potential formation of the whole organism.

Of various forms of arising, propagating and decaying patterns of the system's coherent waves beyond its nonequilibrium phase transition threshold, we will be interested only in non-attenuated time-periodic wave structures, i.e., limit cycles. Then it is natural to consider the Chinese meridians (which form the basis of the BAPs system of the classic Chinese acupuncture) as coherent traveling electromagnetic waves, forming limit cycles. Accordingly, the Chinese meridians and other limit cycles of the organism's electromagnetic fields make up something like its "electromagnetic frame." Being a transmitter of genetic information, this

frame is created by all cells of the organism and simultaneously holds the organism's stability.

With this, a radical possibility is being cleared to answer the questions unresolved by modern theoretical biology, such as: "Why do the individuals differ from each other, with this difference holding?" Controlling cell divisions and differentiation in the processes of growth and morphogenesis, the "electromagnetic frame" connects the molecular intracellular processes of protein synthesis to the supra cellular macroscopic features of the system: shape and proportions of the body, its morphological structure, so forth.

Attacking the alive from the quantum mechanical standpoint, to describe the organism's state we may introduce such quantum mechanical notions as a state vector and statistically construct the basis of a space of such vectors. By using the sets of simultaneously measured clinical indices taken from each patient of a given group under study to determine his (or her) vector of state, we can trace the dynamics of the transition of the patients from the state "illness" to the state "health" (see paper by L.S. Phinkel in this issue). In other words, we may represent empirical data on clinical indices in terms of "observables" of the organism as a quantum mechanical system.

We hope that all this has amply shown the constructivity of physics of the alive, an approach to the organism as a dissipative structure that dynamical stability is that of a macroscopic quantum object. This approach has also turned out to be fruitful in "going downstairs" along the Weisskopf quantum ladder, from the alive to the atomic nucleus. In so doing, we may overcome the difficulties unresolved both in several "fundamental sciences" and in the very quantum mechanics [16].

Apart from being satisfied with the fact that the proposed conceptual fundamentals of physics of the alive add our ideas about the alive to the world outlook created by modern natural science, we may quote some direct outcomes that fill this conceptual shell with a concrete content.

In particular, in the empirical basis of physics of the alive there can be added not only the results of specially performed experiments, but also: the topology of the ancient meridian network examined within the scope of nonlinear electrodynamics (see [14]); the papillary pattern, examined as for wave optics [17], on fingers, palms and feet; the system of visual perception and storing images, examined in converting information from the optical (visual) band to the mm band of the intrinsic characteristic (eigen) frequencies of the organism (see V.V. Gizhko's paper). Many theoretical studies in the field of physics of the alive can be also referred to as those based on well-known data accumulated in various laboratories throughout the world for many years. We mean, first, the proof of a self-consistent character of the bistable functioning of membrane ionic channels [18], an explanation of the mechanism of affecting living objects by applying ultraweak radiation as for disruption of the regime of genetic code retransmission and with allowance for a collective nature of the "resonant" perception of the low-intensive mm-band EMR by biomolecular structures ([19] see also A.A. Serikov's paper), and analysis of the general conditions for a nonequilibrium phase

transition to occur in the presence of external electromagnetic field (see paper by A.V. Chaly).

Of specially performed experiments that have determined our up-to-date vision of the problem of the alive, we may put emphasis on the following: the discovery of the resonant peculiarities of functions of the mm-EMR action upon the human organism (see [9]), genome conformational states [20] and amino-acids [21]; the studies of these [21, 22] and therapeutic effects [23] of the mm EMR action at the densities that correspond to extremely low photon flux intensities; an elucidation of the influence of the circular polarization direction on the character of resonance peculiarities of functions of the mm-ER action upon bioobjects and MRT treatment effect; the investigation of water behavior dynamics under conditions close to those in the organism [24] (this allows an idea of water in the organism as its "physical vacuum" [25] to be substantiated); close to the same direction are the holographic studies of the regimes of the blood plasma behavior in the mm-radiation field [26].

Today, Physics of the Alive is a research program in which synergetic and quantum principles merged. This integration allows a profound theoretical description of the alive to be given, basing on the fundamental role of the coherent electromagnetic mm-radiation field in the origin, existence and stability of the living organisms.

КОНЦЕПТУАЛЬНІ ЗАСАДИ ФІЗИКИ ЖИВОГО

С.П.СІТЬКО

У взаємодії фундаментальної фізики з біологією та медициною досі вбачався лише один напрямок, а саме – використання останніми фундаментальних здобутків різних галузей фізики, що сформувались на вивченні структури суто неживої матерії. Фізика живого виходить з уявлень про те, що живе є четвертим рівнем квантової організації природи після ядра, атома, молекули, тобто само є джерелом її об'єктом нового розділу фундаментальної фізики. Розглядаються передумови існування самоузгодженого синергетичного потенціалу типу Ландау-Хакена в самостійно функціонуючих живих системах.

Експериментальною основою цих нових уявлень про шляхи реалізації генної інформації на макроскопічному рівні цілісного організму є результати наукових, клінічних та експериментальних досліджень впливу наднизьких рівней електромагнітного випромінювання мм-діапазону на біологічні об'єкти різного рівня складності. Важливим аргументом в аналізі цих результатів є можливість поновлювати функціональний стан організму людини (лікувати) діченими квантами електромагнітного випромінювання (~10^{-20} Вт/Гц·см^2), що продемонструвала квантова медицина на масиві в 250,000 пацієнтів.

КОНЦЕПТУАЛЬНЫЕ ОСНОВЫ ФИЗИКИ ЖИВОГО

С.П.СИТЬКО

Во взаимодействии фундаментальной физики с биологией и медициной доселе просматривалось лишь одно направление, а именно – использование последними фундаментальных результатов из различных областей физики, сформировавшихся на изучении

исключительно неживой материи. Физика живого исходит из представлений о том, что живое является четвертым уровнем квантовой организации природы после ядра, атома, молекулы, т.е. само по себе является источником и объектом нового раздела фундаментальной физики. Рассматриваются предпосылки существования самосогласованного синергетического потенциала типа Ландау-Хакена в самостоятельно функционирующих живых системах.

Экспериментальной основой этих представлений о путях реализации генной информации на макроскопическом уровне целостного организма являются результаты научных, клинических и экспериментальных исследований по влиянию сверхнизких уровней электромагнитного излучения мм-диапазона на биологические объекты разного уровня сложности. Важным аргументом в пользу новых представлений при анализе результатов является возможность восстанавливать функциональное состояние организма (лечить) считанными квантами электромагнитного излучения ($\sim 10^{-20}$ Вт/Гц·см^2), что продемонстрировала квантовая медицина на массиве в 250000 пациентов.

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