First World Energy Medicine Congress
Paris, November 20, 1977, pp. 114-122.

This contribution was re-published
in: Proceedings of The International Symposium
On Wave Therapeutics: Interaction
of Non-ionizing Electromagnetic Radiation with Living Systems,
Versailles, May 19-20, 1979. Z.W. Wolkowski (ed),
Paris 1983.

THE UTILITY OF BIOELECTRONICS AND THE BIOPLASMA CONCEPT IN THE STUDY OF THE BIOLOGICAL TERRAIN AND ITS EQUILIBRIUM[1]

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Biochemistry has brought an important contribution to our understanding of the living organism, and synthetic pharmaceuticals, which are the result of the development of biochemistry, now allow for a deep modification of life functions. However, due to numerous factors, we have now reached a point where the advances of pharmacology no longer meet our expectations, and are even harming the health and well-being of man. It appears that an attempt to emerge from this biochemical and pharmaceutical impasse may be looked for in biophysics and related physical methods of therapy. Bioelectronics a new branch of bio-physics concerned with the electrical properties and processes of the organisms, warrants new expectations.

The purpose of this paper is to present two sides of the energetic homeostasis of the organism, viewed as a certain state of balance at the sub-and supramolecular levels of the organism. The first aspect is concerned with the electronic characteristics of the biological terrain, in equilibrium, considered as a balance of the densities of electrically charged particles, Another aspect is the consideration of the organism as a system with a balanced state of electrical oscillations and resulting electromagnetic radiation. In order to characterize these two aspects we will use the results of selected representatives of these directions of investigation. The last part of this paper will deal with similarities and differences in the previously given concepts of electronic homeostasis, and an attempt at indicating some possible practical applications of the concepts mentioned. It is our desire to keep in mind the necessity of developing bioelectronics and bioplasma as tools to study chronic health in the human being.

1. The substrate approach

By substrate we understand here a material "carrier" of life functions. It is understood, that the description of this substrate is determined by acceptation of a specific level of organization of the living system. An example may be given by the well known cellular level or organization, describe by cytology, or the molecular level of organization, most adequately presented in the language of biochemistry. Although in essence the chemical processes which take place in the living system are realized through electrically charged intermediates, or intimidates carrying a magnetic moment, this aspect often escapes the attention of most researchers. And it is this very point, where the interaction between electrons, protons, ions and radicals is considered, that we should expect a more detailed concept of life functions, and perhaps the discovery of new laws in biology. It is within

[1] Presented at The First World Energy Medicine Congress, Paris, November 20, 1977.

this current of thought that we find the work of A. SZENT-GYÖRGYI and followers. Here also we would classify the creator of an organismic interpretation of bioelectronics, L.C. VINCENT, as well as researchers developing the bioplasma concept.

(a). It is difficult to understand the shift of the organism from a state of dynamic equilibrium, without representing what we mean by life on the submolecular level. A. SZENT-GYÖRGYI considers the biosphere as a system which continuously draws solar energy through intermediate electronic excitations of appropriate molecules, biological dyes, autotrophs (1). The energy of this excitation is next transformed into the energy of chemical bonds, and again, with respiration chains, through intermediate electronic processes, transformed into different electronic processes and forms of work executed by living systems. One of the most specific and typical manners in which life utilizes this energy is the building of definite organized structures such as. macromolecules, cells and tissues.

According to SZENT-GYÖRGYI, the living organism utilizes, on a very large scale, the semiconductive properties of macromolecular aggregates. This is a delicate and unusually complicated network, formed by currents of flowing electrons. These charges, moving within biostructures, are also carriers of energy. The flow of electrons is possible under the influence of gradients of electrical potential, and these gradients determine the unique electrical pattern and geometry of the biosphere.

On the molecular scale, electronic transfer is performed through so called "charge transfer", where electrons are spontaneously transferred from one point of the molecule to another, or between molecules. A decisive role is played here by the donor and acceptor properties of molecules. PULLMAN and PULLMAN (3) have accomplished a great deal in the field of study of electronic structure of biological compounds and their ability to donate and accept electrons. It appears from these studies that the essential energetic processes of the organism, such as oxidative phosphorylation or glycolysis are performed through electron transfer between molecules, which in a reversible manner become electron donors (in the reduced state) or acceptors (in the oxidized state), from neighboring molecules in the metabolic cycles. It is highly interesting that compounds capable of very strong interactions with life functions are either strong donors or strong acceptors of electrons. Among such we find steroid hormones, sex hormones, aromatic compounds containing a nitro group (ex. dinitrobenzene) and some hydrocarbons.

Before discussing the role of modifications on the submolecular levels in the processes of loss of homeostasis of the system, one must again note the supramolecular dimension of the processes of electron transfer in a living system. By this we mean the above mentioned semiconductivity of living structures. The idea that energy within a living system may be trans ported within semiconductive bands of proteins was suggested by SZENT-GYÖRGYI (2) in 1941, This idea was also picked-up in numerous experiments. As a result it was established that not only proteins(5,6) and their complexes (4), but also nucleic acids (7,8), biological dyes such as chlorophyll (9), some carotenoids (10) are semiconductors in vitro. Due to these results, some researchers have accepted semiconductivity within the organism as probable. And although the semiconductive mechanism of electronic energy transfer in living systems is not the only possible one, it is however useful for the understanding of some life processes(ll,12).

As mentioned above, electron currents move within the energetic bands of a living system under the influence of the gradient of electrical potential. Therefore any perturbations of the geometry of the mentioned gradients may initiate pathological processes, Among the many possible reasons it is worthy to note, in particular, variations due to piezoelectric (13,14) and pyroelectric effects, during non-physiological changes in temperature or deformations of structures.

The variations in the density of charge carriers, flowing through living structures, may also be of great importance. Among the reasons for these changes we may include: introduction of too strong electron donors or acceptors into the system, thermal fluctuations, and electromagnetic radiation of high quanta. Changes in the electronic structure of DNA may play an important role in the unbalancing of the biological terrain, and this may manifest itself as a variation of the rate of cell division (16). Large variations in the electrical gradient within the cell may produce the grouping of positive or negative charges on one of the ends of the DNA helix, which may trigger the unfolding of the helix,

DNA synthesis and finally cell division. The faster reproducing cells will maintain their metabolic rate on a higher level, without "justification" by the needs of the organism. This may become the reason for the unbalance of the organism, This may become the reason for the unbalance of the entire system.

In the above summary, the macroscopic state of the organism appears to depend on well defined processes taking place with the help of submolecular particles, particularly electrons. The knowledge of this condition may be essential not only in the explanation of the electronic basis of illness, but also prevention, t ha t is the maintenance of chronic health.

(b). It is also possible to study the electronic state of the organism through the measurement of parameters characterizing the macroscopic state of the system. VINCENT has described a set of three parameters (39), pH, rH_2 and for blood, saliva and urine, in a "black box" model of the organism. Hę concluded that this matrix of nine values may be transformed and is in itself sufficient to describe the modification of the biological terrain of the organism. However, the connection between the macroscopic use *o£ bio*-electronics by SZENT-GYÖRGYI and the macroscopic interpretation of VINGENT is lacking. Matrix transformations, that is deviations from optimal positions, lead toward mutually exclusive areas, for example of degenerative diseases and infectious diseases, described by the unbalance of electrons, protons and ions (the latter globally represented by the resistivity factor). Since the interpretation of VINCENT appears to be consistent with many conclusions of natural, that is global therapies, we would like to encourage a search for connections with a microscopic bioelectronic framework, as well as the bioplasma approach.

2.The field approach

Electrical, magnetic fields as well as electromagnetic waves are a constant manifestation of life processes, and these are essentially involved in all metabolic and information processes of the system (18). A view bearing out that the state of health or sickness is directly related to the kin of radiation emitted by cells was developed by G. LAKHOVSKY in 1930. Hę built an electromagnetic wave generator which, according to his writings, was capable of effectively restoring the normal functions of the organism (19). LAKHOVSKY's theory is based on very simple biological observations and basic radiotechnology. And although undoubtedly it is a great oversimplification of biological reality, it contains ideas which may be justified *a posteriori* on the basis of advances in biophysics. This theory may be reduced to the following statement (19): "each living being is simultaneously and emitter and receptor of electromagnetic radiation." The above statement vas justified by this researcher in the following manner: in every living system, and particularly within the cell (and its nucleus), we have the components of an electrical oscillator. These elements are composed of structures capable of gathering electrical charge (capacity C), and conducting parts responsible for induction (L). If there is an energy input into the system, either From nutritive compounds or from any other source, the system begins to oscillate with its own characteristic frequency. Illness, in LAKHOVSKY's view, is the transition of the entire system, or of its elements, into a state of disharmonic oscillations, and these perturbations, if not sufficiently attenuated, will extend to neighboring parts, finally inducing the breakdown (illness and death) of the system.

According to LAKHOVSKY, the factors causing unbalanced, out-of-tune oscillations, are above all bacteria, which in their essence (as living beings), generate their own electromagnetic waves. The infection of an organism leads to a "radiation war", which may be lost by the organism. Another factor perturbing the harmony of electrical oscillations of the organism is a change in the chemical composition of the cells, which is the result of poor diet, environment and aging. The mechanism of cancer cell formation (19, p.94-97) may be given as an example: a large amount of globulin is present in the blood of 40-50 year old persons. These compounds, apart from a large amount of added mineral substances, coexist with lecithins, the chemical structure of which is related to that of cholesterol. LAKHOVSKY in his experiments attempted to show how higher frequency radiation may extinguish lower frequency radiation, and shorter-wave

radiation is propagated to neighboring cells. The process of propagation is in fact the propagation of the cancer itself, which "tunes in" the neighboring cells to its own frequency: it is a process of information transfer, rather than a transport of mass. Although at present it is difficult to accept the mechanism of ontogenesis proposed by this author, we may except his thesis of commonplace electromagnetic emission in living matter, and the sensitization of living organisms to this radiation. The protection of an organism against illness depends less on the avoidance at all cost of an aggression by pathogenic stimuli, as rather on the reinforcement of the biological terrain, in order to make it more resistant to the action of these factors.

3. The bioplasma approach

The approach presented now is in fact a global approach, incorporating both the substrate and field aspects of the body. The unifying element is here the physical plasma existing in biostructures (20,21). The following elements contribute to such a concept:

1. The study of semiconductive properties of biological material and the consideration of the role of semiconductivity in life processes,
2. The plasma interpretation of the behavior of charge carriers in semiconductors,
3. The search for similarities between selected functions of living systems and fundamental properties of physical solid state plasma.

As mentioned previously, the fundamental kinds of biological material posses semiconductive properties, and the involvement of semiconductivity in life processes is very probable.

In order to proceed to the question of existence of bioplasma and the basic parameters, it is necessary to indicate that the charge carriers in the biological semiconductor constitute a solid state plasma (22,23).

On the basis of the rate of consumption of oxygen by tissues and the volume involved in the process of electron transfer, it is possible to estimate the density of charge carriers - one of the essential parameters characterizing physical plasma. For the purpose of the following considerations we may accept the estimate of ELEY and PETHING (24), which gives 10^{16} cm^{-3} for the charge density in mitochondria. Another important parameter determining the properties of solid state plasma is the effective mass of charge carriers. Here also we may utilize the estimate used in the elucidation of the quantum mechanical mechanism of amoeba movement, where this value was taken as equal to $2m_0$ (25). Finally, the last important parameter is the value of the static electrical permeability, ε_o.

For physical plasma in biostructures, high ε_o values are extremely important. The generalization made by ATHENSTADT (26) was utilized, according to which ferroelectric properties are appropriate to all classes of biologically significant material. The value expected here is analogous to the epsilon of DNA (27). The following estimated values and physical constants were used;

ε_r - static relative electrical permeability = 10^4
m_o - rest mass of free electron = 9.11×10^{-28} g
m_e - effective electron mass = $2\ m_o$
a_Q - radius of the first Bohr orbit = 5.29×10^{-9} cm
N - density of charge carriers = 10^{16} cm^{-3}.

and yield a formula representing the condition describing the plasma behavior of charge carriers in degenerate semiconductors (23):

$$\frac{1}{2}\left(\frac{3\pi}{2}\right)^{\frac{3}{2}}\left(\frac{\varepsilon m_o}{m_e}\right)^{\frac{3}{2}}\left(a_o^3 N\right)^{\frac{1}{2}} \rangle\rangle\ 1 \qquad (1)$$

indicating that within the living system may take place collective interactions of particles, participating in cellular respiration. The modifications of many physiological properties of

the system may lead to a change in the left part of inequality (1), of which a particular case may be a drop in the vitality of the system, that is death. This question was considered in more detail (28).

Another important characteristic of physical plasma are its electrostatic oscillations. Their frequency is given by the following equation:

$$\omega_p = \left(\frac{4\pi N e^2}{m_e} \right)^{\frac{1}{2}} \qquad (2)$$

with: ω_p - angular frequency of the oscillation
e - charge of the electron = 4.8 x 10^{-10} cgs units.

After substituting previously given values to equation (2), we obtain $\omega_p \approx 1.3 \times 10^{12}$ Hz, and its biological interpretation will be given later.

The mitochondrion which is related to the present discussion would be therefore a system containing physical plasma and generating energy quanta and oscillations of such magnitude, that they may interact with conformational movements of biomolecules. It is known that the chemical activity of molecules depends on their conformation and their ability to participate in specific biochemical reaction cycles. We may therefore project our ideas by saying that the frequency of plasma oscillations in a living system directs the process of metabolic reactions.

In this physical plasma perspective, the living organism may be viewed as a set of electromagnetic oscillators, in mutual resonant coupling. Moreover we may imagine that a multicellular organism oscillates with its specific plasma frequency, which is a superposition of the frequencies of its composing fragments. Its particular elements, such as organs, tissues and cells may be characterized by specific oscillator frequencies. Such a field description of a multicellular organism and its coordination was given in (29).

In the bioplasma approach, the equilibrium of the biological terrain would be determined chemically, by action on the charge carrier density and also physically - by modifying the structure of conduction bands, this structure affecting the value of the effective mass of charge carriers.

A very important role would be due to resonant effects of interaction of the constituents of the system within bioplasma. Any variation in the oscillation frequency, caused by a drop in charge carrier density (after accepting an invariant m_e value), will induce a situation in which part of the system where the oscillation frequency decreases will be energetically stimulated by surrounding tissues, characterized by higher plasma oscillation frequencies. In this global view, the perturbation of a homeostasis is not a local perturbation, but encompasses the entire organism. Its restoration is a process of modifications of a perturbed oscillatory equilibrium within the entire system. This may be realized by chemical, physical or even psychical means, the latter apparent in the form of psychosomatic illnesses.

4. Conclusions

At this point we should answer the question, whether the above mentioned characteristics of a living system, both in the normal physiological state as in illness have any common factors. The answer is undoubtedly positive. Ali the above mentioned concepts are united by the idea that living systems function by utilizing various mechanisms involving electrically charged constituents of a living organism.

In VINCENT's approach, contrary to the one discussed here, the author dwells little upon the essential electrical processes which constitute the living state. Measurements of these parameters furnish Information whether the organism is in a state of balance or has deviated from it and how far.

This global approach to the system, proposed by YINCENT and his supporters has not

yet found a justification by indicating precise mechanisms relating internal characteristics with processes which take place on the molecular and submolecular levels of the systems. On the contrary, the other approaches mentioned stress microphenomena which lie at the basis of the equilibrium of the biological terrain. SZENT-GYÖRGYI is concerned with electron transmission between molecules, with the existence of conductive bands in their aggregates, with flow of electrons through these bands. Perturbations in electron transfer, either in the transfer chains themselves or by damage done to elements regulating this transfer are a vital reason for deviations of the system from equilibrium.

For LAKHOVSKY the living system is primarily an electromagnetic oscillator. The most fundamental thing for maintaining a state of dynamic equilibrium of the system is not allowing the discoordination of cellular oscillators at characteristic frequencies. The area of frequency of these vibrations, suggested by LAKHOVSKY, extends from the ultraviolet to short radio waves. Although his approach most probably contains a part of the truth about the basic dynamic characteristics of the system, the postulated mechanisms are now unacceptable.

LAKHOVSKY's therapeutical technique may be, to some extent, the reflexion of therapy performed with the PRIORE's generator. This apparatus, besides other, so far fully unidentified effects, generates a constant magnetic field with an intensity of about 1240 Gs and an electromagnetic wave at 9.4 GHz frequency, modulated with a 17 MHz wave frequency. The fundamental wave of this radiation (considered as necessary, yet insufficient condition to produce therapeutical results), lies in the centimeter band region. The application of this apparatus is reported to produce the following biological effects: regression of neoplasms (30), elimination of *Trypanosoma* from animal blood (31) normalization of cholesterol levels in blood, as well as reinforcement of specific resistance to particular kinds of neoplastic infections (31,32).

It is worthy of notice, that electromagnetic radiation in the millimeter range (42 GHz) is characterized by very precise resonance interactions on bacterial strains in vitro (33). Experiments performed with the use of PRIORE's instrument and Soviet investigation seem to neglect the problem of the physical basis of the interaction of radio frequency waves with living systems.

A more complete approach, at least in the fundamental aspects, is the view of the organism as a system containing physical plasma. It combine the substrate and the field approaches to the organism. As has been previously noted, it is sensitive to variations in charge carrier densities, changes in electrical permeability, perturbations of molecular structures as well as field interactions. Deviations from an equilibrium state may result from chemical changes in the system, as well as field interactions - not necessarily electro- magnetic - from the outside. Therapeutic interactions may also take place along these lines.

A particular case of such therapeutic interactions may be the interaction of low-intensity laser radiation on least-resistance (acupuncture) points. INYUSHIN and co-workers (34) at the Kazakh State University at Alma-Ata in the USSR have provoked in this manner beneficial effects, such as an increase of erythrocyte content in the blood, stimulation of surrenal secretions and acceleration of fracture healing and bone regeneration. These effect are explained as stimulation of physical plasma contained in biostructures (particularly nerve pathways) by increasing the charge carrier density in them.

Within the scope of classical acupuncture, HOTOYAMA (35) has utilized the scanning of meridians to determine the localization of misbalances and a computerized interpretation for diagnostic purposes. Twenty-eight "seikutsu" points are reassured on the tips of the fingers and toes, next 3 Volt DC current is applied through electrodes and the machine measures skin current values (GSR) at each "seikutsu" point just before and after the body reacts to the voltage. This reaction of the body, an action of the homeostatic function, MOTOYAMA calls "polarization", and by measuring the skin current before and after the above reaction. He can diagnose the state of the meridian and the corresponding internal organs. MOTOYAMA claims that his instrument is unique since it can measure short polarization phenomena in the range of l to 10 microseconds.

From measurements on 2000 subjects, MOTOYAMA has drawn criteria of normality

and abnormality for values obtained before, after and during polarization, which respectively give information from the bioelectronic stand-point, about the strength of reaction to a stimulus, the basic resistance of tissue and temporary functions of the body, and the reverse potential generated in the body against the stimulus given from the outside. These techniques allow MOTOYAMA to make objective the yin/yang language of Chinese medicine, and to translate it into measurable parameters. Hę is able to learn about the functional situation of each meridian, and the disease tendency before it actually manifests itself. The applications of this instrument for health and preventive medicine, as well as the study of optimal biological terrain maintenance are self-evident.

LIHG-WEI (36), in an attempt at a modern interpretation of the theoretical foundations of Chinese medicine, illustrates the "semi-conductor" effect observed by ADAMENKO (37). In a healthy person, the electrical resistance measured across two symmetrical acupuncture loci (ex. Ho-ku on both hands), is about the same one way or the other, regardless of reversing of the polarity of the terminals. The difference in resistance measured in two directions would be an indication of yin/yang disharmony and hence sickness. ADAMENKO called this the "semi-conductor effect", and used it to measure objectively the process of healing. FENG (38) has also used it as a diagnostic tool.

Both MOTOYAMA's polarization techniques and ADAMENKO's effect have their meaning and possible explanations within the bioplasma concept.

As a conclusion, it is noteworthy summing-up again remarks concerning the practical meaning of the three approaches mentioned here. Their utility is triple: biomedically they are useful in diagnostics, therapy and prevention. The VINCENT approach allows for an evaluation of the actual, global state of the organism, of its trend of development and indicates the factors capable of restoring this balance. It is possible to Indicate potentially noxious substances and influences such as chemically treated or highly mineralized water, positively charged environments, tribo-electric and synthetic clothing, Faraday-cage effects in high-rise housing, and so on.

The substrate approach on a microscale, represented by SZENT-GYÖRGYI, PULLMAN and PULLMAN, LÖWDIN and LADIK, although it does not indicate concrete therapeutical techniques, allows for a description of factors detrimental to health. Most prominent is the action of molecules with excessive electron donor or acceptor properties. The existing tables, elaborated with the help of quantum chemistry, are useful in comparing such properties.

Techniques which stimulate life processes by infrared or microwave radiations have found numerous applications in physical therapy, and explanations are various. It is worthy to investigate the regression of neoplasms under the effect of electromagnetic radiation of 2-10 m wave length in the bioplasma approach, this would be explained by particular sensitivity to that region.

Finally, in the bioplasma approach, similarly as in VINCENT's, it is possible to determine the life potential of the organism. This potential is characterized by three parameters: ε_r, N and m_e. The two first ones appear related to the ones of VINCENT (39), while the practical implications of the connection remain to be determined.

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