Chapter 1

INTRODUCTION TO INTEGRATIVE BIOPHYSICS

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1. INTRODUCTION

If you look through a number of contemporary textbooks and introductions of biophysics, in order to find out what exactly biophysics is and what the field covers, you will be quite bewildered. Even the titles of the books with their diversity of names for the field, which include, besides biophysics itself, *"Medical Physics", "Medical and Biological Physics", "Physical Biology", "Physical Bases of Medicine and Biology", and "Molecular Biology",* already show the existence of different interpretations and tendencies.

Looking at the tables of content, we find that some books have the application of physical devices and measurements to physiological problems as the only subject of biophysics. Some others are structured according to the different categories of physical phenomena, i.e. the mechanical, thermal, acoustical, electromagnetic and nuclear, gaseous, fluid etc. aspects of living systems, or according to the different functional systems in the organism. In not a few instances, life processes such as transport processes, chemical reaction kinetics, the acid-base-balance, and diffusion processes are treated without reference to the organizational level concerned. In general - with a few notable exceptions - the notion of a hierarchy of subsystems within the biological system, and any kind of overall view of the organism as a whole, is completely absent or relegated to the introduction. Rarely we find a chapter on theoretical biophysics aimed at a synthesis of all these partial aspects of the biophysical treatment of organisms.

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Most of the very recent textbooks are dominated by, if not exclusively devoted to, investigations of molecular structures and processes, proteins, nucleic acids, genetic mechanisms, and membrane processes. One of the major modern textbooks, *"Biophysics"* by W.Hoppe et al. (1982), has a clear emphasis on the molecular level (macromolecules, enzymes, molecular interactions, energy transfer etc.). Much less space is devoted to the subcellular and cellular levels (organelles, cell architecture, membranes, neurobiophysics), and even less to the level of organs, organ systems and whole organisms (in subjects such as parts of biomechanics, cybernetics) or to whole populations and the interaction of organisms with the environment (environmental biophysics). Physical methods of investigation take very extended space ($^1/_6$ of the 950 pages of the volume), while, typically, the treatment of the biological effects of electromagnetic fields is restricted to ionizing radiation and that of electrical fields and currents in the organism to membrane potentials, electroreception in fish, and, surprisingly, the control of differentiation and growth by ionic currents.

We find that biophysics covers a very disparate field of investigations; no two textbooks agree on its scope and range, and no one seems to cover all the relevant questions. A notable exception is Otto Glasser's *"Medical Physics"* of 1944 (with two more volumes in 1950 and 1960), which to my knowledge still remains one of the most complete treatments of the full range of biophysical investigations, not surpassed in its scope by anything later; it also includes physical therapies, mitogenetic radiation (now called biophoton emission), the biological effects of light and electromagnetic fields, and a chapter on bioelectric fields by H.S.Burr. The statement of J.R.Loofbourow made in 1940 that there is "no clear agreement, even among biophysicists, as to what the term biophysics means" (Loofbourow, 1940) basically is still valid. At the beginning of the 2nd Russian Biophysical Congress held in August 2000 in Moscow, the luminaries of Russian biophysics once again discussed the question "What is biophysics ?". As it soon became clear that nobody was able to give a strict definition of biophysics, someone in exasperation and half jokingly offered the following one: "Biophysics is the research published in the journals of biophysics". In other words, the situation has not much changed since the 1940's, except for the fact that in the last decades biophysics has so much become identified with molecular biology that today there may not be many biophysicists who are aware that there are other legitimate kinds of biophysics. Just recently, the journal *Nature* reported in an editorial about the heavily funded effort of the total genetic mapping, sometimes called by the military epithet of a "Manhattan project of the life sciences", as the "new physics-biology agenda" of US science (N.N., 1999). This not-so-new agenda actually goes back to the 1930's, when the pioneers of molecular biology first conceived their program of total technological control over life (Kay, 1993).

However, not all biophysicists feel comfortable with the usurpation of biophysics by the reductionistic, molecular-genetic approach to biology, and the number of those who develop and support an entirely different kind of "new biophysics" is steadily increasing. A look into the history of biology and biophysics shows that there always have been alternative traditions to the approach now dominating these fields, giving support to the concept of "integrative biophysics" that is proposed here.

I would like to point out the significance of the recent parallel trend towards an "integrative medicine" to which contribute, besides biomedicine, many other fields of knowledge and healing practice, such as social and environmental medicine, psychosomatic medicine and consciousness research, naturopathic medicine, homeopathy and non-Western medical systems, transpersonal psychotherapy, methods of "body work", yoga, meditation, biometeorology and geomedicine, chronobiology, and not least, biophysical models and methods (Bischof, 2000b; Milburn, 1994, 2001). In a similar way, many different aspects of the study of life are contributing to the emerging field of integrative biophysics.

2. THE CONCEPT OF INTEGRATIVE BIOPHYSICS

Since there is no agreement as to what constitutes biophysics, we may feel free to attempt a redefinition of the field, based on several recent trends converging towards such a concept. As we have already pointed out in our first attempt at such a redefinition (Bischof, 2000a), traditional biophysics has up to now been based on classical physics and equilibrium thermodynamics, and thus mainly needs a redefinition in terms of the revolution brought about by the last few decades of quantum-mechanical experiments and interpretations, and of non-equilibrium thermodynamics. It indeed will entail a revolution based on physical concepts – however, not of the kind alluded to in the *Nature* editorial. While the physical view will be fundamental, it will not be that of classical physics, and the goal will not be the reduction of biology to physics, but an understanding of the physics of the living, and physics must not replace, but support profound biological understanding. As many authors have predicted, the new biophysics may even lead to the recognition that the study of life can yield insights into basic physical laws more fundamental than those obtained from the investigation of nonliving matter, and thus may become a new field of fundamental research in physics. In contrast to molecular biology, the new biophysics should be more than just an empirically based bioengineering technology; it will need epistemological and philosophical foundations. Its goal should be to develop an adequate theory of life, and it should balance the mastery of life with the understanding of life.

As a complement to the onesidedness of the molecular approach, the new biophysics will focus on holistic aspects of organisms, and will attempt to provide a vision able to synthesize the wealth of molecular details accumulated by molecular biologists. The most significant feature of quantum theory for biology is its intrinsic fundamental holism. As Primas points out, the atomistic-molecular view of matter and the reductionistic-mechanist philosophy have no longer any scientific foundation, according to the actual understanding of quantum theory (Primas, 1990, 1999). The description of reality by isolated, context-independent, elementary systems such as quarks, electrons, atoms, or molecules is only permissible under certain specific experimental conditions, and these entities cannot in any way be considered as "fundamental building stones" of reality. Besides the molecular one, there are other, fundamentally different descriptions, complementary to the molecular one, which are quantum-theoretically equivalent and equally well founded. Quantum theory is much richer in possibilities than is admitted in the worldview of molecular biology.

For quantum mechanics, the scientific theory most widely recognized as fundamental and best confirmed by experiment, material reality forms an unbroken whole that has no parts. These holistic properties of reality are precisely defined mathematically by the Einstein-Podolsky-Rosen (EPR) correlations (Einstein, Podolsky, & Rosen, 1935; Bell, 1987). In quantum mechanics, it is never possible to describe the whole by the description of parts and their interrelations. This holistic view of quantum theory, although the phenomena on which it is based are not yet completely understood theoretically, cannot be rejected anymore because the strange EPR quantum correlations of non-interacting and spatially separated systems have been amply demonstrated in many experiments (Aspect et al., 1982; Aspect & Grangier, 1986; Selleri, 1988; Duncan & Kleinpoppen, 1988; Hagley et al., 1997). Therefore the world-view of classical physics, atomism and mechanistic reductionism, definitely cannot anymore be the basis of our worldview, and of biophysics. Quantum mechanics has established the primacy of the unseparable whole. For this reason, the basis of the new biophysics must be the insight into the fundamental interconnectedness *within* the organism as well as *between* organisms, and that of the organism *with the environment*. The new biophysics therefore will be an *integral*, i.e., holistic biophysics.

For the same reason it must also be an *integrative*, i.e., inter- or transdisciplinary, discipline, and has to truly integrate biological, biochemical and medical expertise into its physical models, but should also connect to knowledge from fields such as geophysics, biometeorology, heliobiology etc. The determination of biophysical parameters of the organism, like that of molecular processes in biochemistry or molecular biology or the procedures of any other specialized approach, has no value in itself, but only in the context of the whole range of biological knowledge. Excellence in biophysics will always be based on a good grasp of biological and medical base knowledge – and a "feeling for the organism" (Fox-Keller, 1983) - , and starting from there it will then be possible to transcend the onesided anatomical, molecular-biological approach and to expand its scope by using biophysical concepts and methods. The necessity and justification of an integrative approach results also from quantum theory, which teaches that science from now on has to get accustomed to the simultaneous use of different complementary viewpoints and methods, and cannot anymore in good conscience be practiced from a single approach only.

The new biophysics will be based on quantum theory, and not classical mechanics – therefore it may also be called "quantum biology" –, and also, instead of equilibrium thermodynamics, it must refer to non-equilibrium thermodynamics. Organisms clearly are open systems far from equilibrium. Other central concepts and features of the new biophysics will be coherence, macroscopic quantum states, long-range interactions, non-linearity, self-organization and self-regulation, communication networks, field models, interconnectedness, non-locality, and the inclusion of consciousness.

I postulate that field thinking and field models will have to be one of the central elements of the new biophysics, as a complement to the molecular view, as a means to synthesize the wealth of its details, and as an instrument to adequately model thinglessness, interconnectedness and non-locality – therefore bioelectromagnetics will play a central role in the new biophysics. However, recent experiments have shown that the existence of hitherto unknown, non-electromagnetic fields in and between organisms cannot be excluded. Of course, the field aspect of the organism has to be seen in close connection, and constant interaction, with the solid aspect. Attention should also be paid to the field aspect of biochemical processes, for example in collective processes, reactivity and molecular recognition.

I suggest that the existence of a pre-physical, unobservable domain of potentiality in quantum theory, which forms the basis of the fundamental interconnectedness and wholeness of reality and from which arise the patterns of the material world, may provide a new model for understanding the holistic features of organisms, such as morphogenesis and regeneration, and thus provide a foundation for holistic biophysics – therefore I propose that the usefulness of the theories of the physical vacuum for understanding the phenomena of life is investigated - one important aspect of their usefulness may be as a link between the domain of biology and consciousness.

I postulate that the new biophysics needs to extend its interdisciplinarity even beyond natural science. Consciousness cannot be excluded anymore from biophysics, although the difficulties of such an extension should not be underestimated. There is now enough evidence showing that consciousness is a causal factor in biology and not just an inconsequential epiphenomenon. Starting from the analysis of the phenomenology and the experimental evidence for mind-body interaction, field models and vacuum theories may provide the necessary tools for bridging the mind-body gap. Integrative biophysics is also in a good position to investigate the physical bases of the subjective field experiences of interpersonal fields, field-like states of consciousness and streaming feelings in the body experienced in various altered states of consciousness, occurring, e.g., in the practice of yoga, meditation, Chinese medicine, body therapies, shamanism, spiritual healing etc. Among other things, it may be interesting to investigate the correlation of normal and extraordinary states of consciousness to the biophoton emission of the person during these states, as well as with EEG and bioelectric parameters, for instance. However, in order to attain the goal of holistic understanding it is also necessary to acknowledge the limits of the scientific approach, and value the goal of understanding highly enough to include non-observables into our models, if this supports understanding.

As to the methods used, integrative biophysics will mainly use biophotonic and other bioelectromagnetic techniques, but any other methods suitable for the investigation of holistic functions and features of living organisms, such as self-regulation in growth and healing, morphogenesis etc., will be used as well. Concerning the applications, the development of non-invasive methods to assess the functional state of whole and intact organisms, and that of the organism's subsystems in the context of the whole organism, is its main interest. Measurements of the organism's own fields are well suited to make internal regulation processes accessible at the surface of the body.

3. HISTORY OF THE CONCEPT

Biophysics is a relatively young field of science. Systematic scientific investigations by means of physical instruments, and the explanation of their results by physical and mathematical concepts, have been carried out since about 1840, and as a separate discipline it has established itself only since about the 1920's, if not the 1940's. However, physical approaches to the understanding of life certainly have existed before that time, and so have holistic or integral/integrated biophysical approaches and practices which can be taken as exemplary antecedents of an integrated biophysics.

3.1 Exemplary Pioneers

First I would like to summarize the work of some early pioneers whose work may be considered as inspiring exemplars of integrative biophysics, namely Jagadis Chunder Bose, Alexander L. Chizhevsky, Vladimir I.Vernadsky, Ludwig von Bertalanffy, Walter Beier, and Solco W. Tromp, and to describe two exemplary institutional efforts to develop a new understanding of life based on physical concepts. After this, I will give a historical overview over the development in this field, mainly in the 20th century, and will try at the same time to delineate the main topics of the integrative approach to life.

3.1.1 Jagadis Chunder Bose

The first Indian scientist to receive international recognition, Jagadis Chunder Bose (1858-1937), was a biophysicist before biophysics existed as such (Bose, 1902, 1907, 1915; Geddes, 1930; Susskind, 1970; Dasgupta, 1999). Educated in London and Cambridge in the 1880's, he became a brilliant inventor of instruments, which he used to perform delicate experiments first in physics, then in plant physiology. His research career started in 1894 with work on the electromagnetic waves discovered in 1888 by Heinrich Hertz, mainly investigations of polarization, refraction, reflection and other optical properties. He improved on the "coherer" invented by Eduard Branly in 1890 and perfected by Oliver Lodge, a receiver and detector of electric waves, and was one of the first to produce waves of very short wavelengths (microwaves in modern language). Besides the microwave generator, he also designed microwave lenses, wave guides, electromagnetic horns, and an artificial retina, and first showed that semiconductor rectifiers could detect radio waves. Although generally not mentioned as such in histories of the field, Bose was also one of the pioneers of radio telegraphy; he made experiments proving the feasibility of radio transmission at about the same time as Marconi and Lodge, but never actually tried to transmit any signals.

In connection with his coherer work he discovered in 1899 that the molecular structure of some metals changed under the influence of electric waves, either by increasing or decreasing their electrical resistance; some of them even showed automatic recovery from this change. Another effect was the complete loss of sensitivity to the electric waves which he called "fatigue". He christened this property of materials "electric touch" and ascribed it to a structural modification of surface materials. This work which makes him a pioneer of solid-state physics, already contained the first hints of the subsequent venture into the investigation of certain analogies between the behaviour of inorganic and organic matter. This research occupied Bose from 1900 onwards, and also marked his crossing-over from physics to biology. The concept of fatigue, probably created in analogy to the well-known mechanical fatigue of metals, subsequently carried him into ascribing a common responsiveness to the inorganic and organic worlds, and attributing life-like properties to inanimate matter, thus blurring the boundary between the living and the nonliving. After having proposed this hypothesis in 1900 in a paper read to the International Physical Congress in Paris, he tested it in in a series of experiments conducted in 1900-1902 which showed that not only elementary metals, but also metallic compounds and non-metals such as chlorides, bromides, oxides and sulphides, exhibit similar effects. He also compared the behaviour of these inorganic substances under stimulation to the response of animal muscle, and they showed very similar reaction curves. Bose concluded that metals, when subjected to a succession of electrical vibrations, like muscle undergo the protracted state of fatigue physiologists call "tetanus". In a similar way as drugs and stimulants modify the response of living matter, inorganic matter also could be "poisoned" and then be "revived" by an antidote. The response curves of living and inanimate matter were so similar that one could not distinguish between them.

Bose concluded that there was a continuity between the living and the nonliving. In line with an ancient tradition in physiology, he regarded response (Albrecht von Haller's "irritability"), especially electric response, as the criterion of life. As inorganic matter was also responsive, there must be a continuity between living and nonliving. However, while he regarded electrical response as a sufficient condition for life, physiologists of his time like Augustus Waller made it clear this was only a necessary condition. This made Bose a vitalist in the eyes of many colleagues, but he himself rejected and attacked vitalism and certainly was not a vitalist, but also not content to be an ordinary mechanist. His idea was rather that "the responsive processes seen in life are foreshadowed in non-life" (Bose, 1920), and he tended to ascribe life to all matter. His provocating theses caused a heated response by physiologists denying that metal responds in the way that living matter does, and rejecting that responsiveness of ordinary plants could be compared to that of "sensitive plants" like mimosa, the main experimental subject used by Bose, and that of animal muscle.

In the time of 1903-1913, Bose became a plant physiologist which he remained for the rest of his life. As he had pioneered India's research in modern physics in 1895, he now became his country's pioneer in modern plant physiology. He set out to systematically investigate the effect of stimuli on plants by exact methods of measurement and registration. He used mechanical, electrical, chemical and thermal stimuli to elicit mechanical, chemical and electrical responses, and studied the velocity of transmission of the excitatory wave, the electrical response and the electrophysiology of plants in general, and the growth and movement of water in plants, among other things (Bose, 1907, 1915, 1923). His conclusion was that all plants are excitable, at least to electrical stimulation - not only the sensitive ones that possess motile organs. In contrast to the prevailing view that the transmission of excitation was due to mere mechanical movement of water in the plant, Bose was convinced that the stimulus was transmitted by protoplasmic change, as in animal tissue; for him, living organisms were not just mechanical stimulus-response devices, but had a kind of memory. As a crucial test for this hypothesis he regarded the experiment whether the polar effects, found by the German physiologist Eduard Pflüger in animal tissue, could also be found in plants. According to Bose, this would be inexplicable by the hypothesis of water movement. From the positive outcome he concluded that a basic property of protoplasm common to plants and animals must underlie the similarity of response to stimuli.

When in 1913 the Royal Society published the first time one of Bose's biological writings in their *"Philosophical Transactions"*, this signalled the formal acceptance of the Indian scientist as a plant physiologist by the English biological establishment, and initiated the period of his success. In 1917, he was knighted by King George V. and got his own research institute in Calcutta, the Bose Research Institute that still exists. In 1920, he was elected as a fellow of the Royal Society. However, the rest of his life was almost exclusively devoted to defending his theses and was characterized by constant controversies with his fellow scientists which separated the biologists into "Bosephiles" and "Bosephobes" (Pierce, 1927). His peers generally admired the originality of the instruments he invented and were overwhelmed by the ingenuity and wealth of his experiments. But most of them were exasperated or even outraged by the interpretation he gave his results.

Today, the judgment on his scientific merits should not be as harsh at it was then. As to his work on plants, the 1970 edition of the *"Encyclopedia Britannica"* wrote that "his outstanding work was so much in advance of his time that the precise evaluation of it was controversial" (Vol.3, 1970). Concerning his ideas, a contributor to the *Dictionary of Scientific Biography* (Susskind, 1970) wrote that "today when biophysics is a generally recognized discipline..., [Bose's ideas] seem less controversial and may even be taken as foreshadowing Norbert Wiener's cybernetics".

Bose's work was highly interdisciplinary and in his complex personality he managed to bridge many contradictory tendencies in a way that we recognize today as conducive to scientific creativity. He embodied a highly creative synthesis between his contemplative and metaphysical heritage as an Indian native, and the experimental/mechanistic side of his Western scientific training. For Bose, a friend of the poet Rabindranath Tagore and the mystic Swami Vivekananda, scientist and poet or mystic were not separate and contradictory callings; he regarded scientific and poetical understanding as each incomplete without the other. Also, he held that the scientist, like the poet and the mystic, should strive to see "beyond the expressed" and take the reality of the unmanifest behind the appearances into account.

3.1.2 Alexander L. Chizhevsky

The Russian biophysicist Alexander L. Chizhevsky (1897-1964, sometimes also quoted as "Tchijevsky") was a pioneer in the study of the effects of physical factors of atmospheric and cosmic origin on life processes; he is recognized as the founder of heliobiology and of the investigation of the effects of air ions on life in general and on human health and behavior (Chizhevsky, 1930, 1936, 1940, 1968, 1973; Sigel, 1975; Yagodinskii, 1987). Referring to Claude Bernard, he spoke of the "cosmic milieu" in which the earth existed, and of the "atmospheric milieu" which included atmospheric electricity. From 1920 to 1940, he established in extensive statistical studies the correlation of the sunspot cycle with many phenomena in the biosphere; he showed that the physical fields of the earth should be included among the basic causes affecting the condition of the biosphere. In 1935 he discovered the metachromasia of bacteria, now known as the Chizhevsky-Velkhover effect, which makes it possible to predict solar emissions influencing man on earth as well as in space. From 1919 to 1930, Chizhevsky was the first to experimentally determine the opposite physiological effect of negative and positive air ions on living organisms, the pathological effect of air with reduced ion concentration, and the stimulating effect of negative air ions. In 1930-36 he developed and propagated the use of artificial aerionization in medicine, agriculture, and stock raising. In the 1930's, Chizhevsky also investigated the electrodynamic processes in flowing blood (Chizhevsky, 1936). He showed that the organism's colloids, of which, among other things, the blood is composed, precipitate (ions with electric charge opposite to the charge of colloids) or stabilize (same charge) under the influence of air ions. He demonstrated not only that negative ions shifted the pH to the alkaline side, but also that they stimulated the mitogenetic radiation of blood, while positive ions inhibited it. In 1939, Chizhevsky was elected (in absentia) as president of the International Congress on Biological Physics and Space Biology in New York, in recognition of the fundamental contributions to the biophysics of his time.

3.1.3 Vladimir I. Vernadsky

Although not a biophysicist in the narrow sense, the Russian geologist, mineralogist and one of the founders of geochemistry and biogeochemistry, Vladimir I.Vernadsky (1863-1945), one of the leading Russian intellectual figures of the 20th century, must be considered as another one of the forefathers of integrative biophysics (Vernadsky, 1954-60, 1998; Bailes, 1990). Working mainly in the 1920's, 1930's and 1940's, Vernadsky has proposed a teleological concept of life which can be considered as the basis of ecology and system theory. He showed the function of the distribution and migration of chemical elements in the earth's crust and of their concentration in mineral deposits, and demonstrated the essential significance of "living substance" for these geological processes. From his school originated many new directions of the geological and biological sciences, of ecology, biophysics and bioelectromagnetics. From 1914 onwards, he took up the concept of the "biosphere" from Eduard Suess and gave it a precise quantitative and qualitative meaning; with this he became one of the founders of ecology and provided the foundation of James Lovelock's "Gaia theory". He pointed out how much all life was embedded in planetary and cosmic connections and how central the influence of the sun was on all life, which was inconceivable without the interaction with the electromagnetic radiation field surrounding it. Vernadsky also created the concept of the "noosphere" which may be known from the work of Teilhard de Chardin; he saw it as a new dimension of the biosphere characterized by the evolutionary partaking of man in the natural processes.

Some of the key tenets of the pupil of Pasteur and Pierre Curie can be summarized as follows: The biosphere is a part of every living organism, which on the one hand is inseparably connected to it, on the other hand is an autonomous organism. Everything in nature is intricately connected to everything else. Life is tied in to sensitive regulation processes by means of the surrounding electromagnetic fields, including sunlight. The distribution of energy in the life processes and their deviation from the state of thermodynamic equilibrium constitute an inner space-time structure in the living organisms which is different from linear euclidian geometry. Life is characterized by asymmetries (symmetry breakings) which can be demonstrated all the way down to the molecular level (e.g., in the optical activity of substances).

Vernadsky sought to develop a holistic, interdisciplinary science in which also intuition and speculation had their legitimate places. He considered the entire planet as a whole and the life on it as a part of the geological cycles. In his famous work *"The Biosphere"* (1986) he wrote in 1926: "The living organism of the biosphere has to be studied empirically as a special body not completely reducible to known physical-chemical systems". It was not sufficient to describe the phenomena of life by mere material and energetic properties; future scientists would extend the concept of living matter with additional factors besides matter and energy. Vernadsky himself has identified one of the most essential of these new factors as information, long before cybernetics and information theory developed this concept.

3.1.4 Ludwig von Bertalanffy

One of the most important pioneers of integrative biophysics may well be the Austrian-Canadian biologist Bertalanffy (1901-1972), whose 100^{th} birthday was celebrated in 2001 (see //www.bertalanffy.org). When he started his life as a scientist in Vienna, biology was involved in the famous mechanism-vitalism controversy (Bischof, 1995b). As a biologist with philosophical leanings, he became already in the early 1920's "puzzled about the obvious lacunae in the research and theory of biology, and dissatisfied with the then prevalent reductionist-mechanist approach in science", which "appeared to neglect or actively deny just what is essential in the phenomena of life". As a consequence, he advocated an "organismic conception in biology which emphasizes consideration of the organism as a whole or system, and sees the main objective of the biological sciences in the discovery of the principles of organization at its various levels" (Bertalanffy, 1968). His goal as a scientist was to overcome specialization and reductionism by view on the whole, the "system", and an interdisciplinary and integral approach which investigates the subject in its entirety with all its relations to neighbouring disciplines.

This view also resulted from his disputes with the members of the "Vienna circle" of logical empiricists (Moritz Schlick, Rudolf Carnap, Otto Neurath, Karl Popper). He had obtained his Ph.D. in philosophy under their leader, Moritz Schlick, with a thesis on Gustav Theodor Fechner, and had participated in their discussions in the 1930's, but was never able to accept their variant of positivism. Contrary to their views, he was convinced that absolute objectivity in science was not possible and that interest in human values was fundamental for a scientist.

Since the late 1920's, Bertalanffy strived to arrive at a theoretical biology (Bertalanffy, 1927a, 1932) and, at the same time, he also started to think about the significance of the revolutionary changes in physics for biology (Bertalanffy, 1927b). His book on *"Theoretical Biology"* (Bertalanffy, 1948), first published in 1932, with a second volume in 1942, is still one of the classic and fundamental treatments of holistic biology. Its theoretical penetration of biological principles, processes and structures has prepared the way for a modern physical conception of the organism from a holistic viewpoint and for this reason – even if some details certainly are not up-to-date anymore – is still one of the fundamental texts of integrative biophysics.

In an effort to concretize the organismic program and his theory of life, and based on his experimental work on metabolism and growth, Bertalanffy advanced in 1940 his groundbreaking theory of the organism as an open system (Bertalanffy, 1940). In its basic outlines already put forth in 1926, the theory sprang from the key question that had always concerned his research: How comes, and how is it compatible with the natural laws, that organisms spontaneously develop into higher degrees of order, how do the phenomena of "self-organization" emerge without recourse to any mystical "life force" ? Like the organismic school of developmental biologists in England and the USA (Bischof, 1998a), Bertalanffy was opposed to any narrow mechanistic-reductionistic approach, but equally to any kind of vitalistic principle which would situate organisms outside of the laws of physics and chemistry; any explanation had to be in line with the laws of science.

His solution came from the insight that organisms are not isolated but open to their environment; Bertalanffy transposed the already known physical concept of "open systems" to biology and demonstrated the fundamental significance of this insight. This allowed him to construct the first ever theoretical biology in the strict scientific sense, and signified his entry into biophysics. He recognized that a biophysical model of the organism required an extension of conventional physical theory by way of a generalization of kinetic principles and thermodynamic theory. At this time, it was generally assumed that the state of physical systems was that of a closed system. Statistical mechanics had given a solid foundation to the Second Law of Thermodynamics, the law of entropy; as a consequence, it was clear that isolated systems inevitably must reach a state of complete energetic equalization, thus maximal disorder and maximal entropy. From this it was deduced that every system had to gravitate towards disorder and equalization.

In 1932 Bertalanffy showed that a true equilibrium can only occur in closed systems, while in open systems, a special type of disequilibrium is the predominant and characteristic feature. He postulated that living organisms are in fact such open systems, where the tendency to increase the entropy which stemmed from the organism's own entropy production, could be compensated by an influx of negative entropy (free energy), which made entropy reduction possible. As a consequence, the organism must exist in a state fundamentally different from the equilibrium of thermodynamics, which is characterized by maximal entropy and lack of dynamic. For this state, Bertalanffy introduced the notion of "Fliessgleichgewicht" (equilibrium of flux), now usually called "steady state", which is really not an equilibrium, but a state of stationary non-equilibrium. Open systems are in continuous interaction and exchange with the environment; they continuously exchange their material constituents while keeping their structural integrity. With this concept, not only the reconciliation of biology with thermodynamics was made possible, but it also provided the physical foundation for important biological concepts such as organization, equifinality, hierarchical structure, homeostasis, and regulation. Bertalanffy considered Driesch's teleological concepts of self-regulation and equifinality, for instance, as fundamental properties of open systems. "Every healing process, every dynamic restitution following a disturbance, every return to the normal state after a clinical intervention is the re-establishment of an equifinal steady state". He equated the "equifinal self-preservation of the organism" with the "natural healing power" spoken of by physicians in the tradition of Hippocratic medicine (Bertalanffy, 1975). With the concept of the organism as an open system, Bertalanffy also triggered the further development of the thermodynamics of irreversible systems, which in the 1960's especially was brought forward by the work of Ilya Prigogine (see below).

As a consequence of the concept of the organism as an open system, Bertalanffy then developed his "General System Theory" first announced in 1945 (Bertalanffy, 1945, 1968). In it, the holistic view he had developed on the example of biological systems was extended to other disciplines, such as philosophy, psychology, chemistry, ecology, economics, history, and politics. General System Theory is an attempt to identify general laws of the behaviour and properties of systems of whatever nature, which cannot be predicted from the properties of their components. With his system theory, Bertalanffy wanted to overcome the mechanistic conception of the sciences and to establish a humanistic alternative on the basis of scientific laws. For this reason, he always remained very critical towards the many mechanistic variants of system theory, such as systems engineering, operations research, and even Norbert Wiener's cybernetics. With his systems approach, Bertalanffy also prepared the introduction of the concept of complexity into biology, and he already recognized the role of nonlinearity which can lead to chaotic, unpredictable dynamics. He was also a pioneer of the mathematical penetration of systemic thinking, and with his use of mathematical methods in biology he became a pioneer of modelling and mathematical biophysics, as later developed by Nicolas Rashevsky and Robert Rosen, among others. Rashevsky and Rosen promoted in the late 1950's, 60's and 70's the use of relational and similarity considerations and optimization principles in biophysics (Rashevsky, 1960, 1962; Rosen, 1958-59, 1967, 1970, 1972).

3.1.5 Walter Beier

In this tradition stood also the work of Walter Beier and his school at the Institute of Biophysics of the University of Jena (GDR) in the 1960's and 70's. Applying the findings of the school of Bertalanffy to biophysics, Beier has developed a systemic, comprehensive approach always aiming at the wholeness of the system considered. In this approach, a system is not viewed as a conglomerate of parts, and it does not investigate isolated phenomena, but rather the wide field of interactions. Biophysics is understood as a complex, interdisciplinary branch of science, born as a result of the striving for synthesis of the sciences separated by the classical demarcation lines, and of the development of new disciplines sited at the border between classical disciplines. "The nature and the object of contemporary biophysics follow from the striving for comprehensive knowledge on the problems of life, and therefore are intimately touching the original meaning of physics as the natural science per se, even though its development has first turned towards nonliving nature. The efforts at the conceptual integration of biology and physics contain one of the most exciting problematics of our century" (Beier, 1965). While including the investigation at the molecular and cellular levels of organization, Beier stresses that those at the systemic level should also be included. He also emphasizes the central importance of theoretical studies in biophysics. He bases his theoretical approach on the work of Timofeeff-Ressovsky, Bertalanffy, and Rashevsky, who in his view are responsible for the introduction of mathematical-theoretical considerations into biophysics. However, Beier states that theoretical biophysics is still far from the goal of creating an "axiomatics of biology". His approach can be used as one of the starting points for the development of modern integrative biophysics.

3.1.6 Solco W. Tromp

The Dutch geologist and micropalaeontologist Solco W. Tromp (1909-) became in the late 1950's and 1960's one of the leading biometorologists and founder of the International Society of Biometeorology, one of the research organizations that may serve as a model for the organization of work in the field of integrative biophysics. Before that time, he published a unique and unconventional book containing what may be called an early concept of integrative biophysics (Tromp, 1949). In *"Psychical Physics"*, Tromp attempts to give an explanation of dowsing, radiesthesia, hypnosis and other altered states of consciousness, certain distant influences between organisms and the homing instinct of animals, by an analysis of the influence of external electromagnetic fields on psychic and physiological phenomena in living organisms. In the first two chapters, the voluminous book comprises a comprehensive review of "electromagnetic fields in and around living organisms" which includes bioluminescence, "cell radiation" and bioelectricity, with an extensive discussion of Gurwitsch's "mitogenetic radiation". Next he treats the susceptibility of organisms to electric, magnetic and electromagnetic fields and discusses the physico-chemical nature of the cell and its functions, the properties of colloids and liquid crystals, the high sensitivity of the components of the cells of living systems and of the systems as wholes, its limits and conditions, and finally the geological, geophysical, atmospheric and cosmic factors influencing life on earth, including biometorology. In chapter III Tromp looks at "divining and kindred phenomena" in detail, including various theories trying to explain them, his own experiments that he performed in the physical and physiological laboratories of Leiden University, and those of other researchers, and also unexplained phenomena such as mesmerism, hypnotism and the homing sense of animals. In the last chapter finally he proposes his concept of "psychical physics". In Tromp's view the problems of dowsing and radiesthesia belong to the wider field of "para-psychical problems", into which he includes homeopathy and other unexplained phenomena, and which are connected to the "web of electromagnetic forces which seem to regulate all living process on earth". He is convinced that these problems are of a more general significance and "ask for more extensive physical research". They are so extremely complicated that it is impossible for individual scientists to tackle them alone; a group effort is called for. Their solution is "not only of academic importance, but might throw a completely new light on the medical, physical, chemical, and biological sciences, and its influence will without doubt be considerable". The study of this large field should be taken out of the hands of charlatans and be studied by scientists of good repute. It "has been given by the author the name of psychical physics", but "it could also have been called biophysics", only that of course "existing biophysical laboratories do not concentrate on the use of physical methods in the study of psychical phenomena. The vitalists strongly object to the name of psychical physics, as they are convinced that psychical phenomena are ruled by (...) laws fundamentally different from the physical laws". But "such a distinction is not based on facts; psychic phenomena can be approached by using physical and physicochemical methods".

In a farsighted and daring paper that Tromp published in 1961, these ideas are further extended (Tromp, 1961). We find that in order to understand the place of fields of research such as psychophysics, biophysics and biometeorology in the order of the sciences, he came to classify them into the category of "border sciences". These are defined by him as "those branches of science which interconnect the fringes of well-established basic sciences" such that "new independent sciences" are created. The border sciences "also comprise these types of fundamental research which penetrate into completely unknown realms of human knowledge, until recently considered the domain of vague, unrealistic quasi-scientists and unfortunately often the hunting-ground of unscientific charlatans". According to Tromp, "the greatest achievements in the future of science will result from the interaction of existing and recently developed branches of science, an interaction that creates 'border sciences' ". Tromp differentiates between "established border sciences" and "non-established border sciences" which "may in not too far distant future, develop into new independent branches of border sciences". The former comprise, e.g., geology, psychophysics – which includes "physical neurology" and "physical embryology"– geo-ecology (which concerns the interaction of environment and living organisms, including bioclimatology and biometorology), "biorhythmics", and finally, cybernetics. Among the non-established border sciences he mentions astronautics and "supersensorics", concerning "certain phenomena of perception based on presently not explainable physiological and physical mechanisms" in man and animals, like telepathy, clairvoyance, hypnosis, altered states of consciousness, yogic phenoemena, and the homing instinct of animals. Therefore, many of the scientific disciplines which below are described as contributions or branches of integrated biophysics, would be classified by Tromp as border sciences.

However, Tromp makes clear that for him border sciences are of high significance for the future of mankind. As very complex branches of human knowledge, they can only be developed by the common interdisciplinary effort of many experts in various scientific disciplines, cooperating in a truly universal spirit. Besides interdisciplinarity and international cooperation, they require great mental flexibility – requirements that may not be had without a drastic change in our educational systems, such as the introduction of an early teaching of the interconnectedness of the specific sciences. Tromp also has some good remarks about the reasons for the great resistance of orthodox science frequently encountered by the border sciences. The first reason is that "Scientists are often less unbiased and less open-minded than one would expect". He quotes Alexis Carrel, the great physiologist and Nobel laureate, who wrote in his book *"Man, the Unknown"* (1935): "Our mind has a natural tendency to reject the things that do not fit into the frame of the scientific and philosophical beliefs of our time. After all, scientists are only men. They are saturated with the prejudices of their environment and of their epoch. They willingly believe that facts that cannot be explained by current theories do not exist. Evident facts having an unorthodox appearance are suppressed. By reason of these difficulties the inventory of the things which could lead to a better understanding of the human being has been left incomplete". A second reason for the resistance to the border sciences is the interest shown by charlatans and "cranks" in these subjects which makes a scientist reluctant to enter this field of research. Thirdly, the acceptance of some of the phenomena, e.g., precognition, requires a fundamental revision of basic concepts of the natural sciences, physics in particular, "overthrowing several fundamental pillars of knowledge and creating a feeling of mental unrest and instability which most scientists cannot endure". Finally, Tromp suggests the establishment of a "Universal Academy of Border Sciences" which may be started with the faculty in which work is already most advanced, and then could be extended to the other border sciences.

3.1.7 The Cambridge Biotheoretical Gathering

There are also two group efforts that may serve as inspirational models for the development of integrative biophysics: the *"Biotheoretical Gathering"* of the Cambridge Group of Theoretical Biology active in the 1930's (Waddington, 1968-72; Abir-Am, 1987) and the Paris *"Institut de la Vie"* founded in 1969 and active until the early 1990's.

The first group was formed in 1932 by several speakers of the session on "The historical and contemporary interrelationships between the physical and the biological sciences" at the 2nd International Congress for the History of Science that took place in London in the Summer of 1931 (Abir-Am, 1987), and existed till the outbreak of World War II. The founders of the group, theoretical biologist Joseph H. Woodger, biochemist and embryologist Joseph Needham, experimental embryologist Conrad H. Waddington, mathematician and philosopher of science Dorothy M.Wrinch, and crystallographer John D. Bernal, were non-conformist scientists striving for change in both science and society and were mainly concerned with recasting the historical relationships between the physical and the biological sciences. Most of them subscribed to various forms of holistic views of the organism and considered the concept of biological fields as highly relevant to the understanding of morphogenesis (Bischof, 1998). They viewed biology as the "science of the future" and their common goal was the development of a theoretical biology. According to Abir-Am the group's activities may be divided into three phases. In the early 1930's, they developed a "common theoretical discourse on the epistemological relationship between the biological and the physical sciences", stimulated by the example of D'Arcy Wentworth Thompson, Alfred N. Whitehead and Ludwig von Bertalanffy. In the mid-1930's, the group formulated a "transdisciplinary research program, integrating problems and experimental resources from specific branches in the disciplines of biology, physics, mathematics, and philosophy". Named "mathematico-physico-chemical morphology", the research program "embodied a new rationale for the unity of science and encouraged theoretical and experimental syntheses across the institutionalized boundaries of the above disciplines". In the late 1930's, the group tried to establish a research institute designed to validate this transdisciplinary program and for this purpose negotiated with various science policy agents such as the University of Cambridge, the Rockefeller Foundation, and the Royal Society. For some time, the Rockefeller Foundation was interested in supporting the establishment of such an institute. They funded several smaller research projects of the group, but Warren Weaver, director of its Natural Science Division, eventually terminated support for the project, which ended the activities of the group and the Cambridge career of Needham and Waddington. The main reasons were the renown of the group members as political and scientific radicals and institutional resistance to the transdisciplinarity of the scientific program and to the pluralistic and participatory model of collaboration and organization practiced in the group and proposed for the institute. In retrospective, the transdiciplinary research programs the Cambridge Group of Theoretical Biology had articulated without doubt were one of the main contributions to the emergence of molecular biology; however, their conception of a new type of biology, based on the fusion of morphology with biophysics, may well have led to an alternative conception of molecular biology, had it not failed to get funded and institutionalized.

3.1.8 The Institut de la Vie

Thirty years later, another multidisciplinary effort to "mobilize and conjugate the resources of contemporary science for the fundamental understanding of life" was initiated by the Parisian *"Institut de la Vie"* under the direction of Maurice Marois, professor of medicine at the Sorbonne. It was, however, Herbert Fröhlich at whose suggestion this series of conferences was created (Fröhlich & Hyland, 1995). Fröhlich was introduced to the *Institut* – which up to this moment had been more sociologically oriented - some years after its foundation, when he accompanied his wife Fanchon to the mountain village of Alpbach (Tyrol) where she attended one of the famous Alpbach conferences on science and life, while he only wanted to do some mountain-climbing. At a lunch hosted by Marois, the founder of the Institut asked him what could be done to bridge the "gap between physics and biology". Fröhlich, then president of the International Union of Pure and Applied Physics (IUPAP), suggested that an international conference should be convened to discuss possible cross-fertilizations. An organizing committee was set up – comprising Pierre Auger, Alfred Fessard, Herbert Fröhlich, Pierre Grassé, A.Lichnerowicz, Ilya Prigogine, Leon Rosenfeld and Marois – and at the end of June 1967 the *"1st International Conference on Theoretical Physics and Biology"* took place in the Palais des Congrès at Versailles, jointly sponsored by IUPAP and the French Minister of Scientific Research and Atomic and Spatial Questions, Maurice Schumann. This was the first of a series of conferences of the Institut on this topic (Marois, 1969, 1971, 1973, 1975, 1997), held every two years, except when the lack of funds did not allow it, and attracting many prominent scientists (including several Nobel prize winners) from both the physical and biological sciences, among them Albert Szent-Györgyi, Francis Crick, Jacques Monod, François Jacob, Walter M. Elsasser, Albert Dalcq, Franz Halberg, Eugene Wigner, Henry Margenau, K.Mendelssohn, R.S.Mulliken, Severo Ochoa, Lars Onsager, Manfred Eigen, Hermann Haken, Isidor Rabi, S.L.Sobolev, Etienne Wolff, and Laszlo Tisza.

Here again the attempt was made to develop a theoretical biology, conceived as "a special form of biology which would be the pendant of theoretical physics and which may throw light on those parts of the domain of life that have remained obscure" (Marois, 1969). As the Danish physicist Leon Rosenfeld wrote in the same volume, they were not the usual kind of scientific conferences, but were designed as "experiments in establishing contact between two branches of science, theoretical physics and biology, which so far have developed independently of each other, but which are now converging towards a common ground". Pierre Auger, President of the scientific commission of the UNESCO, emphasized that it was "necessary in a time of specialization to break the barriers between specialities and even between disciplines, and to return to a unitary concept of science as that of antiquity which only made way under the pressure of the immense masses of new and uncorrelated knowledge", in order to find "the grand principles and general laws which cross the entire field of the sciences, be they exact or natural". He predicted that theoretical physics and biology would henceforth enter into a definitive and close union. However, one of the principal postulates of the Institut de la Vie was that it was not sufficient to use classical physics for explaining biological mechanisms; it was necessary to treat living systems by recourse to quantum physics which was considered more adequate. One of the most significant contributions of the Institut de la Vie was probably that Herbert Fröhlich found in these meetings the adequate resonance and expertise to develop the ideas on coherence in biological systems that have proved so essential for the development of quantum biophysics. At the first conference of the Institut de la Vie he gave the famous lecture on *"Quantum mechanical concepts in biology"* (Fröhlich, 1969) in which he introduced the concepts of long-range phase correlations and coherence. In his introduction to the second conference, he criticized the assumption that all important biological principles will be ultimately expressed in terms of molecular properties. He pointed out that "some of the most important properties of materials imply concepts which have no meaning in terms of single particles or of their pair interactions. Order in physical systems is one of these concepts". Ordering by long-range phase correlations, as found in connection with the properties of superconductors and superfluids and also present in lasers, was a feature not explainable by the properties of single molecules that Fröhlich suggested was also essential in biological systems.

3.2 The Founders of Biophysics

For a better understanding of the development of biophysics I would now like to return to its origins. The onset of the scientific study of life was also the beginning of biophysics. The founders of biophysics were a group of German scientists in the mid-19th century who first did systematic physiological studies by using physical methods. Although certain isolated problems in physiology had been treated before 1840 in a physical manner, by such men as Ernst Heinrich Weber, Richard von Volkmann, Hugo von Ziemssen and Johannes Müller, the so-called "Berlin school of physiologists", including Hermann von Helmholtz, Emil DuBois-Reymond, Ernst von Brücke, and Carl Ludwig, were the first to conduct a "broadly planned, systematic investigation of an extensive field of physiological phenomena in accordance with the most rigourous physical methods" and assert as a general law that "a vital phenomenon can only be regarded as explained if it has been proven that it appears as a result of the material components of living organisms interacting according to the laws which those same components follow in their interaction outside of living systems", writes Adolf Fick, pupil of Carl Ludwig and author of the first textbook of biophysics, in his *Collected Writings* (1904). In 1847, this group had set up a program which seems to anticipate that of modern molecular biophysics (Cranefield, 1957). This program is reflected in the following statements by DuBois-Reymond, taken from Cranefield. In 1841 he wrote "I am gradually returning to Dutrochet's view 'the more one advances in the knowledge of physiology, the more one will have reasons for ceasing to believe that the phenomena of life are essentially different from physical phenomena", and in 1842: "Brücke and I have sworn to make prevail the truth that in the organism no other forces are effective than the purely physical-chemical". In 1848, in the preface to his famous *"Untersuchungen über thierische Electricität"*, DuBois-Reymond asserted that "it cannot fail that...physiology...will entirely dissolve into organic physics and chemistry".

In 1856 Adolf Fick, strong adherent of all the goals of the Berlin school, published the first textbook of biophysics (Fick, 1856). But the program of the Berlin school of reducing physiology to physics and chemistry was quite premature; 19th century physics and chemistry were not sufficient to provide molecular explanations or any other complete physical models for living systems. As Cranefield has shown, the Berlin school has failed to carry out its program of 1847 and has mainly lived on through its physiological approach. It was very successful in establishing experimental methods - which they were, however, by no means the first to introduce. Their anti-vitalistic stance, the assertion that the explanation of life processes must be sought in the ordinary laws of inorganic nature, had its most significant importance in the implication of an intelligible and accessible causality, making life processes amenable to experimental investigation. The only biophysical fields developed by it that continued to be of importance in classical physiology are the mechanical and thermodynamical investigation of muscular contraction and the electrical study of the nerve impulse. General physiology, however, till World War I followed a quite different course than the one outlined by the 1847 program. It is only in the program of the molecular-biological variety of biophysics predominating since about 1960 that this program seems to be carried out. The Berlin school also set the agenda for the creation of "scientific medicine" through its influence on the reform of medical research and education in the USA brought about by the famous "Flexner report" in 1910. The leaders of the reform which led to the exclusive acceptance of experimental science as the basis of medicine and the marginalization of homeopathy, electrotherapy and other alternative therapies and schools of thought by 1930, were a group of American pupils of Ludwig, among them W.H.Welch, H.P.Bowditch, F.P.Mall, and J.T.Abel (Flexner & Flexner, 1941).

However, the usual characterization of the German founders of biophysics at the beginning of the 19th century by historians of science as staunch reductionists and opponents of vitalistic and idealist ideas in biology has to be corrected, as Culotta has shown (Culotta, 1974). In reality they were not in such a sharp opposition to the romantic *Naturphilosophie* spirit of the time, and nearer to the antireductionistic approach of Claude Bernard, than is generally assumed. This is especially true if we consider men such as Ernst Heinrich Weber and Gustav Theodor Fechner who constitute a subgroup of the Berlin school that has also been called the "Goettingen school of physiology" (Gallagher, 1984). They even recognized consciousness as the "ultimate problem of biology" and saw the necessity of including it into biology, but at the same time realized that science was not yet prepared to do so (Culotta, 1974). However, it was the French school of physiology founded by Claude Bernard, who really set the course of general physiology till World War I, and can also be considered as the ancestors of a more holistic school of thought in biophysics.

3.3 The Physiology of Regulation, the Fluid Matrix of the Body and Physical Chemistry

3.3.1 Claude Bernard: Inner Environment and "Terrain"

Bernard's concept of the constancy of the "milieu interne" (internal environment), first formulated in 1859 and fully developed in 1865, was central to his experimental work and theoretical outlook and had a considerable influence on later developments in physiology (Bernard, 1859, 1865; Holmes, 1963; Olmsted, 1967). He maintained that "protective functions" (regulative mechanisms) existed in the organism that maintained the internal environment in order to preserve its "vital activity". The "dislocation and perturbation of these functions" first caused pathological changes in the fluid "terrain" (soil) in which cells and organs were embedded, and finally may lead to sickness and death. Bernard also emphasized the interconnection of the organism with the environment; internal regulation was based on full communication with and active response to the changing environment. The maintenance of the constancy of the inner environment had allowed the development of higher organisms and the independence of life from its oceanic origins. Bernard first identified the inner environment only with blood plasma, then extended it to the lymph, and finally emphasized that it consisted of the totality of the body fluids.

Bernard's concept of the "terrain", closely related to the "milieu intérieur", is one of the most seminal and fruitful contributions of early physiology to biophysics and also had a great influence on holistic medicine, especially in France. As Charles Richet, the famous French immunologist, remarked in 1927 in the preface to a book on the "terrain" by his pupil Héricourt (Héricourt, 1927), it originated in the observation that the same pathological factors often produced a great variation in response in different individuals, therefore the physiology – the tissues, immune system, and body fluids - must be, like the psychological personality, very differentiated and vary from one individual to the next. In 1936 the French biochemist Wladislaw Kopaczwewski writes in a paper on the same subject that the terrain actively counterbalances the pathogenic influences (either from external or internal origin) to a certain degree and acts a barrier to noxious agents (Kopaczwewski, 1936). In the period of 1870 to 1920, the success of Pasteur's and Koch's bacteriological work caused a tendency to overvalue external pathogenic factors and to underestimate the role of internal factors, i.e., the terrain and the active regulatory role of the organism. Pasteur also recognized the role of the terrain, but saw it merely as a passive, static and unchanging stage for the activities of the microorganisms, comparable to the culture media he used in his laboratory.

3.3.2 Physical Chemistry and the Homeostasis of the Fluid Matrix

With the concept of the terrain the founder of experimental physiology not only became one of the fathers of the research in physiological regulation, but also triggered a renaissance of humoral physiology based on the introduction of physical chemistry – mainly the concept of dilute ionic solutions, developed by Jacobus H. van't Hoff and Svante Arrhenius - into physiology. The regulation of the internal environment of the body fluids by the control of hormones and electrolytes characterized the work of pioneers like René Quinton, Léon Frédérick, Joseph Barcroft, Ernest H. Starling, Lawrence J. Henderson and Walter B. Cannon.

Starling, pioneer of hormone research, who with W.M.Bayliss in 1902 first isolated a hormone (secretin) and in 1905 introduced the notion of "hormone", was a pioneer in the investigation of peripheral circulation, the role of osmotic forces and the fluid exchange between capillaries, intercellular tissues and the lymph system. He showed the existence of an equilibrium between the blood pressure in the vascular system and the osmotic forces in the peripheral capillaries and the interstitial tissue (now known as "Starling equilibrium"). He was convinced that these processes were an expression of the "wisdom of the body".

Henderson, influenced by the hippocratic idea of a healing force of nature, studied the regulation of acid-base-balance by the various chemical buffer systems, mainly in the blood. In "*Fitness of the Environment*" (1914) he developed the idea, derived from his physiological work, that the physical and chemical properties of the inorganic environment, especially those of water, carbohydrate compounds and carbonic acid, were fit for the development of organic life. This correspondence could not be by chance. In this fitness of the environment for life the unique properties of water played a prominent role.

Cannon in 1929 introduced the the concept of "homeostasis" as a mechanism stabilizing physiological variables within a certain range of variation; this took place mainly in the *"fluid matrix of the body"*. He also introduced the concept of stress, defined as the straining of the homeostatic mechanisms by the breaching of critical levels of the physiological variables; this could in his view be caused by emotions, fear hunger, rage or other emergency situations. In his view, bodily reactions always were protective, purposive, appropriate and "wise" (Cannon, 1929, 1932).

This line of research was later continued by Hans Selye (1907-1982) who in 1936 started a series of experiments to study the nonspecific, systemic responses of the organism to a wide range of stressful challenges like physical exertion, exposure to radiation, heat and cold, traumatic wounds and loss of blood, disease, injury, infection, danger and fear. He had already earlier on made the observation that many different acute and chronic diseases were all accompanied by the feeling of exhaustion and the same group of symptoms, and wanted to understand what this general "state of being sick" was. In the theory of the "General Adaptation Syndrome" (GAS) which Selye formulated as a result of his experiments (Selye, 1936, 1946, 1950; Weiner, 1992), he identified this general state of being sick as a result of an unspecific, systemic and uniform reaction of the organism in which adrenal corticosteroid hormones play a central role and which is characterized by three stages: (1) The "alarm phase" in which the stress is experienced as a hardship, and the organism reacts with restlessness and tenseness, loss of appetite and sexual drive, increased cell-membrane poermeability, and loss of temperature and tension, or even depression and shock, depending on the severity of the stress. (2) The "stage of resistance", where the first reaction to the stress is counteracted by neural and hormonal activation, the organism becomes used to the stress, and the appetite is restored. (3) The "stage of exhaustion" in which the organism cannot stand the stress anymore and gives up, the manifestations of the alarm reaction return and changes in arterial blood vessels occur. Selye's concept of GAS was used to explain the pathogenesis of many diseases, named by Selye "diseases of adaptation", and his concept of stress found wide application in medicine and physiology, but even more in the social and behavioural sciences (Weiner, 1992).

3.3.3 The French School of Biophysics

In the tradition of Bernard, the French biophysics school of Fred Vlès and Wladislaw Kopaczewski continued the humoral-physiologic approach with physico-chemical studies of acid-base-balance and reduction-oxidation potentials and their influence on the proteins and colloids of the "terrain" of the organism (Vlès, 1927, 1929, 1936 a,b; Vlès et al., 1931, 1936c; Reiss, 1926, 1940, 1943/43; Reiss et al., 1942/43; Kopaczewski 1921-22, 1923, 1926, 1930-38, 1933; Garnier, 1959; Benezech, 1962). Vlès, who like the other members of this school held that water was the basis of biology because its properties determined many of the properties of living substance, also was one of the first to recognize and study the biological significance of water structure (Vlès, 1936 d,e). Vlès and his pupils perfected the pH and redox measurement of blood and other body fluids established by Michaelis (1914, 1933) and Clark (1926, 1928) and later taken up and popularized by Louis-Claude Vincent (1954, 1956 a,b), Ernst Ziegler (1960), and Werner Kollath (1968). (For recent biophysical work based on Vincent's approach see Országh, 1990, 1992, and Fougerousse, 1992; a contemporary textbook on electrolytes and acid-base balance in the body fluids is Eccles, 1993). An outstanding early example of the clinical application of the study of tissue pH is Delore's work on its role in pulmonary tuberculosis (Delore, 1926).

3.3.4 A New Concept of the Cell

As usual, the new approach of physical chemistry has not only led to many advances in biological understanding, but also has caused a number of misconceptions that required correction. One of the most fundamental of these probably is the assumption that the cell is in essence a membrane-covered aqueous solution of free proteins, ions, and other small and large molecules. The "membrane-pump theory" of the cell - first proposed in 1877 by the plant physiologist Wilhelm Pfeffer, who also discovered osmosis, established in 1902 by Helmholtz' pupil Julius Bernstein and later refined by Frederick Donnan (1911), Alan L.Hodgkin (1949), Andrew F.Huxley and Kenneth S.Cole - which is based on this assumption, is still one of the paradigmata of contemporary biology. According to the membrane theory, the difference in ionic concentrations between the cytoplasm and the extracellular medium – mainly in sodium, potassium and chloride ions – which also serves to explain the biopotentials – is due to the semipermeability of the membrane (older version of the theory), or to the "active transport" by ATP-driven ionic pumps.

However, since the 1950's a number of alternative conceptions have developed, which trace their origin to early observations of the gelatinous (colloid) properties of living matter, and of the anomalous behavior of water associated with certain biomolecules. Like Abraham Trembley, C.F.Wolff and other biologists before him, Felix Dujardin in 1835 recognized that entity as a "living jelly" that since Jan Evangelista Purkinye (1839) is known as "protoplasm". After the introduction of the concept of the "colloid" by Thomas Graham in 1861, many biologists and physiologists have conceived of the protoplasm as a hydrated polyphasic colloidal system (Fischer & Moore, 1907; Fischer, 1910; Fischer & Hooker, 1933; Schade, 1909, 1921a; Kopaczewski, 1923, 1926a, 1930-38; Lichtwitz, Liesegang & Spiro, 1935; Fischer & Suer, 1951). In 1908, Benjamin Moore and Herbert Roaf, and in the 1920's, Ernst & Scheffer (1928) suggested that the potassium ions in cells, the most abundant intracellular ions, existed in a bound and unionized form. Most prominently, Heinrich Schade already in 1908 recognized the cell as a polyphasic colloid (Schade, 1909) and wrote in his pioneering book on *"The Physical Chemistry in Internal Medicine"* (1921) that "The body of the cell is neither uniformly solid nor uniformly fluid; each cell rather forms a (...) 'microheterogenous system', a mixture of gel-like and sol-like masses and true solutes in a common medium, the colloid nature giving the characteristic feature to the whole as well as to its parts". Martin H. Fischer postulated in 1910 that living cells, together with their intercellular substance, form a water-binding colloid that cannot be compared to a suspension or solution of molecules in water, but rather is a "water-free" hydrated system in which the water is not free, but bound to its colloids, mainly proteins in the form of alkaline and acidic proteinates with a high hydratation potential (Fischer, 1910, 1951). In 1938, Fischer and Suer suggested that protoplasm was the "union of protein, salt and water in a giant molecule" (Fischer & Suer, 1938).

In the view of Schade, Fischer and many other biologists of the time, the water in the cell and in the extracellular spaces was not free but existed in the form of "bound water", also called "Schwellungswasser" (swelling or imbibition water) (Newton & Gortner, 1922; Gortner, 1938). The phenomenon of the strong water affinity of certain biomolecules was first discovered in 1848 by Carl Ludwig of the "Berlin school of physiology" and again observed in 1917 by J.R.Katz. However, in the 1930's Nobel laureate Archibald Vivian Hill and others seemed to show that bound water and bound potassium ions did not exist, and thus the view of the living cell as a membrane-enclosed solution of free ions and free water was saved for a while (Hill, 1930; Hill & Kupalov, 1930). In addition, colloid chemistry in general lost its explaining power in the 1940's. Although in 1938 we find a declaration for the polyphasic colloid character of the cell by the eminent neurophysiologist Charles Sherrington, the more consequential proposition of two major alternatives to the membrane theory of the cell had to wait till the early 1950's; it initiated a controversy that even today has not come to its decisive end.

In 1951 and 1952, Afanasy S.Troshin, student of the eminent Russian cell physiologist Dimitri H.Nassonov, presented his pioneering studies on cell permeability, which were based on his teacher's work and provided the foundation for his "sorption theory" of the cell (Troshin, 1956, 1958, 1966; Nassonov, 1959). Like the other variants of the "phase theories" or "coacervate theories" proposed as alternatives to the membrane theory, this was based on the interaction of macromolecules and ions with cell water and the protein-lipid membrane. Troshin pointed out that in contrast to the low-protein extracellular medium, the interaction of electrolytes with proteins in the cytoplasm is so strong that ionic mobility and therefore electrogenic activity of ions is strongly reduced; the cytoplasm forms a "complex coacervate" in which proteins, ions and most of the water are strongly bound. Cytoplasm and extracellular medium therefore form two distinct phases. A coacervate (a concept introduced into colloid science by Bungenberg de Jong in 1929) is formed when hydrophilic proteins, together with water, form droplets and amoeboid masses that are distinctly demarcated from the ambient fluid. It encloses 80-90% water and remains hydrophilic. Coacervation depends on a strong enough dipole moment and electric charge of the proteins and on the electrolyte content of the medium. Through coacervation the protoplasma obtains the property of liquid-crystallinity (Recently the topic of liquid-crystallinity, first discovered in 1888 by F.Reinitzer and O.Lehmann, as a property of living systems has been again discussed by several authors – see Mishra, 1975, Ho, 1996). Troshin's work was followed up in Germany by Jakob Segal and his group (Segal, 1958; Segal et al., 1983).

The most momentous of these alternative cell theories was the "Association-Induction Theory" put forward at approximately the same time by the Chinese-American cell physiologist Gilbert N. Ling (Ling, 1960, 1962, 1970, 1984, 1992, 2001). It was then extensively tested in the 1960's and 1970's, most notably by Freeman Cope (1970), Carlton Hazlewood (Beall et al., 1967) and Raymond Damadian by means of the newly developed Nuclear Magnetic Resonance (NMR) technology. The subsequent invention of Magnetic Resonance Imaging (MRI) by Damadian actually was a result of Damadian's testing of the Ling theory of cell water, when he discovered a difference in NMR signals from water in cancer cells to those from normal cells (Damadian, 1971). The insight that any theory attempting to explain the unequal distribution of ions between the inside and outside of cells, the dynamic aspects of solute and water exchange and the bioelectric phenomena of cells requires knowledge of the physical state of water in the cells, has stimulated research on the role of cell water and and its supramolecular structure in the following decades, especially after these concepts first reached a wider scientific audience and recognition in 1965 at a conference on the biological role of water structure in the New York Academy of Sciences (Whipple, 1965). The phase theory of the cell assumes the existence of aqueous compartments (phases) in the cell with distinct metabolic activities, and the exclusion of solutes (e.g., sodium), to some extent, from the cell by the changed solvent properties, and also predicts that changes in the physiological state of the organism can alter the physical properties of cellular water (see, e.g., Cope, 1969, 1970, 1973, 1975, 1976, 1977; Drost-Hansen & Clegg, 1979; Clegg, 1981, 1983, 1984, 1987, 1992; Hazlewood, 1971, 1979, 1991; Tigyi et al., 1991; Wiggins, 1971, 1972, 1990).

Of course, the concept of a highly structured cell is also strongly supported by the recent discoveries of the subtleties of cellular architecture. In addition to the discoveries of the first cell organelles (Golgi bodies, mitochondria) in the late 19th century, the application of electron microscopy, beginning with the work of the Belgian-American cytologist Albert Claude in 1945, brought the discovery of the endoplasmatic reticulum, of microtubuli, microfilaments, intermediate filaments, and finally the microtrabecular lattice (Porter, 1981, 1984). Today, it is clear that we have to view the cytoskeleton as a highly structured three-dimensional network of these elements which is very dynamic and labile. Its elaborate structure is very easily disassembled under the influence of small perturbations, and thus oscillates between a gel state in which the structure is up and visible and a sol state in which it is dissolved. Recent molecular-biological research has also shown that the structures of the cytoskeleton pass through the cellular and nuclear membranes and thus establish a continuity between extracellular matrix, cytomatrix and the nucleus and its contents (Pienta & Coffey, 1991).

The discovery of the importance of water structure for the understanding of cell and organism is also significant in connection with the evidence we will describe later, for a role of the structure of cellular water in the reception of environmental information, including ambient electromagnetic fields, by the humoral system formed of body water and extracellular matrix.

3.3.5 Synthesis of Regulative Mechanisms

In 1918, the German pathologist Friedrich Kraus (1858-1936) made a first attempt to synthesize the findings of physical chemistry, the physiology of neural and humoral regulation and colloid science from the standpoint of constitutional medicine. He emphasized the functional unity of the various regulative mechanisms of the endocrine, the vegetative-nervous and the physico-chemical systems, and combined them in his concept of the "vegetative system" which is the functional unity of the organism's colloids, the body fluids with their electrolytes, and the vegetative nervous system. In the "moisture theory of life" he proposed in his book *"Allgemeine und Spezielle Pathologie der Person"* (Kraus, 1918-26), a reformulation of humoral physiology, he viewed the organism as an oscillatory system of ionotropic colloids whose state constantly changes between the liquid "sol" and the solid "gel" state, and whose basic mechanisms are mechanical (hydraulic) and electronic (but with conductors of second order). According to Kraus, the main work of the organism consists of swelling and de-swelling; the transition from the wet to the less wet state performing the work. Kraus saw the stream of water through the body, driven by the dynamics of protoplasm, as one of the major features of the living state, and he considered the degree and the distribution of water saturation and the turgor of the tissues as a measure of life. One of the important elements of the "vegetative system" was thus the "vegetative streaming" of the body fluids in the vascular system, the lymph system, the interstitial spaces (connective tissue) and the cell. However, "the colloidal biosystem is not only driven and regulated by water, but also by specific salt effects respectively by electrical interface potentials", and thus the antagonism of electrolyte cations and anions was important. He considered the electrolyte content of tissue as an essential element of constitution and the distribution and shifting of ions in the organism as an important mechanism of life. The changes in the distribution of electrolytes cause shifts of body water, nervous excitation and changes of the state of colloids. In the tradition of colloid science, surface tension and interface potentials which are seen by Kraus as an expression of the "vegetative system", are considered as essential factors in all phenomena of living substance – "they determine the form of the fluid system and the distribution of solutes" (for more recent work on surface forces in biology, see Ninham, 1982).

Kraus' early effort for a synthesis was continued in the work of later pioneers such as Schade, Ricker, Eppinger, Hauss and Pischinger. They introduced important new elements for such a synthesis missing in his work, mainly the fundamental insight on the central function of the extracellular matrix.

3.3.6 The Extracellular Matrix

While for a long time the investigation of the terrain followed Claude Bernard in almost exclusively emphasizing the role of the body fluids (especially blood), from the first decades of the 20^{th} century onwards some physiologists and pathologists also started to pay attention to the connective tissue. Now usually called extracellular matrix, this is strangely enough one of the most fundamental systems of our organism that at the same time has been largely neglected by physiology and medicine since the time of Virchow.

One of the earliest and most groundbreaking pioneers in this field was the already mentioned founder of molecular pathology, Heinrich Schade (1876-1935) (Schade, 1912a & b, 1913, 1921 a & b, 1922, 1923a,b,c – on Schade see also Hadjamu, 1974). Schade may well be called the founder of modern connective tissue research; he was the first physician in the 20^{th} century to recognize the "organ function of connective tissue" and to establish the nature of the extracellular matrix as an active physiological system in its own right. He criticized its characterization by Rudolf Virchow as "connective tissue", as it fulfilled far more than just connecting and supporting functions. To this contempt of connective tissue by the founder of "cellular pathology", not surprising because of the predominance of cellular mass over the portion of extracellular tissue and by reason of its poor visibility under the earlier staining methods, Schade opposed his colloid-chemical concept. Starting with physicochemical researches on the biological functions of connective tissue in 1911, he experimentally demonstrated some of the fundamental systemic functions of connective tissue, its colloidal nature, the significance of pH for connective and other solid tissues, and of hydrogen ions for pathology in general. He summarized his findings in the groundbreaking work *"Physical Chemistry in Internal Medicine"* (1921). Thus he established connective tissue as a central issue in pathology and thereby laid the ground for the later work by Gustav Ricker, Hans Eppinger, jun., Heinrich Thiele, Werner H.Hauss, Alfred Pischinger, Otto Bergsmann, and Hartmut Heine, among others.

The work of these researchers was concerned with identifying and more precisely characterizing Claude Bernard's "terrain" which is the "locus" of the functional disturbances which predate pathological evidence, as Gustav von Bergmann had shown in 1932 (Bergmann, 1932). Bergmann (1878-1955), prominent professor of internal medicine, had made clear that the morphological changes of pathological evidence must be considered as the end result of a development of disturbed functions that may have taken years. He therefore demanded more attention to the "latent and larvated early forms of illness", which should be recognized and reacted to already before the occurrence of objective morphological signs, by constitutional thinking, clinical tests of functions and the abolishment of artificial demarcations between "functional disease " and "organic illness". Already in 1912, Felix Buttersack (1865-1950) had localized the latent illnesses in the connective tissue and had introduced the notion of "ground tissue" to discriminate between supporting tissue and soft connective tissue (Buttersack, 1912).

Ricker (1870-1948), a pathologist, was a protagonist of "neural pathology" and maintained that the neural regulation of body liquids and vascular permeability was a key process in physiology. He postulated in his "relational pathology" (Ricker, 1905, 1924), against Virchow, that there is no independent activity of cells; he held that the network of relations between nervous system, blood, liquids of the tissues and tissue itself has to be viewed as a single system. He was convinced that tissue alterations of other than nervous etiology do not occur without forcible destruction. The tissue as a living innervate could not but react neurally, because the complete reception of stimuli and the reaction to it was mediated by the nervous system that was especially made for the processing of stimuli. In 1924 Ricker proposed a "law of stages" according to which different neural stimulations cause different changes of flow in the capillaries and consequently changes in tissue. Weak stimuli (first stage) on the vascular innervation excite the dilatators. In the scecond stage (medium stimulation) the constrictors are excited which slows down the capillary and venous flows. Stronger stimulation causes ischemia and anemia. In the third stage (strongest stimulation) the excitability of the constrictors is suppressed, but also that of the dilatators which remain excitable for a longer time, resulting in a "prestatic state" (very slow blood flow in the phase preceding stasis) and "red stasis" (cessation of blood flow).

Eppinger's "permeability pathology" (1949) is also a neural pathology, based on the work of Hess (1948). The permeability changes Eppinger describes are regulated by the vegetative nervous system; vasodilatation is subject to the vagus. Processes like inflammation, serous and more progressive vascular permeability that allows even red blood cells (hemorrhagic permeability) and white blood cells (purulent inflammation) to pass, therefore are vagus excitations. Vasoconstriction which causes a diminishment of permeability and hyperplastic states, is subject to the sympathicus.

The colloid scientist Thiele (1902-1990), a pupil of Nernst, Haber and Einstein and one of the pioneers of histophysics, demonstrated in work spanning the time from the early 1940's to the late 1960's that the interaction of complex colloidal gels with ions is the basic structuring mechanism in organic structures, especially in connective tissue (Thiele, 1947, 1954,1967; Thiele & Schacht, 1957).

The cardiologist Hauss (born 1907) worked with his group on the biochemistry of connective tissue and on the role of the "non-specific mesenchyme reaction" (NMR) in arteriosclerosis, infarction, myocardial necrosis and rheumatic illnesses (Hauss & Losse, 1960; Hauss & Junge-Hülsing, 1961; Hauss et al., 1968). Hauss demonstrated that the NMR is the basis reaction of the organism in its response to any kind of stimuli; the metabolism of the mesenchyme cells that produce the ground substance and the structural fibers of connective tissue, reacts with high sensitivity to all kinds of stimuli to which the organism is subjected, including infections, toxins, proteins and other foreign substances, lack of oxygen, mechanical stimuli, the influence of the weather, noise, radiation, and emotional stimuli (see below). This reaction was called non-specific because it was triggered reproducibly not by a specific factor, but by many different non-specific factors and events. Hauss and collaborators also demonstrated that the NMR was a pathogenetic principle of universal significance. Many different diseases with multifactorial etiology, caused by various noxious agents, including everyday conditions like working and eating habits, muscular, emotional or mental stress, and banal infections, originate in this reaction which is characterized by the fact that the process induced may easily smoulder for years and even decades without obvious objective or even subjective signs. They also showed that it is possible to achieve a physiological "conversion" (Umstimmung), i.e., increase the tolerance of the connective tissue system and lower the degree of the mesenchyme reaction, by training it with a combination of stresses, starting with low doses and increasing the dose during 2-4 weeks.

The Austrian histologist and embryologist Pischinger (1899-in 1980's), one of the founders of tissue histochemistry, has worked in connective tissue research since 1948 and has developed a "theory of ground regulation" (Pischinger, 1991; Bischof, 1992; van Wijk & Linnemans, 1993; Heine, 1997), according to which the "ground regulation system" (GRS) of the extracellular matrix (ECM) is the most fundamental and oldest regulatory and information system in the organism, older than the nervous and hormone systems. It is the basis of all general and nonspecific immune responses and the carrier of all systemic functions, and also triggers the specific regulations. It controls the physicochemical and bioelectrical situation as well as the bioenergetic processes, such as the water, oxygen, electrolyte and heat metabolism, the acid-base balance, and the redox potential. In this task its interaction with water and water structures plays a key role.

The anatomical substrate of ground regulation is the soft connective tissue (the "ground substance") which fills all the extracellular spaces of the organism and reaches every cell. It consists of a network of highly polymerized glycoproteins in which the connective tissue cells (fibrocytes, mast cells and macrophages) and the structural glycoproteins (collagen, elastin, finbronectin, and laminin) are embedded. As was already recognized by Carl B. Reichert in 1845 and by Georg von Rindfleisch in 1869, proved by electron microscopy in 1949 by Eppinger and further elucidated in 1961 by Hauss, blood capillaries and vegetative endfibers nowhere in the body directly reach the organ cells, but end blindly in the ECM. This makes the ECM a "transit space": every exchange of fluids or other materials between the vascular system and the parenchyme cells (organs) is mediated by the ECM, and also the nerves secrete their active compounds (adrenaline, acetylcholine) into the intercellular fluid. It is the connective tissue cells that take care of the complex interaction between capillaries, vegetative fibers and stationary cells, by secreting prostaglandins, interleukins, interferons, proteases, and protease inhibitors. By the same mechanism, they trigger the phases of the immune reaction and regulate the permeability of the capillaries. They are also responsible for the synthesis and decomposition of the ground substance and the structural glycoproteins, and thus are able to regulate the sponge-like structure of the ECM and the width of its pores, on which the passage of water and substances through the transit space depends.

The structural changes in the ECM are mainly due to changes in the structure of the proteoglycan-water complexes of the ground substance, which are the most essential element of the fundamental homeostasis brought about by the GRS. Because of their strong electronegativity, proteoglycans and glycosaminoglycans (GAG) possess the strongest water-binding and ion-exchanging ability of all tissue substances. Based on this, they guarantee osmotic, electrolytic, and ionic equilibrium in the ground substance and establish the electrostatic tonus of the tissue. They also scavenge the surplus electrons and protons in the extracellular space in the form of oxygen and hydroxyl radicals produced in all enzymatically controlled chemical reactions. In this way they homeostatically regulate the redox potential of the organism and counteract the inflammatory tendencies of the ground tissue.

This makes the GRS a highly complex and interconnected humoral regulatory system with innumerable feedback cycles and high redundancy, able to influence even the central nervous and hormonal systems by way of the capillaries and vegetative nerves. The regulatory capacity of the ECM is highly significant for the disease process; in all acute and chronic dieseases and in cancer, regulative disturbances and structural modifications of the ECM have been demonstrated, which also show in changed redox potentials. The electrostatic ground tonus established by the negative electrical charge of the proteoglycans reacts on every change in the ECM with fluctuations of the potential, that become manifest in redox measurements of the body fluids (method Vincent), or those of electric skin potential and resistance. Therefore, these methods can be used to assess the ground regulation.

By reason of the redox properties of ECM, every change of electrical potential in it represents an information; by means of such informations the GRS also exerts an influence on connective tissue and organ cells. This can happen by way of the potential fluctuations of the glycocalyx in the cell membrane, which are able, if strong enough, by depolarizing cell membranes of muscles and nerve cells or by activating transmitters like cAMP, to transmit information into the cell interior and to influence the structure of cell architecture and of cell water or cytoplasmic enzymes. By way of the recently discovered connections between cytoskeleton and nucleus, an information transfer to the nucleus is also possible (Pienta & Coffey, 1991; Oschman, 1996). The proteogylycan-water complexes of the ECM are a very fast information system; because of their nature as dissipative systems, their structural changes can spread rapidly over the ECM and be utilized as information by the cells. This phase change is due to the high lability of the liquid-crystalline water-polysaccharide complex and therefore can be triggered by minimal stimuli without any energy expenditure worth mentioning.

The important work of Pischinger, based on that of the earlier pioneers, was continued more recently by Bergsmann (1994a,b, 1998) and Heine (Heine, 1997; Heine & Anastasiadis, 1992), among others. The biophysics of the ground system was first studied by the Austrian physician F.Kracmar (Kracmar, 1971) and is more extensively treated in Barrett (1976), Heine (1997), Bergsmann (1994a,b, 1998) and Oschman (2000).

3.3.7 Bioelectronics and the Solid-State Model

Another important contribution to integrative biophysics comes from solid-state physics, or condensed matter physics. Its emergence as an autonomous discipline was connected with a strong opposition against reductionism in physics, as it had mainly developed in particle physics (Jordi, 1998). Among the prominent spokesmen of this movement were Eugene Wigner, Michael Polanyi, and Philip W. Anderson. Solid-state physics is characterized by the application of quantum mechanics to macroscopic phenomena, the tendency to work with realistic and phenomenological models of macroscopic systems, and the notion that the principles organizing macroscopic phenomena cannot be completely accounted for by the laws of atomic and molecular behaviour. As a heritage of its origin in wartime research, solid-state physics also was multidisciplinary from its onset and govened by the conviction that different scientific disciplines have to stimulate each other by sharing methods and conceptual tools. This is the reason why this branch of physics became one of the important contributors to integrative biophysics. One of the developments in the field consequential for integrative biophysics was the development of the theory of superconductivity by Fritz and Heinz London in the late 1920's and subsequently by Vitaly Ginzburg and Lev Landau in the 1950's.

If already the colloid-chemical and phase concepts of the cell described above can be considered as steps towards a shift from the "ideal-gas" model of biochemistry and physical chemistry to the "ordered-crystal" model of solid-state science, the work of the great biochemist Albert Szent-Györgyi, based on a novel solid state approach, has led to another, related field of biophysical relevance which can be seen to continue the tradition of humoral-physiologic thinking. Szent-Györgyi's achievements mark the definite advent of this new biophysical view of the organism. By drawing the attention to the submolecular level of organisation and pointing out the biological importance of charge transfer and excited states of biomolecules, Szent-Györgyi created the field of bioelectronics. He suggested it was useful to explain the properties of living organisms in terms of the electrons which are responsible, ultimately, for the chemical reactions driving the organism. In his ground-breaking Koranyi lecture in 1941 Szent-Györgyi drew attention to the study of energy levels and the role of excitation in biochemistry, and suggested that the conduction-band model of solid-state physics could be applied to biological macromolecules which may possess semiconductive properties. Since then, semiconductive behaviour of organic molecules has been established. Important has also been his suggestion that metastable excited states involving triplet states may play an important role in biochemistry. The study of the role of electronic charge transfer in intermolecular interactions became an important field of biochemical research due to his suggestions. The quantum-theoretical framework for it was created in the early 1950's by R.S. Mulliken. Not less significant was that he pointed out the possibility of collective excitation processes in biological systems and their propagation in the form of excitons (excitation waves).

Szent-Györgyi's pioneering work in bioelectronics has not only led to the discovery of the unique electronic properties of biological materials which recently have become an inspiration for the new field of molecular computing, but have also brought new insights into energy transmission and information processing in biological systems. It is now clear that organisms use and process information by using molecules, electrons, and protons (hydrogen ions); they are able to direct electronic, ionic and proton currents along certain defined pathways (Bone & Zaba, 1992). We are also starting to understand the important role water molecules and their supramolecular organization play in this process, another fact that Szent-Györgyi was one of the first to point out. He remarked that like fish who are unable to see the most obvious fact of their life, "biology has forgotten water, or never discovered it" (Szent-Györgyi, 1971). In his view, water who has "the lowest energy and the highest ionization potential among all biological substances", was "at the bottom of nature", was "the matrix of life" – much more than a material medium filling the space between the structural elements in the cell and the intercellular tissues (Szent-Györgyi, 1957)."It is a mistake to talk about proteins, nucleic acids or nucleoproteins *and* water, as if they were two different systems. They form one single system which cannot be separated into its constituents without destroying their essence". Water greatly mediates and modifies energy transmission, reactivity and many other processes between molecules (Szent-Györgyi, 1960). Szent-Györgyi's work has also played an important role in "bioplasma theory", one of the modern biological field theories synthesizing the solid-molecular aspect and the field aspect of organisms (see below).

In the 1970's, Freeman Cope has also done very valuable work in the application of solid-state physics to biological systems (Cope, 1969, 1970, 1973, 1975, 1976, 1977).

3.4 Cosmic and Atmospheric Influences upon Biological Systems (Biometeorology, Cosmobiology)

As already Claude Bernard has emphasized, higher organisms have their existence in two environments at the same time: the inner environment (milieu interne) and the "milieu externe" of terrestrial and cosmic environment; their life is bound to and influenced by both environments (Holmes, 1963). "The conditions necessary to life are found neither in the organism nor in the outer environment, but in both at once" (Bernard, 1865).

The thesis that weather and climate played a significant role in the health and diseases of man is already expressed in the Hippocratic writings, but it was only seriously tested with the beginning of the 20th century, when such prerequisites as, for instance, regular meteorologic observations under standard conditions, reliable epidemiological records, adequate physiological understanding, and the invention of the climatic chamber for exposing human subjects to simulated weather conditions became available.

As one of the first modern scientists, Svante Arrhenius, one of the founders of physical chemistry who became Nobel laureate in Physics in 1903, tried in 1898 to show the impact of cosmic influences, including that of the moon, on the weather and on living organisms (Arrhenius,1898).

3.4.1 Willy Hellpach

An early pioneer of biometeorology (other names of the field are bioclimatology, medical climatology, and meteorobiology) was the German physician, professor of social psychology and politician, Willy Hellpach (1877-1955), also one of the first German physicians to champion Freud's sexual etiology of neuroses. He was also one of the founders of environmental psychology and treated the relation of man and environment in a very interdisciplinary way, with a broad knowledge about its scientific, psychological and social aspects (Hellpach, 1911, 1924). He mainly became famous through his work *"Die geopsychischen Erscheinungen"* (1911), called *"Geopsyche"* from the 5th edition, which experienced many printings and was translated into several languages. It was this unique book - even later there is nothing comparable to it – which first established biometeorology as a science. He first defined biometerology as the investigation of the influence of all meteorological factors and all atmospheric changes on living organisms, e.g., radiation, air pressure, temperature, humidity, weather fronts, atmospheric electricity, etc., especially the relation of weather and climate to certain health disturbances and illnesses, and the question if certain weather situations and factors can cause or trigger illness, and finally the question if different types of people (constitutional types) react differently to influences from weather and climate. Then Hellpach defined his own "geopsychical" approach. The natural environment was one of the three environmental spheres that man lived in, the others being the social-psychological one and the artificial environment created by man himself. According to Hellpach, the natural environment of weather, climate, soil and landscape had two modes of influence on man, namely the sensory "impression", the influences that are directly perceived by means of the senses, such as heat, cold, wind, rain, storminess, gloom or brightness, on the one hand, and the "tonic effects" of influences like air pressure, atmospheric electricity, the moderate oscillations of air pressure etc., that we cannot directly perceive, that are mediated by the vegetative system and have an even greater influence on us. Together with the influence of landscape and soil, the tonic effects of weather and climate determine our life tonus, vitality, freshness or flaccidity, readiness to act, and mood. "Geopsyche" is the total influence of these factors on our psychic life. In *"Psychologie der Umwelt"* (1924) Hellpach pointed out that general psychology has been conceived "environmentless"; it either is concerned with the internal life of the individual or with the psychological interaction between individuals (social psychology), but not with the third sphere of the natural environment. He pleaded for the inclusion of the two modes of environmental influence mentioned above into social psychology; until now it had been "almost exclusively interpersonally oriented" and "no attention had been paid in it to physical objects, in spite of their unmistakable personal and social significance".

Another instance of early modern research on cosmic influences on human physiology is the report on the correlation of the passage of sunspots over the meridian with sudden illnesses and deaths, based on the continuous observation of patients during 267 days, that the French physicians Faure and Sardou, together with the astronomer Vallot, presented in 1922 to the French Medical Academy (Tocquet, 1951). We have already described the work of one of the major early pioneers of cosmobiological research, the Russian biophysicist Alexander L.Chizhevsky, who in the time of 1920-1950 investigated the correlation of the sunspot cycle with human life with statistical methods (see above).

As for other fields, the 1930's were a very fruitful period for biometeorology in which many of the foundations of our modern knowledge were laid. In 1934, the first biometeorological journal was founded, the "Bioklimatische Beiblätter" (bioclimatological supplements) of the "Meteorologische Zeitschrift".

3.4.2 Bernard de Rudder

In the early 1930's, Bernard de Rudder (1894-1962), a pupil of Meinhard von Pfaundler - a pioneer of constitutional thinking in medicine - and director of the department of pediatrics of the University of Frankfurt, Germany, published the first textbook on biometeorology, *"Grundriss einer Meteorobiologie des Menschen"*(1931), an extensive review and critical analysis of the already vast amount of literature in the field. It helped considerably to overcome many misconceptions of his medical colleagues (Tromp, 1963). Rudder established the seasonality of disease, now a fundamental tenet of biometeorological concepts, and concluded that constitution was clearly a factor in weather sensitivity; weather-sensitive persons usually exhibited an unstable vegetative nervous system. However, he found that the usual constitutional studies of correlations of body types and other classifications with weather sensitivity were not convincing. The question of how important weather-induced vegetative stress was for the induction of illness needed further research. Besides biometeorological studies, de Rudder also did research on growth and development, child psychology, and constitutional anomalies, and examined the question of human cosmic rhythms (de Rudder, 1937, 1948). His broad outlook, interdisciplinarity and talent for synthesis, the ability to discern complex interrelations among phenomena of medical and natural science in a time of specialization, made him the Nestor of German biometeorology (Sargent, 1982).

3.4.3 William F. Petersen

Another important pioneer of clinical biometerorology was William F.Petersen (1887-1950), professor of internal medicine and head of the Department of Pathology and Bacteriology at the University of Illinois, Chicago (Petersen, 1935-37, 1947; Berg et al., 1940; Büttner, 1951; Sargent, 1982). He had been already one of the leading researchers in constitutional medicine, the non-specific resistance to disease and the pathophysiology of the autonomous nervous system, and was just writing the first draft of *"The Skin Reactions, Blood Chemistry and Physical Status of 'Normal' Men and of Clinical Patients"* (Petersen & Levinson, 1930), when in the late 1920's he discovered the hippocratic writings. They led him into intensive investigations of the relationship between weather and illness. In the late 1930's, he started to publish the results in the voluminous studies *"The Patient and the Weather"* (Petersen, 1935-37) and *"Man, Weather, Sun"* (Petersen, 1947). They are the most extensive and comprehensive investigations of man's ability to cope with weather and climate ever undertaken (Sargent, 1982).

In summary, Petersen found that the organismic response to environmental forces comprised a rhythmic pendulation of the autonomic nervous processes of the vegetative system, connected with endocrine and biochemical changes. He called this vegetative rhythm, discovered by him in 1930, the "ARS-COD rhythm", because of its connection with the two types of reactions to weather stimuli. One was the sympaticotonic reaction to cold fronts which he called "ARS phase" because it comprised anoxemia, reduction, spasm (vasoconstriction), and relative alkalosis, and the other was the vagotonic reaction – which could, but not always did, coincide with the succeeding warm front -- of the "COD phase", a period of stimulation comprising catabolism, oxidation, dilation (vasodilatation), and relative acidosis. There were of course individual differences in these reactions at the cellular, organ and organismic levels, but "on the whole the entire population swings in a chemical and physiochemical rhythm that is identical" (Petersen, 1935).

Petersen's key contribution was his insight into the essential unity of man with his geophysical environment – he called man a "cosmic resonator" – , which he proved with the best tools available in his time and explained with a rational theory (Sargent, 1982). His model drew on constitutional medicine and neuroendocrine physiology and clearly explained the successes and failures in coping with the impacts of atmospheric influences. His understanding of the individuality and variability of man, which he successfully applied to the explanation of biometeorological influences, was amply confirmed by later studies of biochemical and physiological individuality and chronobiology (Williams, 1956; Halberg, 1969b; Luce, 1971).

3.4.4 Wladislaw Kopaczewski

In the late 1930's, the French physician, biochemist and physical chemist, Wladislaw Kopaczewski (1886-1953), also made an early attempt to produce a synthesis of the research in the field; he also tried to develop a theoretical foundation for it based on his work on biological colloids (Kopaczewski, 1938, 1939). His fundamentally biophysical conception shows when he writes that "we are now already in possession of a rich documentation which permits the codification of this new branch of pathology. (...) This codification is necessary, as there is already a deplorable tendency to attribute a dominating role to statistics and to clinical observation, when only physics and experimental physiology are able to give the development of this child of our century a happy impetus" (Kopaczewski, 1938).

3.4.5 Ellsworth Huntington

Another contemporary of Petersen, one of America's most distinguished geographers, Ellsworth Huntington (1876-1947), was mainly concerned with the occurrence of climatic cycles in historical time and their influence on human history, health and welfare, but also investigated the influence of seasonal cycles and weather (Huntington, 1915, 1923, 1924,1930,1945;

Sargent, 1982). He was one of the founders of the Ecological Society of America in 1916 and in the same year invented the term "human ecology" to distinguish the work of geographers from that of biologists (see below). In works like *"Civilization and Climate"* (1915), *"Earth and Sun"* (1923), *"Weather and Health"* (1930), and *"The Mainspring of Civilization"* (1945), he concluded from the statistically highly significant correlations found, that were also consistent with the findings of other biometeorologists, that physical environment, constitutional factors (including heredity), and cultural influences work together in determining the rate at which culture and civilization advance; of the physical environment, he concluded that the atmospheric factors had the greatest impact, and found that physical vigour, intellectual performance and health were the most sensitive indicators of that impact. He believed he could demonstrate that certain weather and climatic conditions were optimal for physical vigour and health, including temperature, moisture, and storminess. However, he found that weather factors could only account for one third of the variance in the physiological and pathological processes he studied.

In 1941, the Japanese professor of medicine, Maki Takata, found the influence of an unknown radiation from the sun on blood serum (Takata and Murasugi,1941; Takata, 1951). His findings inspired much of the later biochemical research, as did the work of Piccardi.

3.4.6 Giorgio Piccardi

Highly influential work on the influence of extraterrestrial forces on chemical and biological processes was done from the 1930s to the 1970s by Giorgio Piccardi (1895-1972), professor of physical chemistry at the University of Florence, Italy, in his study of "fluctuating phenomena" (Piccardi, 1962; Capel-Boute, 1974, 1983, 1985, 1990; Manzelli et al., 1994). It began in the late 1930's with his research on the removal of calcareous incrustations in water boilers, which he was able to prevent by adding water pretreated by the glow produced by stirring it with a glass sphere containing a drop of mercury in a low-pressure neon atmosphere. However, he made the strange observation that the action of such "activated water" was not uniformly effective, and he came to believe this was due not to chance, but to some extraterrestrial influence. Already at that time, he suspected that this may be a more general phenomenon, and that often the cause for the well-known non-reproducibility of chemical reactions resided not in the imperfection of experimental conditions, as traditionally assumed, but had their origin in the surrounding space. To test this hypothesis, he devised what he called "chemical tests", standardized reactions like the sedimentation rate of inorganic colloids, such as bismuthyl chloride (BiOCl) and other substances. In order to eliminate known environmental factors such as temperature, atmospheric pressure and humidity, the sedimentation rate of unshielded BiOCl in either activated or normal water was compared with that in shielded condition, in a series of experiments that were made three times daily for more than 22 years; similar series of experiments were made by Carmen Capel-Boute in Brussels and other researchers in other locations.

The effect of the activated water and/or of a metal screen on the sedimentation rate was found to vary with solar eruptions, the 11-year sunspot cycle, and bursts of cosmic rays. In his book *"The Chemical Bases of Medical Climatology"* (1962) he therefore proposed a solar origin for the changes observed, and concluded that "certain phenomena which take place in geophysical space and all of the phenomena which take place in solar space and astrophysical space act at a distance. No matter what the nature of the far-off spatial phenomena, their action is exercised by means of radiation of an electromagnetic or corpuscular nature, or by means of variations in the general field, electrical, magnetic, electromagnetic or gravitational. All of this may today be listed as being distant actions". However, the effects seemed also to depend on the position of the earth relative to the plane of its equator and on the speed of the earth on its motion through the galaxy. Piccardi also investigated the influence of the phases of the moon on his chemical test, and the influence of terrestrial, solar, and cosmic phenomena on biological reactions such as the blood sedimentation rate. He came to believe from these experiments that the basis of what is now called the "Piccardi Effect" is the influence these cosmic factors exert on the structure of water and aqueous solutions. He thought that such an effect would mainly occur in systems that are not in thermodynamic equilibrium, and believed that colloid systems are especially suited to demonstrate these effects. He assumed that even small changes in the intensities of electromagnetic fields were able to exert dramatic and long-lasting effects on the properties of water and aqueous solutions.

Piccardi's work was continued by Capel-Boute, by Tromp's International Society of Biometeorology, by the International Committee for the Research and Study of Environmental Factors (known by its French acronym, CIFA) founded by Capel-Boute, and by Simon E. Shnol' and his group at the Institute of Theoretical and Experimental Biophysics of the Russian Academy of Sciences in Pushchino, among others. CIFA's last meeting was the seminar "Cosmic Ecology and Noosphere" on October 4-9, 1999 at Partenit, Crimea, and was dedicated to the 30^{th} anniversary of its foundation (see http://www.ccssu.crimea.ua/eng/conf/cen99/).

In the time of the 1950's and 1960's biometeorology developed rapidly, chiefly as a result of many environmental studies carried out mainly in Great

Britain and the USA. The deeper physiological mechanisms involved in the observations reported by earlier authors were extensively treated in Solco W.Tromp's *"Medical Biometeorology"* (1963). This was made possible through the creation of the International Society of Biometeorology, founded in 1956 at the occasion of a symposium held at the UNESCO headquarters in Paris, by Tromp, Frederick Sargent II, and many others. The now established discipline was defined at the symposium as follows: "Biometeorology comprises the study of the direct and indirect interrelations between the geophysical and geochemical environment of the atmosphere, and living organisms, plants, animals and man". With a membership of more than 600 scientists from more than 50 countries (1983), representing many disciplines, it was very active and had a high output of publications, such as the *International Journal of Biometeorology* (from 1957), and the book series *"Biometeorology"* (proceedings of the triannual conferences, from 1966) and *"Progress in Biometeorology"* (from 1970). (see Lieth, 1981, and Schnitzler & Lieth, 1983). The society is still active, but underwent a schism, with the partisans of the Piccardi type of work going their own way and founding CIFA. Tromp with his Biometeorological Research Center in Leiden, Netherlands, has performed much interesting research himself, mainly on the influence of weather and climate on blood pressure, blood composition and the physico-chemical state of the blood (see his review on effects of extraterrestrial stimuli on colloidal systems and living organisms, 1972).

For more recent work, see Tomassen (1990) and Shnol' (1996).

3.4.7 Human Ecology

The further development of biometeorology led to the establishment of the wider concept of a "Human Ecology" in which the comprehensive significance of the ecological viewpoint also implicit in quantum physics becomes clear (Sargent & Shimkin, 1965; Sargent, 1974, 1982, 1983). The notion of human ecology goes back to Huntington, who coined it in 1916 and in 1921 initiated a project on the "general study of human ecology relations" of the U.S. National Research Council, in which health is seen as a consequence of complex interactions between man and environment, and disease treated as a consequence of many, not a single factor acting on man, including microbes, but also meterological influences, socioeconomic conditions, and the nature of community health care. Jan Christiaan Smuts' holistic philosophy in *"Holism and Evolution"* (1926) and the ideas of Huntington and Petersen became the basis for the emerging field of "human ecology" as first expressed by botanist J.W.Bews in a book with the same title (Bews, 1935). Since then, many different disciplines have adopted the notion, but always with the common concept of considering man-environment relationships in a holistic and multicausal way, based on the study of the effects of the physical, biological, and socioeconomical environments on man and those of man on his environment; the modeling of the consequences of man-environment relations for health and disease is always treated in this general framework and therefore departs from conventional biomedical thinking.

3.5 Chronobiology

While the crystal model of the solid-state approach clearly brought a further advance in the physical understanding of living systems, it was not sufficient to ascribe only spatial order to the organism, which so obviously displays temporal order as well. Temporal organization is as important as spatial organization for the functioning of living organisms. Franz Halberg, one of the pioneers of this field, has stressed that at the physiological level, not only must the "right" amount of the "right" substance be at the "right" place, but also this must occur at the "right" time (Halberg, 1979). Also, Claude Bernard's concept of homeostatic constancy proved to be too static and had to be expanded by the idea of a rhythmic order. It was the discipline of chronobiology that developed from the discovery of the temporal dimension of biological organization.

Rhythmic movements of plant leaves of carob trees have already been reported by Androthenus, scientist in the retinue of Alexander the Great's military expedition to India in the 3rd century B.C. In 1729, the French astronomer Jean Jacques de Mairan discovered that the diurnal movements of mimosa leafs continued even when kept in the dark for several days. He suggested that the plant knew the time of the day because it possessed its own clock. Also in the 18th century, the Swedish botanist Carl von Linné studied the consistent opening and closing of of flower petals and in his *"Philosophia Botanica"* (1751) inaugurated the study of periodic phenomena in the development of organisms. In 1797, the German physician Christoph Wilhelm Hufeland, one of the protagonists of Romantic medicine, noticed the connection between the rhythmic organization of living organisms and that of our terrestrial and cosmic environment, when he remarked that "the 24 hour period which is transmitted by the regular rotation of our earth to all its inhabitants, is the unity, so to speak, of our natural chronology". In 1832, the Swiss botanist Auguste de Candolle continued the observations on mimosa and reported their adaptation to artificially changed lighting conditions such as shortening or phase shifting of the lighting period. At the same time, the first systematic investigations on the rhythmicity of human physiological functions were done by Grützmann in 1831, by Schweig in 1843, by Gierse in 1842 and by Bergmann in 1845. By experimenting on themselves, Davy in 1845 and Ogle in 1866 observed changes in their body temperatures, and assumed the existence of regular biological cycles in functions such as sleep and body temperature that are undisturbed by external cues. In his last years in the early 1880's, Charles Darwin studied the rhythmical phenomena in plants and animals and tried to relate them to the evolutionary process; he proposed that the daily movements of leaves had a survival value. In experiments on grass seedlings he showed that the tip of the seedlings was the part of the plant that is responsible for the plant's response to the changing light.

One of the most popular versions of biorhythmology was created in 1887 by the Berlin physician and biologist, Wilhelm Fliess, a friend of Sigmund Freud. In his book *"Der Ablauf des Lebens – Grundlegung zur exakten Biologie"* (Fliess, 1906) he postulated that every human had male and female cycles of 23 and 28 days which controlled the physiology of every cell and the tides of bodily and psychological vitality. He even believed the length of individual life and the day of death could be predicted on this base, and proposed a simple mathematical formula to predict favourable and adverse days. However, Fliess' biorhythmology proved to be too simplistic, as many more cycles were discovered in the course of time. Today we know that they cover a spectrum of 10 orders of magnitude, and occur on all levels of organization, from biochemical processes, cellular components and cells, to cell populations, organs, organisms, and populations. In 1898, Svante Arrhenius, in a paper that was also an important milestone for biometeorology (see there) stated that the clock of an organism constituted an open system and that in constant conditions the timing of the periods is derived from the external environment.

The beginning of modern research in chronobiology could be connected with the 1915 hypothesis of an autonomous internal clock by German botanist Wilhelm Pfeffer. After the first observations on time memory of bees by Auguste Forel in 1910, the investigations of Ingeborg Beling done on the instigation of Karl von Frisch in the late 1920's, gave definite proof of a memory of time and place, with elimination of the influence of external Zeitgebers like light, temperature, humidity and atmospheric electricity. At the same time, the Swedish physicians E.A.Forsgren and J.Möllerström investigated the diurnal rhythmicity of bile production in the rabbit and of the erythrocyte sedimentation rate in humans. In 1937 these studies led to the foundation of the medically oriented first International Society for the Study of Biological Rhythms in Stockholm.

The 1930's were very fruitful for the study of chronobiology. The zoologist Erich von Holst studied the interelationships of various rhythms and came to an understanding of the ways they are coupled and lead to a coordination of movements. The physiologist Albrecht Bethe investigated the mechanisms of biological periodicity and stated that rhythmicity was a fundamental property of life and that seesaw oscillations could serve as a model for understanding them. Hoagland postulated the existence of an internal clock and suggested that physiological time may depend on the rate of certain chemical reactions.

However, the most influential hypothesis, based on the actual state of chronobiological research, came from plant physiologist Erwin Bünning (1936, 1958), who took up Arrhenius' suggestion of external (cosmic or atmospheric) influence on biological processes. He did not succeed in showing an influence of electrical charges in the atmosphere on rhythmical movements of leaves, but found that the plants kept in constant darkness deviated from the 24 hour rhythm. He took the periodicity shift as a proof for the endogenous character of the biological clock. Further experiments formed the basis of his hypothesis on the mechanism of timing in plants, namely that the organism undergoes a change of a photophilic and of a photophobic phase of 12 hours each. Light stimuli given in the first phase accelerate the flowering, but stimuli given in the second phase inhibit it. This hypothesis became the starting point of a considerable rise of chronobiological research, which however came to a climax only in the late 1940's, when the hypothesis of the internal clock became more widely known.

It was in the late 1940's and in the 1950's that most of the great pioneers of modern chronobiology, among them Franz Halberg, Frank A.Brown, jr. (1954), Jürgen Aschoff (1965), and A.Sollberger (1965), started their systematic researches that have established the discipline. Franz Halberg and his associates (Halberg, 1953, 1960, 1962, 1969,1979, 1998) started their pioneering chronobiological research with the investigation of eosinophil levels in blood, and with detecting and documenting circadian rhythms in many endocrine functions. They also tracked such rhythms in cell division. Until the late 1940's, most physiologists had believed the meaning of the body's homeostasis was that its normal state was one of constancy. This assumption influenced the norms of medical diagnosis, treatment, and laboratory research, and still continues to influence many branches of physiology, biology and medicine, despite ample evidence to the contrary. Halberg also coined the notions of "circadian" (roughly 24 hours), "ultradian" (periods shorter than circadian, 90-100 minutes) and "infradian" (longer than circadian, i.e. weeks or months) cycles. Frank A.Brown started his investigations with research on the endocrine systems of fiddler crabs (Brown, 1954) which led him into chronobiology. In 1959, he postulated that biological rhythms are imposed by external rhythms. He suggested that diurnal fluctuations in air pressure and gravity associated with rotation of the earth in relation to sun and moon may be responsible. This geographical effect, however, was refuted by K.C.Hammer in the 1960's on the base of experiments at the South Pole.

For a long time, the field was characterized by a controversy between the advocates of exogenous origin of biological rhythmicity and those of an endogenous timing. The former, with Brown as their leading proponent, held that the organism was dependent on environmental rhythms. All known properties of clock-timed rhythms can be explained by entrainment through external "Zeitgebers", rhythmic changes in the organism's ambient physical environment, including light cycles, temperature changes, pulsating magnetic, electric, and extremely low frequency electromagnetic fields (Brown, 1976). The advocates of internal timing, most prominently Erwin Bünning and C.S.Pittendrigh, believed that the organism was independent of environmental rhythms, and possesses an inherited autonomous, self-sustained, temperature-compensated internal clock-timing system (Edmunds, 1976). However, as Edmunds has pointed out, all characteristics of circadian clocks – ubiquity, approximate 24-hour period, entrainability, persistence, phase shiftability, and temperature-compensation – are accounted for by either hypotheses.

If we consider that in the course of evolution all organisms have developed in an environment rhythmically structured by the planetary and cosmic radiation fields, we may assume that originally biological rhythms have been established by the integration of the temporal structure of environmental stimuli into the evolving organisms. Later, they probably have detached themselves from these Zeitgebers and have become autonomous pulsations, but still are in resonance with the external cycles. Anyway, the search for linear monocausal relationships which underlies these controversies must very probably be given up in favour of ecological concepts that take the interwovenness of all phenomena into account.

Such a concept has been developed by Rainer Sinz, physiologist at the University of Leipzig, in the late 1970's (Sinz, 1978, 1980). His concept of the "dynamical multioscillatory functional order of the organism" represents the perfect connection between chronobiological research and integrative biophysics. Based on the developments from Claude Bernard and Walter B. Cannon to Erich von Holst's central-nervous coordination and Werner Rudolf Hess' "functional organization of the vegetative nervous system" (Hess, 1948), Sinz' proposes a dynamical systems theory of the organization of regulation, coordination, and oscillation in the organism, based on the functional unity of regulatory processes, functional coordination and rhythmicity. It integrates the insights of the non-equilibrium thermodynamics of irreversible ordering processes with the knowledge on the hierarchical coordination of nonlinear regulatory and oscillatory systems in the organism. The spatial organization of the organism is correlated to the endogenous time structures arising from the nonlinear processes of regulation and oscillation of dissipative structures and their coordination at various levels of organization, which, according to Sinz, have been optimized by phylogenetic adaptation to the dominating environmental rhythms. If we consider this "oscillator model of the organism" in the light of our field model, the living organism with its innumerable rhythmical processes basically is a highly complex resonating system of oscillating fields coupled nonlinearly by their phase-relations.

Today, chronobiology (the name was coined in 1960) appears as a well founded and highly significant, but still somewhat marginal science – common fate of all the "border sciences" (Tromp) that do not fit into the classical disciplinary scheme and challenge the conventional scientific world view (for reviews and recent work see Luce, 1971, Halberg, 1979, 1998; Edmunds, 1984; Gutenbrunner et al., 1993).

3.6 Non-Equilibrium Thermodynamics and Self-Organization

One of the most fundamental conceptual shifts making the new biophysics possible certainly was that from classical equilibrium thermodynamics to non-equilibrium thermodynamics. Although generally associated with the name of Ilya Prigogine, who formalized non-equilibrium thermodynamics in the late 1940's and in 1977 received the Nobel prize in chemistry for this achievement, the concept of living organisms as non-equilibrium (open) systems was first developed by Alexander G.Gurwitsch, Ervin S.Bauer, Ludwig von Bertalanffy, and Erwin Schrödinger.

3.6.1 Alexander G. Gurwitsch

Gurwitsch, also known as discoverer of mitogenetic radiation (now called biophoton emission), suggested in the early 1920's that the molecular aggregates in living cells and tissues existed in a state of non-equilibricity which in his view was due to the action of biological fields (Gurwitsch, 1923; Gurwitsch & Gurwitsch, 1959). These excited "unequilibrated molecular constellations" were the foundation of the aliveness of the cell, and in their decay, the potential energy stored in their conformation would be released in the form of mitogenetic radiation (biophotons) or transformed into kinetic energy which then would cause the directed movement of substance. Aliveness was based on the constant change between the excitation of molecules by the field and the relaxation of the molecular binding energy which was retransformed into field energy. According to Gurwitsch, the individual atomic and molecular composition of living substance was of no import; it was their spatial organization that was decisive. As this was solely determined by the biological field, it was the latter that became the central element of biological understanding.

With these concepts Gurwitsch became one of the pioneers of modern biophysical thinking. The fact that he designated the "molecular constellations" as "states of mutual alignment and orientation" of molecules, makes him the first one to postulate what is now known as "collective states" or "cooperative phenomena" as the basis of life processes. He also was the first to realize that the distribution of energy in the living system was of paramount importance. The cooperative behavior of many molecules "greatly enhances the chances of energy transmission from one molecule to the next" and also "the propagation of chain reactions is only possible due to the regular arrangement of the reacting particles". He pointed out that the ability of the protoplasm to shift easily between its "immobile" (solidified) and fluid states was understandable as a "result of the spatial rearrangement of the regular molecular order and therefore as a result of a redistribution of energy" (Gurwitsch & Gurwitsch, 1959).

3.6.2 Ervin S. Bauer

Very similarly, Bauer, Russian theoretical biologist of Hungarian origin, already in the 1920's and then 1935 set forth three fundamental postulates, from which all biological phenomena may be derived (Bauer, 1920, 1935). (1) All living systems are always in stable non-equilibrium condition and therefore have energy to perform work. They use this energy to sustain the non-equilibrium state, therefore they are purposeful. From this postulate follows homeostasis. (2) Living systems are performing internal work, but also external work (interaction with environment, obtaining food etc.). The postulate states that the proportion of the energy used in external work to that used in internal work increases in development. (3) Non-equilibricity in living systems consists of molecular compounds in whose conformation the metabolic energy used to form them is stored.

As already described above, some of the most decisive work about the non-equilibrium nature of living systems was done in the 1940's and 1950's by the Austrian-Canadian biologist and founder of "General System Theory", Ludwig von Bertalanffy (Bertalanffy 1940, 1949, 1950, 1953). Together with A.C.Burton (Burton, 1939), he introduced the concept of the living organism as an "open system" in the sense of thermodynamics.

3.6.3 Erwin Schrödinger

In his small, but influential book *"What is Life ?"* (1944), Erwin Schrödinger (1887-1961), one of the founders of quantum physics and Nobel laureate of 1933, also engaged in the discussion of the thermodynamics of living systems. After discussing the nature of heredity and predicting the structure of the then still hypothetical gene, calling it an "aperiodic crystal" which he suggested was storing information as a code in its structure, he discussed the problem of how organisms could retain their highly improbable (from the standpoint of equilibrium thermodynamics) ordered structure in the face of the Second Law of Thermodynamics (the entropy principle). Schrödinger pointed out that organisms retained order by feeding on "negative entropy" from the environment. They liberate themselves from the entropy which they cannot avoid producing by exporting it into their environment. The term "negative entropy" Schrödinger coined (like its later abbreviation into "negentropy" by Brillouin), has not been well received by other scientists. He used it instead of talking of the free energy, the non-equilibrium of the environment, upon which organisms feed, a fact that had already been pointed out by F.G.Donnan in 1928 (Donnan, 1929). It was this new principle, "order from order", Schrödinger said, that was they key for understanding life. He explained there were two principles for creating order in nature – the statistical one which creates "order from disorder", and the new "order-from-order"-mechanism, which was much simpler and much more able to explain the behaviour of living matter. He stated the new one was not foreign to physics – it was nothing else than the principle of quantum theory.

Schrödinger, like Niels Bohr, was intrigued by the idea that understanding living systems may involve "other physical laws" beyond the "known law of physics", but without evading these. He stated that "the living organism seems to be a macroscopic system which behaves in some of his aspects like matter close to absolute zero, where molecular disorder is removed". Thus, the new laws Schrödinger was looking for were of the nature of the intermolecular forces of solid state physics.

3.6.4 Ilya Prigogine

One of the most fundamental contributions to this field is certainly the work of Ilya Prigogine, Nobel laureate in chemistry of 1977, on the thermodynamics of irreversible processes and on the theory of self-organization (Prigogine 1947, 1961; Glansdoff & Prigogine, 1971; Nicolis & Prigogine, 1977). Although there are earlier contributions to the theory of self-organization, such as the classical works by Henri Poincaré, Alexander M.Lyapunov and later Alan M.Turing, it was Prigogine's work that definitely established non-equilibrium thermodynamics and allowed its use in the explanation of life processes. Using the earlier experiments of the Germans F.Ferdinand Runge and Raphael E. Liesegang, the French physicist H.Bénard, and the Russians Boris P.Beloussov and Anatol M.Zhabotinsky on self-organization in chemical reactions (Kuhnert & Niedersen, 1987), Prigogine established that these nonlinear reactions are just inorganic examples of the more general phenomenon of "dissipative structures". The work of Beloussov probably would not have been noticed, if not Simon E.Shnol' had recognized the general significance of the phenomenon (Shnoll et al., 1981, 1982). He then commissioned Zhabotinsky to do a more detailed investigation, who extended the reaction considerably (Kuhnert & Niedersen, 1987). These pattern-forming, oscillating chemical reactions, used by Prigogine as a model for the physical understanding of biological order, exhibit the properties of cooperative behaviour, sensitivity to small perturbations, and memory. When a continuous and sufficiently strong flow of energy is fed into a collection of disordered molecules, spontaneous order arises in them and is maintained as long as the inflow is kept up. This new class of order "far from the thermal equilibrium" arises from the sudden collective behaviour of a great number of particles, triggered by small fluctuations which in thermal equilibrium do not have such an effect. Thus, non-equilibrium thermodynamics can explain how biological systems use nutrition as an external pump to establish a stable state far from equilibrium. The stability of living systems is based on what Popp has called the main optimization principles of physics, the First and Second Law of Thermodynamics, applied to the common system of both biological systems and their surrounding, which together can be treated as closed systems.

A first textbook on non-equilibrium in biophysics was published in 1967 by Aharon Katchalsky and P.F.Curran (Katchalsky & Curran, 1967).

3.6.5 Herbert Fröhlich

While the physico-chemist Prigogine uses the concept of coherence to characterize the mutual spatial alignment and the "collective", holistic behaviour of a large number of particles, Herbert Fröhlich (1905-1991), British theoretical physicist of German origin, directed his attention to the electromagnetic interactions of these particles. In contrast to Prigogine, he not only referred to thermodynamics which is concerned with the statistical behaviour of large numbers of particles, but based his work on the quantum theory of solids and liquids. Before introducing the concept of coherence into biology, Fröhlich had created the foundations for understanding supraconductivity. However, the 1972 Nobel prize for this achievement was not awarded to him, but to John Bardeen, Leon Cooper and John Schrieffer. Superconducting behaviour is due to the establishment of long-range coupling forces binding particles together in pairs separated by hundreds of atomic diameters. Fröhlich's application of quantum field theory to the physics of solids revolutionized this field not less than his introduction of coherence changed biophysics.

In the fundamental paper of 1968 in which he did this, he writes that biological systems should show longitudinal vibrations (so-called "optical phonons") of frequencies between 10^{11} and 10^{12} Hz (microwaves) arising from the dipole properties of cell membranes, macromolecular bonds such as hydrogen bonds and probably also from delocalized electrons. The non-equilibrium state created by the continuous supply of a certain minimum of energy should then bring about a stationary state in which the energy is not completely thermalized, but stored in an very orderly way. The strong excitation of a particular frequency of these phonons leads to long-range phase-correlations. Fröhlich pointed out that this phenomenon had a strong similarity to the condensation of a Bose gas at very low temperatures, the so-called Bose condensation (Fröhlich, 1968).

Fröhlich's concept of coherence corresponds in all essential points to Prigogine's dissipative structures. In both concepts nonlinear, autocatalytic (self-amplifying) processes lead to the system's stabilization far from thermodynamic equilibrium and in the form of a dynamic order, provided that energy beyond a certain minimum is continuously fed into the system. Like Prigogine, Fröhlich concludes that long-range correlations and coherent structures must play a fundamental role in living organisms, by regulating biological processes like the function of enzymes, the storage of energy, growth and the establishment of order.

However, in contrast to Prigogine, Fröhlich does not consider the molecular structure of the organism as most essential in this process, but the electromagnetic fields coupled to the molecules, which in his view are responsible for the higher order of the non-equilibrium state. Fröhlich's model is more fundamental and far-reaching, because electromagnetic interactions are the most fundamental couplings in living systems. All binding forces between atoms and molecules are of electromagnetic nature, and as a consequence, all chemical reactions are basically electromagnetic processes. Fröhlich has also suggested to use the heat bath as an idealization of the external world, and the chemical potential to describe the interaction between the surroundings and the biological system.

Popp has pointed out that the energy distribution over the spatio-temporal structure has to be considered, which in the form of the equal spectral distribution of electronic excitations over all possible modes (wavelengths) constitutes the non-equilibrium threshold of a system, i.e., thermodynamic non-equilibrium corresponds to the predominance of excited species over non-excited ones, and thus to the lasing state.

However important the thermodynamic aspects of life may be, the mechanisms of establishing coherent states, considered by Popp as the fundamental biophysical principle of life, cannot be explained by thermodynamics (or electrodynamics), but concern quantum theory (Popp, 1994).

3.7 Biological Fields

The "building-stone" view of equilibrium thermodynamics which underlies classical physics and chemistry, has, up to now, been the world-view upon which biophysics has, like the rest of the biological sciences, based its picture of the organism. One of the first and most important steps in the development of a holistic biophysics must therefore be not only to complement the classical view with the field aspect, but even to build its model of the organism completely on the field picture. The electromagnetic field theories of Faraday and Maxwell proposed in the second half of the 19th century have inspired biologists already from 1900 onwards to develop biological field theories. As I have shown elsewhere, the concept of the field has occupied a central place in the school of "organismic" or "holistic" biologists in the first half of the 20th century (Bischof, 1998). Leading biologists of the time, such as Hans Spemann, Ross Harrison, Paul A.Weiss, Joseph Needham, Conrad H.Waddington, and Alexander G.Gurwitsch (Lipkind, 1998), used the hypothesis of a biological, or morphogenetic, field, introduced by Gurwitsch and Weiss in the early 1920's, as a tool for understanding the phenomena of development, regeneration and morphogenesis and to make predictions for experimental testing. They generally considered the biological field as a purely heuristic concept and left the exact nature of the fields open. The time (and electromagnetic science) was not yet ripe for the notion of real electrical, electromagnetic or otherwise physical, fields of long-range force. At this time, there was neither enough experimental evidence for the existence of bioelectromagnetic fields nor for the biological effects of EM fields. Another reason for the late acceptance of the electromagnetic aspect of organisms was the success of the biochemical approach to life.

There are several reasons why the concept of the biological field has almost completely vanished from biology in the 1950's (Gilbert et al., 1996). The main reason was the rise of genetics as an alternative program to explain development. In the 1930's, the biological field had been a clear alternative to the gene as the basic unit of ontogeny and phylogeny, and this was seen as a threat to the rise of genetics as the leading field of biology. This was the reason why Thomas Hunt Morgan, himself originally a developmental biologist, actively fought the concept of the morphogenetic field and tried to ridicule it in all possible ways. He denounced field theorists, and embryologists in general, as old-fashioned, metaphysical, holistic, mystical and bad scientists, not to be taken seriously in the new gene-based reductionist biology (Mitman & Fausto-Sterling, 1992). However, Morgan never presented any evidence against fields or gradients (Gilbert et al., 1996), and at that time genes were not less abstract and metaphysical than morphogenetic fields. On the other hand, most embryologists also did not feel they needed to take genes seriously (Gilbert et al., 1996), which helped to push embryology out of the "New Synthesis" of genetic-evolutionary theory. By the late 1930's, evidence started to come for the role of genes in embryogenesis, but then, embryologists still had reason to doubt the geneticists' claim to be able to explain development, as it was not possible to explain how identical genes in each cell created different cell types and no genes active in early development had been identified. However, with the breakthrough of genetically oriented molecular biology through Watson and Crick's 1953 model of DNA, field theories were definitely out (Bischof, 1996) and the predominance of the molecular approach in biology began, as we know it today.

More recently, however, a group of leading U.S. biologists, Scott F.Gilbert, John M.Opitz, and Rudolf A.Raff, have challenged the adequacy of genetics for alone explaining evolution and the devaluation of morphology, and have demanded the rehabilitation of the biological field (Gilbert et al, 1996). They suggest that evolutionary and developmental biology should be reunited by a new synthesis, in which morphogenetic fields are proposed to mediate between genotype and phenotype. As an alternative to the solely genetic model of evolution and development, the new synthesis should be based on the morphogenetic field as a major unit of ontogenetic and phylogenetic change. Gene products should be seen as first interacting to create morphogenetic fields in order to have their effects; changes in these fields would then change the ways in which organisms develop.

3.8 Bioelectromagnetics

Of course, investigations of bioelectromagnetism have a long history, and electrophysiological studies have played a major role in early biophysics, starting from the Berlin school and the French school of Claude Bernard (Bischof, 1994). Among the less known pioneers of bioelectromagnetic research I would like to mention the early French school of biophysics, with Bernard's pupil Arsène d'Arsonval (Delhoume, 1939; Chauvois, 1941; Kopaczewski, 1947), Fred Vlès and his collaborators, Georges Lakhovsky, and Charles Laville. Arsonval, who in 1894 succeeded his teacher Bernard on the chair of physiology at the Collège de France, founded in 1882 the first official laboratory of biophysics in France at the École des Hautes Études.

Various bioelectromagnetic field concepts were proposed in the first decades of the 20th century, e.g., by Rudolf Keller, George W.Crile, Charles Laville, Harold S.Burr, Elmer J.Lund, and Georges Lakhovsky (Bischof, 1994). Laville, French electrical engineer and biologist, proposed in the 1920's that muscles behave like capacitors and that the cell was an electrical engine; he pointed out the significance of electronegativity for biology and proposed that cancer is an "electromagnetic disturbance of the cell". He was convinced that the organization of living matter was due to the structure of underlying force fields, and ascribed changes in it to changes in the distribution of energy (Laville, 1925, 1928, 1932, 1950). Lund concluded from decades of work on the bioelectric potentials of plants and animals that all polar systems are surrounded by and possess interpenetrating electric fields generated by each one of the constituent polar cells in order to maintain electrical correlation within the system (Lund, 1947). He hypothesized that the fields constitute a primitive type of integrating mechanism that plays an important role in the spatial organization of metabolic processes and coordinates growth and possibly other processes. The hypothesis of Burr and Northrop (Burr and Northrop, 1935), based on Burr's work on bioelectric potentials (Burr, 1972), is summarized in the following quote:

> *The pattern of organization of any biological system is established by a complex electro-dynamic field, which is in part determined by its atomic physico-chemical components and which in part determines the behaviour and orientation of those components. This field is electrical in the physical sense and by its properties it relates the entities of the biological system in a characteristic pattern and is itself in part a result of the existence of those entities. It determines and is dertermined by the components. More than establishing pattern, it must maintain pattern in the midst of a physico-chemical flux. Therefore, it must regulate and control living things, it must be the mechanism the outcome of whose activity is "wholeness", organization and continuity. The electro-dynamic field then is comparable to the entelechy of Driesch, the embryonic field of Spemann, the biological field of Weiss"* (Burr and Northrop, 1935).

Lakhovsky (1963), French engineer of Russian origin, postulated that each living being is simultaneously a broad band emitter and receptor of EM radiation, and that every cell of the organism is an electrical resonator. According to Lakhovsky, the chromosomes of the cell nucleus constitute oscillatory circuits and are surrounded by a weak electromagnetic field which interacts with the ambient EM fields. Perturbations of the natural frequency of the cell can induce illness; they may be caused by changes in the composition of the medium in the cell, by the presence of bacteria or viruses, which are supposed to emit their own EM fields, or by unusual fluctuations of solar or cosmic radiation.

However, these proposals were premature, and the breakthrough and beginning of modern EM field theories in biology came only in 1970, with Alexander M.Presman's report of the pioneering work of Soviet bioelectromagnetics researchers, which also contained a first outline of a holistic EM field theory of the organism and his relationships to the environment (Presman, 1970). Since then, there is ample evidence for bioeffects of EM fields and endogenous EM fields (Bischof, 1994, 1998). It is now established that organisms react sensitively to the impact of electromagnetic fields, including very weak ones; effects of various types of endogenous physical fields on cellular organization and morphogenesis are very likely. We also know that several kinds of electromagnetic fields, including microwaves and optical frequencies (biophotons), are emitted from living beings. There is also evidence that weak endogenous electrical currents are involved in regeneration and growth of new tissue; the role of ionic currents in morphogenesis and development has also been demonstrated. Communication by electromagnetic fields is established for fishes and insects, which suggests this may be a more general phenomenon.

Presman's idea of the role of EM fields in the organism is still valid. Based on his review of the Russian and Western work on biological effects of EM fields and on biological EM radiations, he argued that environmental EM fields have played some, if not a central, role in the evolution of life and also are involved in the regulation of the vital activity of organisms. Living beings behave as specialized and highly sensitive antenna systems for diverse parameters of weak fields of the order of strength of the ambient natural ones. According to Presman, EM fields serve as mediators for the interconnection of the organism with the environment as well as between organisms, and EM fields produced by the organisms themselves play an important role in the coordination and communication of physiological systems within living organisms. In all these biological functions, in addition to energetic interactions, informational interactions play a significant (if not the main) role. These bioinformational capacities of electromagnetic fields occur, thus Presman's conclusion from experimental evidence, in their fullest state of development only in the organism as a whole, and are either not present, or not present in comparable form, at the molecular level. As these capacities seem to be a function of the complexity of organisms, it may be useless to attempt to investigate EM interactions with biological systems on the molecular level. In healthy organisms, the internal EM information systems are reliably shielded from interference by natural EM fields, but in pathological states spontaneous variations of EM fields can upset the regulation of physiological processes.

4. CONTEMPORARY ASPECTS OF INTEGRATIVE BIOPHYSICS

4.1 The Quantum Nature of Life

Although the concept of a "quantum biology" has already been proposed in the 1930's by Pascual Jordan, one of the founders of quantum theory (Jordan, 1934, 1942; Beyler, 1996), and was taken up by Friedrich Dessauer, one of the founders of modern biophysics, in the 1950's (Dessauer & Sommermeyer, 1964), and carried in the name of the famous "Cold Spring Harbor Symposia on Quantum Biology" that were involved in the birth of molecular biology, full use of the consequences of quantum physics has not yet been made in biology (Dürr, 1997). The philosophical implications of quantum mechanics have played an important role at the very origin of molecular biology, but today the Schroedinger equation is merely used for calculating molecules and their interactions, while until recently, its philosophical implications rarely have been taken into account.

The philosophical contribution to the rise of molecular biology (Culotta, 1974) originated in Niels Bohr's speech *"On Light and Life"* at the International Congress on Light Therapy at Copenhagen, August 15, 1932 (Bohr, 1932), where he postulated that a new physics was required for interpreting life; life was not reducible to atomic physics. His suggestions were taken up by Pascual Jordan, who in his "amplifier theory of life" proposed that living systems may be able to amplify weak signals, even single photons, in such a way that they could trigger macroscopic events (Jordan, 1938, 1948). However, in this farsighted suggestion he did not take the nonlinearity of the amplification process into account.

Bohr's views also strongly influenced some of the key figures in early molecular biology, mainly Max Delbrück and Erwin Schrödinger (Kay, 1985). Schrödinger took them up in his famous small book *"What is Life ?"* (Schrödinger, 1944), which inspired many young physicists traumatized by the wartime use of physical expertise, to go into biology and had a strong influence on the development of molecular biology (Murphy & O'Neill, 1995).

However, the book certainly was more influential by interpreting the genetic viewpoint of Herman Joseph Muller, Thomas Hunt Morgan and Max

Delbrück in physicist's terms and by backing it with the prestige of physics, than by convincing biophysicists of the Bohr-Schrödinger hope of discovering new physical laws through biophysical investigation of biological phenomena (Keller, 1990). These latter ideas – which have to be seen in the context of the rather strong holistic tendency of the biology of the time – did not exert any lasting influence on molecular biology. On the other hand, they have been, and still are, a seminal influence for the later emergence of a holistic biophysics.

Today, molecular biology proposes itself as the manageable project of refashioning life and redirecting the course of evolution that some of its early pioneers like H.J.Muller and Warren Weaver had envisioned (Carlson, 1971; Kay, 1993). Because of the enormous technological and social power promised by molecular biology, even the increasing awareness of the bad science on which it is based in many respects, such as the numerous weak points in genetic and evolution theory (Ho, 1999), does not prevent it to carry us into such immature and dangerous projects as genetic engineering biotechnology in agriculture and medicine, and the *"Human Genome Project"*, whose deeper nature is revealed by the military epithet of a *"Manhattan Project of the life sciences"*.

The noted quantum chemist, Hans Primas, agrees with this fundamental criticism (Primas, 1990; Primas et al., 1999). He writes that molecular biology, as it exists today, is in fact engineering, not science. It is pragmatic, instrumental knowledge which aims at the power over nature, but not at understanding. It does not constitute a scientific theory of life able to give us orientation to live rationally with nature, but only provides technological control over life. Contemporary molecular biology has become a scientific technology which has lost contact with the epistemological sciences. Aspects of life that cannot be treated or understood from the molecular viewpoint, such as morphology, are glossed over. The assessment Robert Rosen made in 1967 is actually still valid: *"...it must be pointed out that the older problems* [he refers to the questions that preoccupied an older generation of biologists] *have merely been displaced and not solved by the recent developments at the molecular level. These problems involve the very core of biological organization and development: homeostasis, ontogenesis, phylogenesis"* (Rosen, 1967).

4.1.1 The Intrinsic Holism of Quantum Theory

For Primas (1990), the primary shortcoming of molecular biology is that the holistic character of the physical world now recognized in quantum theory is either not acknowledged by the bioengineers or rejected as irrelevant. He emphasizes that molecular biology, though well grounded in empirical knowledge, has no foundation whatsoever in the principles of quantum theory, contrary to a widely held belief to the opposite. It uses the methods and technologies of quantum mechanics, but its way of thinking is still committed to the classical physics of the 19th century and has not taken notice of the fundamental insights of quantum mechanics on the structure of the material world.

According to Primas, on whose statements the following is mainly based (1981, 1982, 1985, 1990, 1992, 1995, 1999), the atomistic-molecular view of matter and the reductionist-mechanist philosophy have no longer any scientific foundation, according to the actual understanding of quantum theory. The description of reality by isolated, context-independent, elementary systems such as quarks, electrons, atoms, or molecules is only permissible under certain specific experimental conditions, and these entities cannot in any way be considered as "fundamental building stones" of reality. Besides the molecular one, there are other, fundamentally different descriptions, complementary to the molecular one, which are quantum-theoretically equivalent and equally well founded. Quantum theory is much richer in possibilities than is admitted in the worldview of molecular biology.

In Primas' view, the feature of quantum theory that is most significant for biology is its *intrinsic fundamental holism*. Already Max Planck said that "the conception of wholeness must (...) be introduced into physics, as in biology, to make the orderliness of nature intelligible and capable of formulation" (Planck, 1931). Since then it has been made clear that for quantum mechanics, the scientific theory most widely recognized as fundamental and best confirmed by experiment, material reality forms an unbroken whole that has no parts. These holistic properties of reality are mathematically precisely defined by the Einstein-Podolsky-Rosen (EPR) correlations which are experimentally well defined. Primas postulates that, by virtue of this, quantum mechanics constitutes the first and up to now only logically consistent, universally valid, mathematically formulated holistic theory. In quantum mechanics, it is never possible to describe the whole by the description of parts and their interrelations.

With this view of quantum mechanics Primas follows Bohr and the school of Heisenberg (Heisenberg, 1976; Dürr, 1968), while quark physics as founded by Murray Gell-Mann continues to cultivate democritean atomism with their clinging to the concept of elementary particles (Kanitscheider, 1979). Similar holistic views of quantum theory are the *"bootstrap theory"* of Geoffrey Chew (1970), David Bohm's *"Causal Quantum Theory" or "Holographic Theory of Reality"* (Bohm, 1980; Bohm & Hiley, 1993), and others advocated by Henry Stapp (1997), Amit Goswami (1989, 1993, 1994), Menas Kafatos & Robert Nadeau (1990), Norman Friedman (1997), David Peat, Fritjof Capra, Harald Atmanspacher

(1996), and many others. This holistic view of quantum theory, although the phenomena on which it is based are not yet completely understood theoretically, cannot be rejected anymore because the strange EPR quantum correlations of non-interacting and spatially separated systems have been amply demonstrated in many experiments (Aspect & Grangier, 1986; Duncan & Kleinpoppen, 1988; Hagley et al., 1997). Therefore the world-view of classical physics, atomism and mechanistic reductionism, definitely cannot anymore be the basis of our worldview, and of biophysics. Quantum mechanics has established the primacy of the unseparable whole.

Another important epistemological consequence of quantum mechanics, complementarity, is also connected to its holism. As Primas writes, there is no single description, such as the molecular-reductionistic one, which can alone represent the whole reality of the subject of a scientific investigation, or is better or "truer" than any other. Nature is extremely diverse and stratified; each description comprehends only a minute partial aspect of its unfathomable multiplicity. Any scientific description of a natural phenomenon is only possible if we renounce the description of its complementary aspects. Quantum theory can only be applied if we abstract from certain aspects and thereby break the holistic symmetry. However, the kind of abstraction we use is not prescribed by the first principles of the theory, such that quantum mechanics allows, and even requires, many different, but equivalent, complementary descriptions of nature. As an important postulate for future science, Primas (1990) therefore emphasizes that we will have to learn to work simultaneously with several complementary descriptions of nature.

In this perspective, the molecular view is legitimate and important and should not be abandoned; molecular biologists can be rightly proud of their successes. It should be cultivated, but not at the expense of other viewpoints. It is its extreme one-eyedness that must be criticised. However, as Primas points out, *"biology is more than molecular biology"*. He postulates that science must now redirect its attention to the wholeness of nature, and therefore will have to ask radically new questions. It has to develop a concept of reality which does not exclude any part of it. Those properties which belong to organisms only as wholes must remain within the scope of science. Therefore, it will be necessary to consider the phenomena as well from "bottom-up", as in mechanistic understanding, as from "top-down", as in vitalistic and holistic understanding. According to Primas, the notion that the latter is not legitimate or secondary is a prejudice that must be overcome. From the viewpoint of the quantum-theoretical worldview, both are completely equivalent, but lead to fundamentally different research agendas and insights. Even the criteria according to which the scientist decides what is scientifically defendable and interesting, are completely different from these two viewpoints. Also, according to quantum theory functional and teleological explanations are completely legitimate and equivalent to causal ones; even the primacy of causality has no foundation in the first principles of physics. Primas points out that it is not possible to distinguish between causal and final processes by purely mechanical means and that such a distinction only makes sense for irreversible processes. As to the existence of the hypothetical vitalistic forces, Primas states that modern physics is well able to integrate new forces into its system.

4.1.2 The Hidden Domain of Potentiality and Connectedness

Thus, matter has become "dematerialized" by modern quantum theory, and this property of "thinglessness" in the quantum worldview is closely connected to the property of "interconnectedness". The emphasis is no longer on isolated objects, but on relations, exchanges, interdependences, on processes, fields, and wholes. Quantum theory is a non-local theory (Stapp, 1997). It is important to see that it is not sufficient to retain the classical world of objects and only add the interconnectedness as a supplementary property of these objects.

They are two of the complimentary descriptions or aspects of reality which Primas has alluded to and cannot be used simultaneously; thus they rather should be considered as different dimensions of reality. The holistic interpretation of quantum theory in fact may also be taken as implying a multidimensional structure of reality (Shacklett, 1991; Friedman, 1997). In this view, there are, besides the world of objects, one or several more fundamental levels of reality where interconnectedness rather than separatedness dominates. Fields certainly belong into this category; however, apart from electromagnetic and other physical fields which are still among the phenomena considered as belonging to the four fundamental forces of the observable world, we must assume the existence of additional field-like levels of reality not directly observable at present, which may be beyond space-time and represent the realm of potentiality (Heisenberg, 1958), or of the "noumena", the realm behind the phenomena assumed by Newton, in contrast to the actuality of the observable. The Schroedinger wave function of quantum theory actually describes this hidden domain of potentiality, of the non-observable, unmanifested, pre-physical world of non-local correlations and superluminal, instantaneous connections, rather than the world of observable phenomena (Friedman, 1997). Only with the act of measurement this infinity of potentialities, described in the Schroedinger equation as a superposition of all possible quantum states, is "collapsed" into one single actuality. Connected to the concept of potentiality is the concept of "entanglement" which describes the characteristic of interconnectedness (Shimony, 1988). In the absence of any interaction (such as a measurement), two systems are in an entangled state in which neither system by itself can be said to be in a "pure state", i.e., can be fully specified without reference to the other.

This hidden domain can be considered as a fundamental dimension of reality, a domain of dynamical connectivity, from which the patterns of the physical world arise. According to some authors, this realm of pre-physicality is not only the basis of the physical world and of matter, but also seems to be connected to, consciousness, which some see as the fundamental field underlying it (Bohm, 1980; Hagelin, 1987; Goswami, 1989, 1993; 1994; Shacklett, 1991; Gough & Shacklett, 1993; Laszlo, 1995, 1996; Friedman, 1997; Grandpierre, 1997). In physics, it is treated by the various models of the physical vacuum. Its possible relevance to biophysics as a basis for a true quantum biology (Josephson & Pallikari-Viras, 1991; Zeiger, 1998; Zeiger & Bischof, 1998; Thaheld, 1998, 2001a,b) seems obvious to us, as we will explain later. Therefore we postulate the development of a *"vacuum biophysics"*.

The "hidden domain" of connectivity has characteristics completely different from those of the classical, macroscopic world of separated objects. For a long time, the quantum description that reveals the properties of phenomena belonging to this domain, or arising from it, was taken to apply only to the microscopic world of atoms and molecules, while the world of macroscopic phenomena of our experience was considered to be purely classical and not to manifest quantum properties. However, today we know that this is not true, and that there are many macroscopic quantum manifestations, although our knowledge about them is still limited (Leggett, 1986, 1992, 1996; De Martino et al., 1997; Sassaroli et al., 1998). Biological systems obviously possess the characteristics of macroscopic quantum systems.

4.1.3 Macroscopic Quantum Phenomena

The usual assumption is that quantum properties disappear at macroscopic scales. But already in the 1960's, Herbert Fröhlich pointed out that low-temperature phenomena in fluids, like liquid helium, had shown "macroscopic quantization of a more subtle nature", and that these observations made it necessary to assume the existence of "a new kind of order based on the concept of phase correlations" (Fröhlich, 1969). Fröhlich, one of the foremost protagonists of the superconductivity and superfluidity research of the time, was convinced that this concept could be applied beyond low-temperature physics, "in particular in systems that are relatively stable but not near thermal equilibrium, and which show an organized collective behaviour which cannot be described in terms of an obvious (static) spatial order", i.e., biological systems. He pointed out that macroscopic concepts expressed in terms of microscopic (particle) behaviour were well developed for systems near thermal equilibrium, but not so much for explaining the existence of a macroscopic spatial order which is not of such an obvious nature as that of crystal structures, such as in the phenomena of superconductivity and superfluidity (Fröhlich, 1969).

As described above, Fröhlich introduced the concept of coherence into biology in 1968 by suggesting that the kind of macroscopic quantum behaviour first observed in low-temperature physics, namely the so-called Bose condensation, may also be observed in biological systems (Fröhlich, 1968, 1969, 1975). The concept of Bose (-Einstein) condensation originated in 1924, when Albert Einstein and his Indian colleague Satyendra Nath Bose predicted that atoms at extremely low temperatures would not dissipate as in an ordinary gas, but fall into their lowest energy state and collectively oscillate in a common coherent state. For technical reasons, this assumption could not be confirmed until 1995, when Eric A. Cornell and Carl E. Weiman of the University of Colorado (Andersen et al., 1995) and Wolfgang Ketterle of Boston's MIT (Davis et al., 1995) first succeeded with their research teams in producing Bose condensates of rubidium and sodium atoms; the three physicists received the 2001 Nobel prize for this achievement. Fröhlich's suggestion that this new, macroscopic, non-equilibrium quantum state of matter, very different from all known physical states, played a fundamental role in living systems, was later taken up and developed by Bhaumik et al. (1976), Mishra et al. (1979) and others, and is a central element of biophoton theory and integrative biophysics.

4.2 Quantum Electrodynamics and Optics

4.2.1 Quantum Coherence

The bases of our knowledge of quantum coherence have been established by in the 1960's by Roy J.Glauber of Harvard University in Cambridge, USA (Glauber, 1963a,b, 1964), based on an early suggestion by Erwin Schrödinger (Schrödinger, 1926). Starting from the theory of single-photon detection, Glauber developed the concept of "coherent states" which transcends the classical concept of coherence. Coherent states – in terms of the Schrödinger equation, "eigenstates of the annihilation operator" – are not just characterized by the ability for interference ("coherence of the second order"), but fulfil the ideal relations of a coherence of an arbitrarily high order. They are wave packets of which neither position nor momentum are exactly known and which have minimal uncertainty. They integrate the otherwise unbridgeable opposites of the wave and the particle nature of light into a new and higher unity, and simultaneously partake of the localized nature of particles and of the long-range delocalization of waves, and in coherent states these two modes are feedback-coupled to each other in such a way that one never can annihilate the other completely. As already Heisenberg has shown (1930), the state of minimal uncertainty is the most stable state and can carry the highest amount of information of all states.

As Popp has pointed out, this situation of coherent states between particle and wave, coherence and incoherence, corresponds to their existence at the laser threshold and enables them to act as homeostatic regulators allowing flexible switching of the field between coherence and incoherence. Because of their extremely low quantum fluctuation and therefore low noise they have a very high signal-to-noise ratio. According to Popp, coherent states are fundamental for biological systems; they enable them to optimize themselves concerning organization, information quality, pattern recognition, etc.

4.2.2 The Dicke Theory of Coherent Emission of Coupled Multiatomic Emitters

In 1954, Richard H.Dicke, later an eminent astrophysicist, pointed out that antenna systems, e.g., groups of molecules, with distances smaller than the wavelength of the radiation they emit, always will emit coherently (Dicke, 1954). The reason for this is that in this case they cannot emit independently from each other, but are coupled to each other by a common radiation field. The field consists of interference patterns reflecting the structure of the antenna system to which it is feedback-coupled. The emission can happen in two ways, either explosively in the form of intense "superradiance" flashes, or in the slowed down and attenuated form of weak "subradiance". The smaller the distances between the emitters compared to the wavelength of the radiation, the higher is the coherence of the emission. DNA perfectly fulfils the "Dicke condition" in the optical region, as the distances of 3 Ångstrom between base pairs are very much smaller than the wavelength of visible light (around 5000 Å). Dicke's predictions have been extensively tested in the past decade and have led to the establishment of the new field of "Cavity Quantum Electrodynamics" (Haroche & Kleppner, 1989; Haroche, 1991; Berman, 1994; Benedict et al., 1996). Independently, in the last few years many experimental physicists have followed up and confirmed the related suggestion of V.S Letokhov (1968) that amplification and superradiant emission could take place in strongly scattering media such as gases, dye solutions, powders or collections of styrofoam balls (Lawandy et al., 1994; Genack & Drake, 1994).

These findings refute a frequent objection against the assumption of a function for light in the organism, namely that tissues and cells are optically dense (opaque) and therefore light could not transmit information. Popp has pointed out that Emil Wolf in 1963 has predicted an increase of the coherence of light in highly dispersive media with increasing thickness of the layer (Wolf, 1963), and has shown in absorption experiments (Popp et al., 1984) that biophoton emission – in opposition to artificial light – is able to penetrate disperse media like sand and soybean cultures of a thickness of thousands of cells. The optical transparency of biological tissue has also been demonstrated by Mandoli & Briggs (1982, 1984) and others (e.g., van Brunt et al, 1964; Vogelman, 1989). Cavity Quantum Electrodynamics makes it clear that just *because* tissues are optically dense, they interact with the vacuum by cavity formation and thus create special coherence effects.

4.2.3 Nonclassical Light

Recent findings in the new field of "nonclassical light" confirm that these phenomena of quantum coherence are the more pronounced, the lower the intensities of the light, or in many cases, only are possible at low intensities (Pike & Walther, 1988; Meystre & Walls, 1991). Nonclassical light is light at very low intensities (single photons), which shows properties, such as antibunching and squeezed states, not explainable in the framework of classical optics. For this reason, it can only be treated nonclassically. Recently it has become clear that squeezed states actually are a more general concept than coherent states, and the latter should be considered as special cases of the former (Li, this volume). While in coherent states the uncertainty of momentum and that of position are equal, in squeezed states either the momentum uncertainty is bigger than position uncertainty, or vice versa. Therefore, in squeezed states, we still have coherence, but not a coherent state. Squeezed light can both be focused narrowly to a spot of atomic dimension, or extended over the whole volume of an organism. When the phenomena predicted and experimentally verified by this very young field of quantum optics became known, they perfectly seemed to fit the findings of biophoton research; recently the earlier proposition of Li (1992), Gu (1998) and Bajpai et al. (1998) that squeezed light existed in living systems was confirmed by Popp et al. (2001).

4.2.4 Coherence Space-Time

Finally, in a series of fundamental papers the theoretical physicist Ke-Hsueh Li of the Chinese Academy of Sciences has demonstrated that the concept of coherence is really rooted in Heisenberg's uncertainty principle, and that coherence space-time is actually equivalent to uncertainty space-time (Li, 1992, 1994, 1995). As Li has shown, the insight that the uncertainty relation is only an alternative approach to describe coherence properties of fields and particles can be traced back to Heisenberg himself (1958b). Li points out that the interference between different probability amplitudes, hence the coherence properties of probability packets, constitute the essential point of quantum theory. Coherence time is the time within which interference is kept up; coherence length or coherence volume is the distance or space within which this happens. The latter corresponds to the breadth of the wave function which is the region within which matter (in the case of matter fields) or radiation is statistically distributed. Any field, including chaotic ones, has a coherence space-time.

Coherent states exist only within the coherence space-time; it is the region where the phase is defined. Outside, phase information is lost. Within the coherence volume – and *only* within it -, interference patterns are formed and a particle loses its classical picture; the particles and fields within it must be considered as an indivisible whole. As a consequence, it is not possible to assign the emission of a system situated within the coherence volume to any particular emitter within it. The field, even if consisting only of single photons, is delocalized within the whole system, and can be trapped (stored) within it for a long time. According to Li the relationship to the Dicke theory is evident: Inside the coherence volume, the Dicke principle applies; outside the coherence volume, when particles are separated by a distance larger than the coherence length, they are independent of each other. Therefore, Planck's radiation law is only valid in cases not within the coherence volume, while the Dicke principle applies to the cases within it. Li's insight concerns matter waves as well as electromagnetic waves. In the case of atoms or molecules, the electrons are always within the coherence volume, which is the reason why it is not possible to assign any determined orbits to them. Equally, the Pauli principle and the covalent bonding between two atoms or molecules appear in a new light, and can be explained by the destructive interference of the electron wave packets within the uncertainty/coherence volume. Finally, Li points out that Schrödinger's principle of the production of "order from order" (Schrödinger, 1945, see above) finds a solid physical basis in this mechanism, which appears to be more fundamental than the statistical mechanism producing order from disorder conventionally used by physics as a basis for deriving its laws.

Li emphasizes that the coherence volume is a region with unusual properties where other laws rule than in ordinary space-time. Space and time within it are different than those outside. All usual measurements of physics are done outside it, and up to now, physics has been concerned only with the properties of space-time outside the coherence volume. The recent experiments on the Einstein-Podolsky-Rosen (EPR) effect and on quantum tunneling that indirectly have shown the existence of superluminal velocities, can easily be understood in terms of coherence space-time, because velocities "higher than the speed of light" only occur within the coherence volume, or more precisely, space and time are not defined within coherence space-time. In this volume, all phenomena happen at the same time, and are interconnected; they form an "unbroken whole without any parts". The coherence volume can become macroscopic; actually coherent states have unlimited coherence space and time, or rather, these cannot be defined for coherent states. Thus, coherence space-time is of general significance for physics, beyond optics, and of course very important for biophysics. In the organism, many different coherence volumes can exist simultaneously, can overlap, and can change, while technical systems like lasers have always fixed coherence volumes.

4.3 Modern Bioelectromagnetic Field Theories

Modern electromagnetic field theories could only be created as a result of the recent developments in thermodynamics, quantum electrodynamics and quantum optics described above, and especially not without the theory of quantum coherence and Fröhlich's work on coherence. These achievements became important elements in the *"biophoton theory"* developed by Popp and his group (Popp et al, 1989, 1992; Bischof, 1995; Chang et al., 1998; Beloussov et al., 2000). Like most modern field-theoretical proposals, it tries to reconcile particle and field approaches. Based on the modern evidence for the coherent emission of ultraweak luminescence by organisms first discovered in the 1920's by Alexander Gurwitsch (Bischof, 1995; Lipkind, 1998), it conceptualizes organisms as biological lasers of optically coupled emitters and absorbers operating at the laser threshold. The solid part of the organism is coupled with a highly coherent, holographic biophoton field which is proposed to be the basis of communication on all levels of organization. The components of the organism are seen to be connected in such a way by phase relations of the field, that they are instantly informed about each other at all times. The biophoton field is also postulated to be the basis of memory and of the regulation of biochemical and morphogenetic processes.

A related approach, *"bioplasma theory"* (Inyushin et al., 1968; Inyushin, 1970, 1977, 1983; Sedlak, 1967, 1976, 79, 1980, 1982, 1984; Wolkowski et al., 1983; Zon, 1980;Wnuk & Bernard, 2001), was developed from early suggestions by Szent-Györgyi, who pointed out that biomolecules in the organism are predominantly present in the excited state, and that the energetics of living systems are based on excitation-deexcitation dynamics which are also the basis of chemical bonding. Biological plasma is described as a "cold" plasma of highly structured collective excitations produced by the dielectric polarization of biological semiconductors, which functions as a single unit. The collective excitations of the molecules propagate in the form of excitons.The complex aggregates and configurations formed by the plasma particles serve as an energy network in the organism. External and intrinsic radiation is stored in the bioplasma in the form of trapped cavity oscillations which form the biological field; it has a complex broadband holographic wave structure of great stability. The biological effects of external radiation are ascribed to resonance properties of the whole system, and not to any of its parts. Like biophoton theory, the bioplasma concept implies non-equilibrium and electronic population-inversion, and therefore laser-like processes, as postulated by Inyushin in the early 1970's.

Pribram's *"holographic theory of perception and memory"*, first proposed in 1971 (Pribram 1971; Pribram et al, 1974), has also been an important contribution to modern biological field theory. It proposes that information from the sensory input is enfolded by Fourier-like transformations and stored in the brain in the form of holographic interference patterns, i.e., coherent EM fields. For reading it out in remembering, it is unfolded again by inverse Fourier transformation. In 1975 Pribram synthesized his model with the more general *"holographic theory of reality"* proposed by Bohm in 1971-73 (Bohm, 1980). It suggests that the organization of reality itself may be holographic, the world of objects we perceive (the "explicate order") being a second-order manifestation of the more fundamental *"implicate order"* or *"holomovement"* forming the basis of the world's fundamental unbroken wholeness.

The *"holographic concept of reality"* proposed by Miller et al. (1979, 1992) is a useful attempt to sketch the outlines of a possible synthesis of field models emphasizing the particle aspect, like bioplasma theory, and those who focus on the connecting and/or underlying fields, like biophoton theory and the holographic theories. At the same time, it tries to elucidate the significance of biolectric phenomena and physico-chemical parameters like the acid-base and electrolytic balances and redox potentials within the bioelectromagnetic fields.

Today, the field view of the organism and its interactions is finding increasing acceptance in biology, biophysics and medicine (see e.g., Tiller, 1977; Tiller et al., 2001; Braud, 1992; Bistolfi, 1991; Dossey, 1992; Goodwin, 1987; Gough & Shacklett, 1993; Ho, 1993, 1997; Jerman & Stern, 1996; Morton & Dlouhy, 1989; Rubik, 1996; Sit'ko & Gizhko, 1991; Welch, 1990, 1992; Wolkowski, 1985, 1988, 1995; Savva, 1999; Oschman, 2000; Thaheld, 2001a,b).

4.4 Biophysics and Consciousness

Already the German founders of biophysics in the early 19th century had recognized consciousness as the *"ultimate problem of biology"*, but science at that time was not prepared to include consciousness into biophysics, although the necessity was not denied (Culotta, 1974). Today, the situation is different. Since around the turn of the last century, Freud and his followers have made the problem of consciousness a central topic of a broad research effort whose results widely influenced Western society, but were hardly taken seriously by the natural sciences.

The last few years have changed this: consciousness has ceased to be a "non-subject" and is now definitely on the scientific agenda (Gray, 1992; Chalmers, 1995). An increasing number of authors are emphasizing the necessity of introducing consciousness into the scientific worldview, and some believe it should even become its very foundation (Cowan, 1975; Bohm, 1980; Bohm & Hiley, 1993; Goswami, 1989, 1993, 1994; Atmanspacher, 1996; Hagelin, 1987; Jahn & Dunne, 1987; Elitzur, 1989; Harman, 1992; Rubik, 1996; Radin, 1997; Amoroso et al., 2000). As to the consequences of a "biology without consciousness", Efron (1967) has pointed out the disastrous epistemological confusion the exclusion of consciousness from biology has caused.

Although the highly animated discussion in consciousness research is characterized by widely divergent standpoints, the decades-long dispute about the inclusion of the observer and the possible role of consciousness in quantum mechanics (Shimony, 1963; Walker, 1970, 1974, 2000) has certainly been a significant influence. As can be seen from the new discipline of *"Quantum Neurodynamics"* (Pribram, 1993; Jibu & Yasue, 1993, 1995), Pribram's and Bohm's holographic theories, together with Eccles' suggestion that fields analogous to the probability fields of quantum theory could be responsible for the coupling between consciousness processes and neural events (Eccles, 1986), have also been of considerable influence. Thus, an important segment of the most recent efforts in consciousness research is based on the hypothesis that consciousness may have a field-like nature, and/ or that fields may play a mediating role between consciousness and the biological organism. This hypothesis has already a considerable history and is more widely held than commonly is known (Bischof, 1998b).

4.4.1 Consciousness as a Field

It was probably William James who first introduced the concept of a field of consciousness into modern psychology in 1890. Carl Gustav Jung's *"Collective unconscious"*, first proposed in 1917, is conceived as a deeper, fundamental field-like unitary psychophysical reality *("unus mundus")* occasionally producing *"synchronicity"* effects. Gestalt Theory, initated by Christian v.Ehrenfels and Wolfgang Köhler, postulates an isomorphism between psychological and psychophysiological processes, mediated by fields analogous to Maxwell's electromagnetic fields and not bound to the nervous substrate, whose geometrical structure mirrors that of the perceived stimuli (Ash, 1995). In the 1930's Kurt Lewin proposed in his field theory of social psychology that social interactions are best understood by a field model (Lewin, 1936, 1951). In the 1940's Gardner Murphy developed a field concept of the organism, of personality, and of communication and suggested the existence of an interpersonal field which he thought to be part of a wider universal field (Murphy, 1945, 1947, 1961). Murphy also explained Psi effects in groups as a loosening of the usual interpersonal barriers and opening up to the interpersonal field. Paul Schilder demonstrated the existence of a "body-image", a 3-dimensional picture of the "perceived body", different from the body of anatomy and physiology, a kind of a constantly reorganized field that is constructed from the visual, tactile, kinesthetic, postural etc. experiences of an individual's lifetime (Schilder, 1950). In 1964, Aron Gurwitsch proposed a field theory of experiential organization in the tradition of Gestalt theory, Kurt Lewin's work and Edmund Husserl's phenomenology (Gurwitsch, 1964). The Russian mathematician and philosopher, Vassily V.Nalimov, has recently proposed a theory of the *"semantic vacuum"*, according to which there is a deeper, unobservable process from which ordinary, reflexive consciousness emerges which he calls the semantic vacuum, in deliberate analogy to the concept of the physical vacuum (Nalimov, 1981, 1982, 1989). Today, the field view of consciousness is proposed by many authors who suggest it may possess the property of quantum "nonlocality" (Dossey, 1992, 1999; Thaheld, 1998, 2001a,b).

4.4.2 Quantum Neurodynamics

A school of thought that has found wide interest and has led to a new branch of neuropsychology, has its origin in the work of Pribram and Eccles. In the early 1970's Karl H.Pribram had proposed that coherent holographic fields mediate between consciousness and neurological processes; John Eccles postulated in 1977 that consciousness has an existence independent of the brain, and that the self interacts with the body and the material world using the brain as an instrument (Popper & Eccles, 1977). The physicist Henry

Margenau suggested in 1984 that mind may be a unique type of non-material field, analogous to quantum probability fields; this suggestion was taken up in 1986 by Eccles who proposed that this field may modify the probability of emission of neurotransmitters at the dendritic synapse (Eccles, 1986). This finally led to the formation of the new field of Quantum Neurodynamics, based on the hypothesis that brain processes are to be understood on the basis of quantum field theory and are based on quantum fields, or potentials (Pribram, 1993; Jibu & Yasue, 1995). Long-time memory is conceived as a structured complex of vacuum states; remembering as the emission of coherent biophoton signals from the vacuum state. The coupling of neurophysiology with the "quantum sea" of the vacuum is assumed to be the basis of brain processes (Jibu & Yasue, 1993).

Quantum neurodynamics illustrates the many recent efforts to find approaches bridging consciousness as an entity which is not directly measurable, and the solid material aspect of the organism, with the hypothesis of a mediating field domain. Similar efforts have been made in the last few decades in many areas, not least in connection with the scientific investigation of Eastern medical systems, such as acupuncture, of contactless healing and various other phenomena.

4.5 Interpersonal Fields and "Subjective Anatomy"

The existence of electromagnetic fields emitted by living organisms, including humans, is now well established, even if there is not much secure knowledge about their biological functions. On the other hand, man has a long history of subjective experience of field-like interpersonal connections which usually are relegated to the realm of imagination by the scientifically minded. More recently, however, a number of scientific experiments have to some extent given evidence for the physical reality of these field observations (Bischof, 1998b).

As to the observations, an important example are the studies of nonverbal behaviour that have shown a synchrony of the body motion of speakers and listeners with the speech pattern (McBroom, 1966; Condon & Sander, 1974; Hatfield et al., 1994), which probably serves to establish empathic resonance. Such a synchronization between mother and child may be the basis and origin of human bonding and communication (Condon & Sander, 1974; Bullowa, 1975). A related phenomenon is the well established phenomenon of *"emotional contagion"* (Hatfield et al., 1994). Psychiatrists and psychotherapists have been familiar since decades with the *"praecox feeling"*, the field-like aura displayed by their patients announcing impending psychosis or schizophrenic episodes, and have been well aware of the contagious nature of these states (Deane, 1961; Ihle, 1962). The phenomenon of *"transference"* between therapist and patient is equally well known and has led a number of authors to the hypothesis of an *"interpersonal field"* (Schwartz-Salant, 1988; Mansfield & Spiegelman, 1995). In mutual hypnosis two persons create a common psychic field which in the more advanced stages can turn into a shared hallucinatory or dreamlike reality (Tart, 1969). Families may, according to some psychotherapists, possess a common unconscious and shared emotional field (Taub-Bynum, 1984).

A number of recent experimental studies give evidence that such interpersonal field effects may have some physical basis. Already in 1965, Duane & Berendt have shown brain-wave correlations between the brains of identical twins (Duane & Berendt, 1965). In order to test the many anecdotal reports that illness or trauma in one of a pair of identical twins affects the other, even when the twins are far apart, they altered the EEG pattern of one twin to see if this would produce a similar response in the other twin. In 2 of 15 pairs of twins tested, eye closure in one twin not only produced an immediate alpha rhythm in his own brain, but also in the brain of the other twin, even though he kept his eyes open and sat in a lighted room. This effect was reproduced in several experiments. In 1981, Jean Millay demonstrated in an EEG study of 22 individuals designed to test the old hypothesis that telepathy involves a mental resonance, that the ability to identify and increase interhemispheric EEG phase synchronisation and the ability of 11 pairs formed from the same individuals to identify and increase EEG phase coherence between their right hemispheres (interpersonal brain-wave synchronisation) corresponded to their ability for telepathic communication (Millay, 1981).

Conducted under much more stringent conditions, studies of empathically bonded pairs by Jacob Grinberg-Zylberbaum have shown interhemispheric and interpersonal EEG coherence and the appearance of transferred (evoked) potentials in the unstimulated partner after separation by a Faraday cage (Grinberg-Zylberbaum, 1987, 1992, 1994). A series of experiments to replicate the Greenberg-Zylberbaum studies and to investigate the possibility that states of consciousness can exert biological effects at a distance, are currently under way at Bastyr University and the University of Washington in the United States (Richards & Standish, 2000; Thaheld, 2001a,b). As a second neurophysical measure of the transfer of information between the two brains they are also using functional Magnetic Resonance Imaging (fNMR). According to preliminary results, the experiments have been successful so far. These studies are being conducted under a 2 year grant from the National Institutes of Health (Thaheld, 2001a,b). Thaheld (2001a,b) proposes that the experiments of Duane & Berendt and of Grinberg-Zylberbaum demonstrate the possibility of controllable biological quantum nonlocality and imply superluminal communication between individuals. Since neither neural nor electromagnetic energy could have penetrated the two Faraday cages used in the Grynberg-Zylberbaum experiments, Thaheld holds that they also demonsterated that mental events can influence or control neuronal events, a question that in present consciousness research is referred to as the "reverse direction" problem. Thaheld (1998, 2001b) has proposed several variations of these experiments to test the hypothesis of biological nonlocality and the interpersonal transfer of states of consciousness, which may also be used to address the question of animal consciousness.

The *"field-REG experiments"* done by the Princeton Engineering Anomalies (PEAR) Laboratory demonstrate anomalous influence of group events with a "high degree of subjective resonance between participants" on the random output of portable random event generators (REG) that suggest the presence of a field within such groups (Nelson et al., 1996, 1998; Radin et al., 1996; Bierman 1996; Radin 1997). Experiments on distant mental influence on living systems (DMILS) show that persons are able to exert direct mental influences upon various distant biological systems shielded from all conventional informational and energetic influences (Braud & Schlitz, 1983, 1991; Braud, 1992).

While these experiments suggest the possible non-electromagnetic nature of the studied fields, the measurements of the "Copper-Wall Project" performed by Elmer Green demonstrate that in healing sessions, exceptional subjects, such as healers and sensitives, are able to generate anomalous voltage surges in electrical body potential which are transmitted to and measured by electrometers attached to the four highly polished copper walls surrounding them in some distance (Green, 1990, 1991).

The former category of fields fits somewhere between the more physiology-related electromagnetic fields and the consciousness field of the organism; this field dimension of the organism belongs to both the "objective anatomy" and to what some have called "subjective anatomy". Their investigation may help in the future to understand and integrate the "subjective anatomy" of Schilder's "body image" and the "felt body" or "experienced body" investigated by the phenomenologists, experienced by most of us and most important for the understanding of the symptoms reported by the patient to the doctor (Schilder, 1950; Schutz, 1975; Fisher, 1986; Uexküll, 1997). One may also ask if the "phantom sensations" of amputees could not be more than just representations of lost limbs in the brain, perceptuomotor memories of a once functional body part. Since Brugger et al. have recently shown that phantom sensations are also experienced by persons with congenitally absent limbs (Brugger et al., 2000), we may all have an internal blueprint of a fully developed organism. This blueprint may have the form of a field instead of being just represented in material structures of the brain – a field that we even occasionally may experience as a "felt body". Some authors also feel that the "chi" of Chinese medicine and other life-energy concepts of non-Western medicine, including the "subtle bodies" of Oriental anthropology, possibly could be substantiated by research in the area of "subtle energies" that becomes increasingly important by the name of "energy medicine" (Morton & Dlouhy, 1989; Oschman, 2000; Bischof, 2000c).

4.6 The Physical Vacuum

In some of the above described experiments showing the existence of interpersonal field phenomena (Grinberg-Zylberbaum and DMILS) electromagnetic fields have been excluded; therefore we must consider the possibility that some kind of probably unknown, non-electromagnetic field(s) may be involved. Recently, a number of authors have suggested that electromagnetic potentials (vector and scalar potentials) may play a role in living systems (Tiller, 1993, 1995, 1999; Tiller et al., 2001; Taylor, 1996, 1998; Zeiger & Bischof, 1998; Bischof, 1998), and a series of preliminary experiments (which still have to be reproduced independently) seems to show biological effects of vector potentials different from those of ordinary electromagnetic fields (Rein, 1989, 1991, 1993, 1997, 1998; Ho et al., 1994; Smith, 1994; for a summary see Bischof, 1998). It has been proposed that there may be a whole class of non-electromagnetic fields underlying electromagnetic phenomena, which have been called "subtle energies" by some authors, following a suggestion by Einstein (Tiller, 1993, 1999; Taylor, 1998).

In fact, while the potentials have long been considered mere mathematical conveniences without physical reality, the reevaluation of their significance made possible by the groundbreaking paper by Aharonov & Bohm (1959), is now opening up a new field of electromagnetic research which we suspect may turn out to be highly significant for bioelectromagnetics and biophysics in general. A number of recent attempts to formulate extensions of electromagnetic theory point to the existence of an additional, hitherto unsuspected dimension of electromagnetism, which seems to be able to interact with the very structural fabric of space and time (Lakhtakia, 1993; Barrett & Grimes, 1995). Aharonov & Bohm (1959) have shown that in certain cases the potentials act as real physical fields and must even be considered more fundamental than the electric and magnetic forces; in the experiment they proposed the potentials exert an physical effect on charged particles in a field-free volume but not in the way force-fields do – they only influence the phase, and thus are fields of information.

However, the reason for the now well proven Aharonov-Bohm (AB) effect has only become evident in the wake of its analysis and generalization by Wu & Yang (Wu & Yang, 1975; Wu, 1975). Terence W. Barrett (1990; 1993) has given evidence that in the AB experiment the electromagnetic field, normally of U(1) symmetry, is "conditioned" into SU(2) form (in other cases even higher symmetries can be obtained) by the geometrical constraints of the experiment, which adds a degree of freedom to the field allowing an interaction with the space-time metric (neutrino network) and its topological structure, and endows it with a gravitation-like essence and form. Barrett also has shown that the AB effect is only one of a whole class of effects where this is the case.

According to William Tiller (1993) potentials have the important function of mediating between electromagnetic fields and the macroscopic quantum states of solid matter on the one hand, and the physical vacuum on the other hand, because of their property of controlling the phase of electromagnetic fields. He suggests that the subtle energy" fields of the vacuum domain, belonging to a higher dimension beyond space-time, organize the structure of space-time, which in turn, by the intermediate of the potentials, generates the corresponding electromagnetic fields. These finally give rise to the observed processes in space and time.

This hypothesis is supported by the work of Barrett (1990, 1993) on the conditioning of the electromagnetic field. In this process, the phase-controlling property of potentials is central. This is highly significant for biophysics, not only because of the coherence of biolectromagnetic fields; its importance can also be illustrated by the fact that the living organism with its many rhythmical processes basically is a complex system of oscillating fields coupled nonlinearly by their phase-relations.

Apart from potentials, a number of further non-electromagnetic fields have been forwarded in the various proposals for extensions of the Maxwell theory, as possible elements of an intermediate subtle realm" between particles and force fields and the vacuum, or as elements or aspects of the vacuum itself, for instance, *torsion fields*" (Akimov & Moskowski, 1992, Akimov & Tarasenko, 1992, Akimov, 1995; Akimov & Shipov, 1997, 1998; Shipov, 1998) and the B(3) ghost field" of longitudinal magnetic polarization (Evans, 1992, 1994; Evans & Vigier, 1994, 1995; Evans et al., 1996, 1998; Evans, 1998).

4.7 The Concept of Vacuum Biophysics

We are convinced that it is one of the central tasks of biology and biophysics, as it is of physics itself, to investigate the process of becoming and of manifestation, the arising of actuality from potentiality. It is clear that this is not yet completely realized in quantum physics, although the recent discussions about the interpretation of quantum theory and the alternatives to the Copenhagen interpretation have shown that it is groping in this direction. The same tendency can be found in some recent attempts at developing unfied theories of all physical interactions.

In the various unification programs of physics the concept of the physical vacuum occupies a central place. *The vacuum is fast emerging as* the *central structure of modern physics*" (Saunders & Brown, 1991). We postulate that it also merits such a central place in biophysics (Zeiger, 1998; Zeiger & Bischof, 1998; Bischof, 1998). It has in fact already been used in a number of recent models, e.g. by Conrad (1989a,b), Grandpierre (1997), Laughlin (1996), Laszlo (1995, 1996), Jibu & Yasue (1993, 1995), Shacklett (1991), and Tiller (1993, 1995, 1999; Tiller et al., 2001). We would not be surprised if it would turn out to be the very foundation a holistic quantum biophysics needs. The holistic quantum logic of biological processes and structures may not be sufficiently understood without the explicit inclusion of the vacuum concept into biophysics. Biophysics should be able to explain how, in the generation and development of organisms, pre-physical potentialities are transformed into physical realities. For practical reasons, it should also be interested in improving our knowledge on the more subtle, early levels of biological manifestation, where we may have access, for instance, to the formation of preconditions for illness, and which may also be the interface for the influence of the mind on the body. The assumption of a pre-physical dimension of potentiality is a prerequisite for the full understanding of life. To quote the Heisenberg pupil Hans-Peter Dürr: *"Living systems prove that actuality (factuality) is not all there is, but potentiality is also important. Like all macroscopic quantum systems, they are emergences of potentialities into factuality"* (Dürr, 1998).

We postulate that the concept of the vacuum is the appropriate framework to model the fundamental quantum-mechanical domain of potentiality. The vacuum is the "ground of being" from which the information for the structured development and regeneration of inorganic as well as living forms arises. All the features of the unbroken wholeness of reality implicit in quantum theory – non-separability, non-locality, fundamental connectedness – which are so fundamental for biological understanding, are an expression of the properties of the vacuum. The vacuum is the origin of microscopic and macroscopic coherence, an essential feature of living organisms. And, finally, the understanding of the vacuum may provide the crucial insights on the role of consciousness in physical reality, and in the various stages in which the creativity of the ground of existence unfolds on its way from pure potentiality and information to physical manifestation.

The concept of of the quantum vacuum may provide an important tool in developing both, a holistic terminology, and a holistic methodology for the integration of biology and physics necessary for the emergence of a holistic biophysics, or quantum biophysics. Especially significant may be its usefulness as a suitable framework for the treatment of organisms as macroscopic quantum systems (cf. the significance of vacuum degeneracy).

However, it must be clarified that we are not only talking about the electromagnetic vacuum of zero-point fluctuations, but of a more inclusive and fundamental unified vacuum of all four interactions.

4.8 Superfluid Vacuum Model of the Organism

In biophoton research first considerations on the possible role of the vacuum have been made in the 1980's in connection with the stability and optical properties of DNA and the optimal signal/noise ratio in the information transfer by biophotons. The central role that the vacuum plays in the Dicke theory and in Cavity Quantum Electrodynamics is well known. In 1985, Popp has suggested that biophoton emission as measured may arise from a non-measurable, virtual, delocalized, highly coherent field within the tissue, denoted by him as the realm of *"potential information"*in the organism; he conjectured it may be a kind of vacuum state (Popp, 1986; Bischof, 1995).

More recently, Zeiger (Zeiger, 1998; Zeiger & Bischof, 1998) has developed a *"superfluid vacuum model"* for understanding the biophoton emission of seeds and its connection to their viability. According to this model, seed vitality and biophoton emission are two parallel expressions of the same underlying reality: the superfluid Bose-condensate of photons. He proposes that the radiation field coupled to biological systems has to be understood on the basis of a twofold ground state. It consists, on the one hand, of a non-perturbative, collective-coherent state responsible for stability, internal communication and photon storage, which endows the organism with a quiet background field connecting all its components by long-range phase relations with each other and with the environment. The second ground state, a perturbative, fluctuating-coherent state consisting of the excitations of the collective-coherent state, is responsible for flexibility, adaptation and external communication, and from it the observed biophotons are emitted. The two states are separated by an energy gap which controls the behaviour of the system and is a basic measure for the overall state of the organism. It is a parameter that promises to become an important new tool in biophysics providing additional information on the living system. Zeiger's model may be a significant step in the biophysical modelling of the process of the emergence of "becoming" from the potentiality of the "ground of being".

Thus, if we speak of the electromagnetic field, or biophoton field, of cells, tissues or of the whole organism, as opposed to the biophoton emission measured, we may actually be dealing not with an electromagnetic field in the usual sense, but with a virtual field, or vacuum state. This has actually been proposed by Thomas E. Bearden (1991, 1993, 1995) and is partially supported by the work of Barrett and others, already mentioned, on one or more deeper level(s) of electromagnetism.

If we define vacuum physics as that branch of physics concerned with the fundamental pre-physical level of potentiality from which matter and fields arise and which contains the information for their dynamic structuring processes, I suggest that the corresponding field of biophysics concerned with the investigation of the biological role of the physical vacuum and of the mediating role of potentials and other nonelectromagnetic fields between the vacuum on the one hand and force fields and solid matter on the other hand, should be called "vacuum biophysics". It may become an important theoretical element and research subject of the new biophysics.

5. CONCLUSION: A MULTIDIMENSIONAL MODEL OF THE ORGANISM

Under the above assumptions a hierarchy of levels of biological function, or regulation systems, based on fields, may be envisaged as a working hypothesis, where we have (for the human case), between the solid physical body on the one hand, and consciousness on the other hand, the intermediate levels of the primitive holistic regulation systems and physiological-biochemical regulation, bioenergetic (EM) fields, bioinformation fields, and finally the "subjective anatomy" of the "experienced body".

The model is not only based on the inclusion of consciousness and the subjective aspects of our existence, but also on a tentative reversal of the usual primacy of matter over consciousness. In the diversity of standpoints in contemporary consciousness research it is now again possible to hold a view like that of Popper and Eccles, who have proposed that consciousness may not be a (secondary) product of (primary) material brain structures, but rather an independent entity that uses the brain as an instrument to interact with the body and the material world. It may be useful to remember what James Clerk Maxwell said to his friend, Professor Hort, on his deathbed: "What is achieved by the so-called Me, is in reality achieved by something greater than myself in me" (Norretranders, 1998). This view also roughly corresponds to that of some of the anthropologies of non-Western cultures and our own past, which assume that the innermost core of man consists of a "self" or a "soul", i.e., a consciousness, but one without activity and without an object, and therefore to differentiate from the mental (thoughts, imaginations etc.) arising from this deeper level. This self is regarded as the highest instance of the person, the origin of all intentions, and as the "place" of the wholeness of our psychic and corporeal existence, and therefore as the "highest regulatory instance" for psyche and body. Following the phenomenologists, and in accordance with non-Western models, this concept has to be supplemented by the insight that our body has not only an objective, but also a subjective aspect. Therefore in the spectrum of the dimensions of human existence the "experienced body" forms an intermediate state between the domain of the "objective body" of the biosciences and the "subjective anatomy" of the psychosocial and spiritual worlds. Consequently, we obtain the following model of a "multidimensional anatomy of man", whose dimensions are at the same time levels of self-regulation, levels of regulatory disturbance, and levels of external (therapeutic) intervention:

Table 1. Multidimensional Model of the Organism. Hierarchy of regulation levels, regulatory disturbances and regulatory interventions

PHYSICAL BODY	Solid-Physical Body	morphological changes, reversible and irreversible "lesions", « medical evidence », repair and replacement
	Primitive, Non-specific Systems and Regulations	
	holistic regulation systems Friedrich Kraus' "vegetativum": functional unity of humoral system of body liquids (hormones, electrolytes, acid-base balance, redox potentials etc.), ground regulation system of connective tissue, and autonomous nervous system	« Terrain » predisposition to disease functional disturbances, latent and larvated early forms of disease, premorbid states prevention healthy life style

ELECTROMAGNETIC FIELD-BODY	Bioenergetic Fields electromagnetic (force-) fields energetic interactions distribution of energy biophotons in the narrow (optical frequencies) and in the wider sense (all wavelengths)	energetic imbalances field interventions, electromagnetic medicine phototherapy etc.
NON-ELECTROMAGNE-TIC FIELD-BODY	Bioinformation Fields Quantum potentials, scalar waves etc. « higher » dimensions of EM field made possible by extensions of EM theory, may interact with space-time and consciousness possibly interface to consciousness “vacuum biophysics”	dysregulations on the level of the infor-mation fields subtle field interven-tions homeopathy etc.

Subjective Anatomy

SENSATE BODY **SOMATIC UNCONSCIOUS** **MENTAL BODY** **EMOTIONAL BODY** **DREAM BODY**	“Experienced Body” Subjective Condition Emotions, Thoughts, Moods “subtle bodies” body sensation body image (Schilder) streaming sensations “life energy” ? only partly conscious closely connected with “atmosphere” of environ-ment and with transper-sonal fields and moods of others no sharp separation of I and world	unhealthy thoughts emotional instability negative feelings and moods stress social integration good relationships psychotherapy placebo effects

SELF	Deepest Core of Person Soul consciousness level of wholeness of the organism and of interconnectedness with the world highest regulatory instance	unbalanced mental and spiritual atti-tudes and intentions, often unconscious meditation metanoia mysticism

A consequence of this model of a hierarchy of regulatory levels is the idea of a gradual pathogenesis and corresponding therapeutic interventions which I would like to formulate as a conclusion. I start from the premise that upon transgression of a certain range of tolerance, of fluctuations which the organism just can tolerate, dysregulations on one level will lead to disturbances on the next lower level. If all intentions originate primarily from the deep self, then inadequate or unbalanced mental and spiritual attitudes or intentions would represent the first level of dysregulation. If the imbalance is not corrected on this level, then it will cause dysregulation on the next level, e.g. unhealthy thoughts, emotional instability, negative feelings and moods, and stress. Without a correction of these imbalances, they will again cause dysregulations on the next level of bioinformation fields and the electromagnetic body, on whose properties we know not enough to describe their exact nature. Without adjustment, again these energetic imbalances will lead to functional disturbances in the primitive non-specific systems. And only now, if no correction on the level of the physiological "terrain" is done, we get the "medical evidence", i.e., the morphological lesions and changes in the tissues, that make the whole chain of dysregulations manifest at its very end.

REFERENCES

Abir-Am, P.G. (1987) The Biotheoretical Gathering: Trans-disciplinary authority and the incipient legitimation of molecular biology in the 1930's. *History of Science*, **25**, 1-70.

Aharonov, Y., Bohm, D. (1959) Significance of electromagnetic potentials in the quantum theory. *Physical Review*, 2nd Ser., **115 (3)**, 485-491.

Akimov, A.E., Moskovskii, A.V. (1992) *Quantum Non-Locality and Torsion Fields*. Moscow: Center of Intersectorial Science, Engineering and Non-Conventional Venture Technologies (CISE-VENT).

Akimov, A.E., Tarasenko, V.Ya. (1992) Models of polarized states of the physical vacuum and torsion fields. *Soviet Physics Journal* **35 (3)**, 214-222.

Akimov, A.E., ed. (1995) *Consciousness and the Physical World.* Collected Papers. Moscow: Publishing Agency "Yakhtsmen".

Akimov, A.E., Shipov, G.I. (1997) Torsion fields and their experimental manifestations. *Journal of New Energy* **2 (2)**, 67.

Akimov, A.E., Shipov, G.I. (1998) Experimental manifestation of torsion fields and the torsion model of consciousness. *Consciousness and Physical Reality*, **1 (1)**, 42-63.

Amoroso, R., Antunes, R., Coelho, C., Farias, M., Leite, A., and Soares, P. (eds.) (2000) *Science and the Primacy of Consciousness.* Orinda, CA., Noetic Press.

Anderson, M.H., Ensher, J.R., Matthews, M.R., Weiman, C.E. and Cornell, E.A. (1995) Observation of Bose-Einstein condensation in a dilute atomic vapor. *Science*, **269**, 198-201.

Arrhenius, S. (1898) Die Einwirkung kosmischer Einflusse auf physiologische Verhältnisse. *Skandinavisches Archiv für Physiologie*, **8**, 376-416.

Arsonval, A. d', Chauveau, J.B.A., et al. (1901-1903) *Traitè de Physique Biologique.* Paris , Masson. 2 vols.

Aschoff, J. (1965) *Circadian Clocks.* Amsterdam, North-Holland.

Ash, M.G.(1995) *Gestalt Psychology in German Culture 1890-1967. Holism and the Quest for Objectivity.* Cambridge, Cambridge University Press.

Aspect, A., Dalibard, J., and Roger, G. (1982) Experimental test of Bell's inequalities using time-varying nalyzers. *Physical Review Letters*, **49**, 1804-1807.

Aspect, A., Grangier, P. (1986) Experiments on Einstein-Podolsky-Rosen-type correlations with pairs of visible photons. In *Quantum Concepts in Space and Time*, R.Penrose and C.J.Isham (eds.) Oxford, Clarendon Press, 1-15.

Atmanspacher, H. (1996) Erkenntnistheoretische Aspekte physikalischer Vorstellungen von Ganzheit. *Zeitschrift für Parapsychologie und Grenzgebiete der Psychologie* **38 (1/2)**, 20-45.

Bailes, K.E. (1990) *Science and Russian Culture in an Age of Revolutions. V.I. Vernadsky and His Scientific School, 1863-1945.* Bloomington, Indiana University Press.

Bajpai, R.P., Kumar, S., Sivadasan, V.A. (1998) Biophoton emission in the evolution of a squeezed state of frequency stable damped oscillator. *Applied Mathematics and Computation*, **93**, 277-288.

Barcroft, J. (1934) *Features in the Architecture of Physiological Function.* Cambridge: Cambridge University Press. Reprinted: New York, Garland Publishing, 1988.

Barrett, T.W. (1976) Mechanoelectrical transduction in hyaluronic acid salt solution is an entropy-driven process. *Physiological Chemistry and Physics*, **8**, 125-134.

Barrett, T.W. (1990) Maxwell's theory extended. Part 1: *Annales de la Fondation Louis de Broglie* 15 (2), 143-183. Part 2: Theoretical and pragmatic reasons for questioning the completeness of Maxwell's theory. *Annales de la Fondation Louis de Broglie,* **15 (3)**, 253-283.

Barrett, T.W. (1993) Electromagnetic phenomena not explained by Maxwell's equations. In: Lakhtakia, Aklesh (ed.):*Essays on the Formal Aspects of Electromagnetic Theory*. Singapore, World Scientific Publishing, 6-86.

Barrett, T.W., Grimes, D.M. (eds.) (1995) *Advanced Electromagnetism: Foundations, Theory & Applications*. Singapore World Scientific.

Bauer, E. (1920) *Die Grundprinzipien der rein naturwissenschaftlichen Biologie und ihre Anwendungen in der Physiologie und Pathologie*. In W.Roux (ed.), Vorträge und Aufsätze über Entwicklungsmechanik der Organismen, No. XXVI. Berlin, Julius Springer Verlag.

Bauer, E. S. (1935) *Theoretical Biology*. Moscow. Reprinted Budapest: Akademiai Kiadó, 1982 (in Russian, with abridged English translation and commentaries by B.P.Tokin and S.E.Shnol).

Beall, P.T., Cailleau, R.M., and Hazlewood, C.F. (1967) The relaxation times of water protons and division rate in human breast cancer cells: a possible relationship to survival. *Physiological Chemistry and Physics*, **8**, 281-284.

Bearden, T.E. (1991) *Gravitobiology*. Ventura, California: Tesla Book Company.

Bearden, T.E. (1993) Information content of the field: Dynamic EM structuring of the scalar potential and its use by biological systems. Paper presented at the *2nd Estrian Workshop on "The Organization of Information Transfer in Living Systems", August 26-28, 1993, University of Sherbrooke, Canada.*

Bearden, T.E. (1995) Vacuum engines and Prioré's methodology: The true science of energy-medicine. Parts I and II. *Explore!* **6 (1),** 66-76 and **6 (2),** 50-62.

Beier, W. (1965) *Einführung in die theoretische Biophysik*. Stuttgart: Gustav Fischer.

Bell, J.S. (1987) *Speakable and Unspeakable in Quantum Mechanics*. Cambridge, Cambridge University Press.

Beloussov, L.V. (1988) The problem of biological morphogenesis: General approaches and mechano-geometrical models. In Kull, K. and Tiivel, T. (eds.), *Lectures in Theoretical Biology*. Tallin, Estonia, Valgus, 55-64.

Beloussov, L.V. (1993) Transformation of morphomechanical constraints into generative rules of organic evolution. *World Futures*, **38**, 33-42.

Beloussov, L.V. (1998) *The Dynamic Architecture of a Developing Organism. An Interdisciplinary Approach to the Development of Organisms*. Dordrecht, Kluwer Academic Publishers.

Beloussov, L.V., Popp, F.A., Voeikov, V., and Wijk, R. van (eds.) (2000) *Biophotonics and Coherent Systems*. Moscow, Moscow University Press.

Benedict, M.G., Ermolaev, A.M., Malyshev, V.A., Sokolov, I.V., Trifonov, E.D. (1996) *Super-Radiance - Multiatomic Coherent Emission.* (Optics and Optoelectronics Series). Bristol and Philadelphia, Institute of Physics Publishing.

Bénézech, C. (1962) *L'Eau, Base Structurale et Fonctionelle des Êtres Vivants*. Paris, Masson.

Berg, M., Mayne, A., and Petersen, W.F. (1940) Variability of blood pH and its association with meteorological factors. *American Journal of Physiology*, **130**, 9-21.

Bergmann, G.von (1932) *Funktionelle Pathologie*. Berlin, Julius Springer,.

Bergsmann, O. (1994a) *Bioelektrische Phänomene und Regulation in der Komplementärmedizin.* Vienna, Facultas.

Bergsmann, O. (1994b) *Struktur und Funktion des Wassers im Organismus*. Vienna, Facultas.

Bergsmann, O. (1998) *Chronische Belastungen*. Vienna, Facultas.

Berman, P.R. (1994) *Cavity Quantum Electrodynamics*. (Advances in Atomic, Molecular, and Optical Physics, Supplement 2). San Diego and London, Academic Press.

Bernard, C. (1859) *Leçons sur les propriétés physiologiques et les altérations pathologiques des liquides de l'organisme*. Paris , Baillière.

Bernard, C. (1865) *Introduction à l'étude de la médecine expérimentale*. Paris, Baillière. English ed.: *An Introduction to the Study of Experimental Medicine*. New York, Dover, 1957.

Bertalanffy, L.v. (1927a) Studien über theoretische Biologie. *Biologisches Zentralblatt*, **47**.

Bertalanffy, L.v. (1927b) Über die Bedeutung der Umwälzungen in der Physik für die Biologie. *Biologisches Zentralblatt*, **47**.

Bertalanffy, L.v. (1940) Der Organismus als physikalisches System betrachtet. *Naturwissenschaften*, **28**, 521-531.

Bertalanffy, L.v. (1945) Zu einer allgemeinen Systemlehre. *Deutsche Zeitschrift für Philosophie*, **18** (3/4).

Bertalanffy, L.v. (1948) *Theoretical Biology*. Ann Arbor: J.W.Edwards.

Bertalanffy, L.v. (1949) Open Systems in Physics and Biology. *Nature*, **163**, 384 ff.

Bertalanffy, L.v. (1950) The Theory of Open Systems in Physics and Biology. *Science*, **111**, 23-29.

Bertalanffy, L.v. (1968) *General System Theory*. New York, George Braziller.

Bertalanffy, L.v. (1975) Perspective on General System Theory. New York, George Braziller.

Bertalanffy, L.v. ,Beier, W. and Laue, R. (1977) *Biophysik des Fließgleichgewichts*. 2nd ed. Braunschweig, Vieweg.

Bews, J.W. (1935) *Human Ecology*. London: Oxford University Press.

Beyler, Richard H. (1996) Targeting the Organism – The scientific and cultural context of Pascual Jordan's Quantum Biology. *History of Science*, **87**, 248-273.

Bhaumik, D., Bhaumik, K., Dutta-Roy, B. (1976) On the possibility of Bose condensation in the excitation of coherent modes in biological systems. *Physics Letters*, **56A**, 145-148.

Bierman, D.J. (1996) Exploring correlations between local emotional and global emotional events and the behavior of a random number generator. *Journal of Scientific Exploration*, **10 (3)**, 363-373.

Bigu, J. (1976) On the biophysical basis of the human "aura". *The Journal of Research in Psi Phenomena*, **1 (2)**, 8-43.

Bischof, M. (1992) "Wasser (water)", in *Dokumentation der besonderen Therapierichtungen und natürlichen Heilweisen in Europa*, Vol.II, Wissenschaftliche Grundlagen der besonderen Therapierichtungen und natürlichen Heilweisen, Essen, Verlag für Ganzheitsmedizin VGM (co-authored by F.Rohner), 91-148.

Bischof, M. (1994) The history of bioelectromagnetism. In *Bioelectrodynamics and Biocommunication*, M.W.Ho, F.A.Popp and U.Warnke (eds.), Singapore, World Scientific.

Bischof, M. (1995a) *Biophotonen – das Licht in unseren Zellen.* Frankfurt, Zweitausendeins; 11th ed. 2001.

Bischof, M. (1995b) Vitalistic and Mechanistic Concepts in the History of Bioelectromagnetics. In *Biophotonics - Non-Equilibrium and Coherent Systems in Biology, Biophysics and Biotechnology*. L.V.Belousov and F.A.Popp (eds.), 3-14. Moscow, Bioinform Services.

Bischof, M. (1996) Some Remarks on the History of Biophysics and its Future. In: *Current Development of Biophysics*, C.L. Zhang, F.A. Popp and M. Bischof (eds.), Hangzhou, China, Hangzhou University Press.

Bischof, M. (1998a) Holism and Field Theories in Biology - Non-Molecular Approaches and their Relevance to Biophysics. In: *Biophotons*, J.J.Chang, J.Fisch and F.A.Popp (eds), Dordrecht, Kluwer Academic Publishers, 375-394.

Bischof, M. (1998b) *The fate and future of field concepts – from metaphysical origins to holistic understanding in the bio-sciences*. Invited lecture given at the Fourth Biennial European Meeting of the Society for Scientific Exploration, Valencia, Spain, October 9-11.

Bischof, M. (1998c) Skalarwellen und Quantenfelder als mögliche Grundlage biologischer Information. *Erfahrungsheilkunde* **47 (5)**, 295-300.

Bischof, M. (2000a) Field concepts and the emergence of a holistic biophysics, in Beloussov, L.V., Popp, F.A., Voeikov, V.L., and Van Wijk, R. (eds.) *Biophotonics and Coherent Structures.* Moscow, Moscow University Press, 1-25.

Bischof, M. (2000b) Wege zu einer integralen Heilkunde. In *Salutive*, ed. Gesundheitsakademie e.V. Frankfurt, Mabuse.

Bischof, M. (2000c) Energiemedizin - Heilkunst der Zukunft. *Esotera*, **8**, 16-21, and **9**, 20-25.

Bohm, D. (1980) *Wholeness and the Implicate Order.* London, Routledge.

Bohm, D.; Hiley, B.J. (1993) *The Undivided Universe. An Ontological Interpretation of Quantum Theory.* London, Routledge.

Bohr, N. (1932) Light and Life. *Nature* **131**, 421-423, 457-459.

Bone, S., Zaba, B. (1992) *Bioelectronics.* Chichester, Wiley.

Bose, J.C. (1902) *Response in the Living and Non-Living.* London, Longmans, Green & Co..

Bose, J.C. (1907) *Comparative Electro-Physiology.* London, Longmans, Green & Co.

Bose, J.C. (1915) *Plant Autographs and Their Revelations.* Washington.

Bose, J.C. (1920) *Collected Physical Papers.* London, Longmans, Green & Co.

Bose, J.C. (1923) *The Physiology of the Ascent of Sap.* London, Longmans, Green & Co.

Braud, W.G. (1992) Human interconnectedness: Research indications. *ReVision*, **14 (3)**, 140-148.

Braud, W., Schlitz, M.J. (1983) Psychokinetic influence on electrodermal activity. *Journal of Parapsychology*, **47 (2)**, 95-119.

Braud, W., Schlitz, M.J. (1991) Consciousness interactions with remote biological systems: Anomalous intentionality effects. *Subtle Energies*, **2 (1)**, 1-46.

Brown, F.A., jun. (1954) Biological clocks and the fiddler crab. *Scientific American*, **190**, 34-37.

Brown, F.A., jun. (1976) Evidence for external timing of biological clocks. In Palmer, J.D., *An Introduction to Biological Rhythms.* New York, Academic Press, 209-279.

Brugger, P. et al. (2000) Beyond re-membering : Phantom sensations of congenitally absent limbs. *Proceedings of the National Academy of Science USA*, **97 (11)** 6167-6172.

Brunt, E.E. van , Shepherd, M.D., Wall, J.R., Ganong, W.F., Clegg, M.T. (1964) Penetration of light into the brain of mammals. *Annals of the New York Academy of Sciences*, **117**, 217-227.

Bullowa, M. (1975) When infant and adult communicate, how do they synchronize their behaviors ? In: Kendon, A., Harris, R.M., Key, M.R. (eds.), *Organization of Behaviour in Face-To-Face Interaction.* The Hague, Mouton, 95-129.

Burns, J.T. (1997) *Cosmic Influences on Humans, Animals, and Plants. An Annotated Bibliography.* (Magill Bibliographies). Lanham, MD, Scarecrow Press and Pasadena, CA, Salem Press.

Bünning, E. (1958) *Die physiologische Uhr.* English ed. *The Physiological Clock.* 3rd rev. ed. Berlin, Springer 1973.

Burr, H.S. (1947) Field theory in biology. *The Scientific Monthly*, **64 (March)**, 217-225.

Burr, H.S., Northrop, F.S.C. (1935) The electrodynamic theory of life. *Quarterly Review of Biology*, **10**, 322-333.

Burr, H.S. (1972) *Blueprint for Immortality - The Electric Patterns of Life.* London, Neville Spearman.

Buttersack, F. (1912) *Latente Erkrankungen des Grundgewebes, insbesondere der serösen Häute.* Stuttgart, Ferdinand Enke Verlag.

Büttner, K. (1951) W.F.Petersen †. *Archiv für Meteorologie, Geophysik und Bioklimatologie*, Series B, **2**, 291.

Cannon, W.B. (1929) *Bodily Changes in Pain, Hunger, Fear, and Rage.* 2nd. ed. New York, Appleton.

Cannon, W.B. (1932) *The Wisdom of the Body.* Philadelphia, W.W.Norton.

Capel-Boute, C. (1974) L'oeuvre scientifique de G.Piccardi. *Medicina Termale e Climatologia*, **22**, 69-74.

Capel-Boute, C. (1983) Fluctuating phenomena in physical chemistry and biology. *Cycles*, **34 (3)**, 49-53.

Capel-Boute, C. (1985) Water as receptor of environmental information? *Journal of Biometeorology*, **29**, Suppl.2, 71-88.

Capel-Boute, C. (1990) Water a receptor of environmental information: A challenge to reprodcibility in experimental research – The Piccardi scientific endeavour. In Tomassen, G.J.M. (eds.), *Geo-Cosmic Relations – The Earth and its Macro-Environment.* Wageningen, Pudoc, 75-91.

Carlson, E.A. (1971) An unaknowledged founding father of molecular biology, H.J.Muller's contribution to gene theory, 1910-1936. *Journal of the History of Biology*, **4 (1)**, 149-170.

Carrel, A. (1935) *Man – the Unknown.* New York.

Cat, J. (1998) The physicists' debates on unification in physics at the end of the 20th century. *Historical Studies in the Physical and Biological Sciences*, **28**, part 2, 253-299.

Chalmers, D.J. (1995) Facing up to the problem of consciousness. *Journal of Consciousness Studies* **2 (3)**, 200-219.

Chauvois, L. (1941) *D'Arsonval – une vie, une époque 1851-1940.* Paris, Librairie Plon.

Chew, G. (1970) Hadron bootstrap: triumph or frustration ? *Physics Today* **23**, 23-28.

Chizhevsky, A.L. (1930) *Epidemic Catastrophes and the Periodic Activity of the Sun* (in Russian). Moscow.

Chizhevsky, A.L. (1968) *The Earth in the Universe.* V.V.Fedynsky, ed. NASA TT F-345 TT 66-51025.

Chizhevsky, A.L. (1973) *The Terrestrial Echo of Solar Storms.* Moscow: Mysl (written in 1936).

Clark, W. M. (1925) *The Determination of Hydrogen Ions.* Baltimore, Williams & Wilkins.

Clark, W. M. (1928) Studies on oxidation-reduction. *Hygienic Laboratory Bulletin,* No.151. Washington, United States Public Health Service.

Clegg, J.S. (1981) Intracellular water, metabolism, and cell architecture. Part I: *Collective Phenomena,* **3**, 289-312.

Clegg, J.S. (1983) Intracellular water, metabolism, and cell architecture. Part II. In: Fröhlich, H., Kremer, F. (eds.), *Coherent excitations in biological systems.* Berlin, Springer, 162-177.

Clegg, J.S. (1984) Properties and Metabolism of the Aqueous Cytoplasm and its Boundaries. *American Journal of Physiology,* **246**, R133-R151.

Clegg, J.S. (1987) On the physical properties and potential roles of intracellular water. In G.R.Welch and J.S.Clegg (eds.), *The Organisation of Cell Metabolism.* (Nato ASI Series.Series A: Life Sciences, 127). New York, Plenum, 41-55.

Clegg, J.S. (1992) Cellular infrastructure and metabolic organization. *Current Topics in Cellular Regulation,* 33, 3-14. New York, Academic Press.

Condon, W.S., Sander, L.A. (1974) Neonate movement is synchronized with adult speech. *Science,* **183**, 99-101.

Conrad, M. (1989) Physics and Biology: Towards a Unified Model. *Applied Mathematics and Computation* **32**, 75-102.

Conrad, M. (1989) The Fluctuon Model of Force, Life, and Computation: A Constructive Analysis. *Applied Mathematics and Computation* **56**, 203-259.

Cope, F.W. (1969) Nuclear magnetic resonance evidence using D_2O for structured water in muscle and brain. *Biophysical Journal,* **9 (3)**, 303-319

Cope, F.W. (1970) The solid-state physics of electron and ion transport in biology. *Advances in Biological and Medical Physics,* **13**, 1-42.

Cope, F.W. (1973) Supramolecular biology: A solid state physical approach to ion and electron transport. *Annals of the New York Academy of Sciences,* **204**, 416-433.

Cope, F.W. (1975) A review of the applications of solid state physics concepts to biological systems. *Journal of Biological Physics* **3**, 1-41.

Cope, F.W. (1976) A primer of water structuring and cation association in cells. I. Introduction: The big picture. *Physiological Chemistry and Physics*, **8**, 479-483; II. Historical notes, present status, and future directions. *Physiological Chemistry and Physics*, **8**, 569-574.

Cope, F.W. (1977) Pathology of structured water and associated cations in cells (the tissue damage syndrome) and its medical treatment. *Physiological Chemistry and Physics*, **9**, 547-553.

Cowan, D.A. (1975) *Mind Underlies Spacetime – A Idealistic Model of Reality*. San Mateo, CA, Joseph Publishing.

Cranefield, P.F. (1957) The organic physics of 1847 and the biophysics of today. *Journal of the History of Medicine*, **12**, 407-423.

Culotta, C.A., (1974) German biophysics, objective knowledge, and romanticism. In *Historical Studies in the Physical Sciences*, ed. R. McCormmach. **4**, 3-39.

Damadian, R. (1971) Tumor detection by nuclear magnetic resonance. *Science*, **171** (3976), 1151-1153.

Dasgupta, S. (1999) *Jagadis Chandra Bose and the Indian Response to Western Science*. New Delhi, Oxford University Press.

Davis, K.B. et al. (1995) Bose-Einstein condensation in a gas of sodium atoms. *Physical Review Letters*, **75**, 3969-3973.

Deane, W.N. (1961) The reactions of a nonpatient to a stay on a mental hospital ward. *Psychiatry*, **24**, 61-68.

Delhoume, L. (1939) *De Claude Bernard à d'Arsonval*. Paris, Baillière.

Delore, P. (1926) *Facteur acide-base et tuberculose pulmonaire. Étude physiologique du terrain dans la tuberculose*. Paris Doin.

De Martino, S., De Siena, S., De Nicola, S., Fedele, R., Miele, G., (eds.) (1997) *New Perspectives in the Physics of Mesoscopic Systems - Quantum-like Descriptions and Macroscopic Coherence Phenomena*. Singapore, World Scientific.

Dessauer, F., Sommermeyer, K. (1964) *Quantenbiologie*. 2nd ed. Berlin, Springer.

Dicke, R.H. (1954) Coherence in Spontaneous Radiation Processes. *Physical Review*, **93**, 99-110.

Donnan, F.G. (1929) The Mystery of Life. *Report of the British Association for the Advancement of Science*, Glasgow, 96th meeting, 660.

Dossey L (1992) Era III Medicine: The Next Frontier. *ReVision* **14 (3)**, 128-139.

Dossey, L. (1999) *Reinventing Medicine*. San Francisco, HarperCollins.

Drost-Hansen, W. , Clegg, J.S., (eds.) (1979) *Cell-Associated Water*. New York, Academic Press.

Duane, T.D., Behrendt, T. (1965) Extrasensory electroencephalographic induction between identical twins. *Science*, **150**, 367.

Dubrov, A.P. (1978) *The Geomagnetic Field and Life - Geomagnetobiology*. New York, Plenum Press.

Duncan, A.J., Kleinpoppen, H. (1988) The experimental investigation of the Einstein-Podolsky-Rosen question and Bell's inequality. In Selleri, F. (ed.), *Quantum Mechanics versus Local Realism – The Einstein-Podolsky-Rosen Paradox*, New York, Plenum Press, 175-218.

Dürr, H.P. (1968) Dynamik der Elementarteilchen. In Süssmann, G. and Fiebiger, N. (eds.), *Atome, Kerne, Elementarteilchen*, Frankfurt a.M., 229 ff.

Dürr, H.P.: (1997) Ist Biologie nur Physik ? *Universitas*, No.607, 1.

Dürr, H.P. (1998) Paper read at Gelterswoog symposium on biophysics, March 14th, Kaiserslautern, Germany.

Eccles, J.C. (1986) Do mental events cause neural events analogously to the probability fields of quantum mechanics ? *Proceedings of the Royal Society ,London,* **B 227**, 411-428.

Eccles, R. (1993) *Electrolytes, Body Fluids and Acid Base Balance*. London, Edward Arnold.

Edmunds, L.N., jr. (1976) Models and mechanisms for endogenous time keeping. In Palmer, J.D. *An Introduction to Biological Rhythms*, New York, Academic Press, 209-279.

Edmunds, L.N., (ed.) (1984) *Cell Cycle Clocks*. New York, Marcel Dekker.

Efron, R. (1967) Biology without consciousness – and its consequences. *Perspectives in Biology and Medicine*, **11(1)**, 9-36.

Einstein, A., Podolsky, B, and Rosen, N. (1935) Can quantum-mechanical description of physical reality be considered complete ? *Physical Review*, 47, 777-780.

Elitzur, A.C. (1989) Consciousness and the incompleteness of the physical explanation of behaviour. *The Journal of Mind and Behaviour* **10**, 1-19.

Endler, P.C. and Schulte, J., (eds.) (1994) *Ultra-High Dilution – Physiology and Physics*. Dordrecht, Kluwer Academic.

Eppinger, H. (1949) *Die Permeabilitäts-Pathologie als die Lehre vom Krankheitsbeginn*. Vienna, Springer-Verlag.

Ernst, E., Scheffer, L. (1928) *Pflügers Archiv f. d.ges. Physiol.*, **220**, 655.

Ernst, E. (1963) *Biophysics of the Striated Muscle*. Budapest, Akadémiai Kiadó.

Evans, M.W. (1992) The elementary static magnetic field of the photon. *Physica B* **182**, 227-236.

Evans, M.W. (1994) Classical relativistic theory of the longitudinal ghost fields of electrodynamics. *Foundations of Physics* **24 (11)**, 1519-1542.

Evans, M.W.; Vigier, J.P. (1994) *The Enigmatic Photon.* Vol.1: *The Field B^3.* Fundamental Theories of Physics, Vol.64, Dordrecht, Kluwer Academic Publishers.

Evans, M.W.; Vigier, J.P. (1995) *The Enigmatic Photon.* Vol.2: *Non-Abelian Electrodynamics.* Fundamental Theories of Physics, Vol.68, Dordrecht, Kluwer Academic Publishers.

Evans, M.W.; Vigier, J.P.; Roy, S.; Jeffers, S. (1996) *The Enigmatic Photon.* Vol.3: *Theory and Practice of the $B^{(3)}$ Field.* Fundamental Theories of Physics, Vol.77, Dordrecht, Kluwer Academic Publishers.

Evans, M.W., Vigier, J.P., Roy, S., Hunter, G. (1998) *The Enigmatic Photon.* Vol.4: *New Directions.* Fundamental Theories of Physics, Vol.90, Dordrecht, Kluwer Academic Publishers.

Evans, M.W. (1998) Electrodynamics as a Non-Abelian Gauge Field Theory. *Frontier Perspectives* 7 **(2)**, 7-12.

Fick, A. (1856) *Die medizinische Physik.* Braunschweig, Vieweg.

Fick, A. (1904) *Gesammelte Schriften*, vol.3, pp.492 and 767, Würzburg.

Findl, E. (19xx) Bioelectrochemistry - Electrophysiology - Electrobiology. In Bockris, J.O'M., Conway, B.E., White, R.E. (eds.), *Modern Aspects of Electrochemistry.* New York, Plenum Press, 509-555.

Fischer, M.H., Moore, G. (1907) *American Journal of Physiology*, **20**, 330.

Fischer, M.H. (1910) *Oedema: A Study of the Physiology and the Pathology of Water Absorption by the Living Organism.* New York, John Wiley.

Fischer, M.H., Hooker, M.O. (1933) *The Lyophilic Colloids (Their Theory and Practice).* Springfield, Illinois, Charles C. Thomas.

Fischer, M.H., Suer, W.J. (1938) *Archives of Pathology*, **26**, 51.

Fischer, M.H., Suer, W.J. (1951) *Der kolloide Aufbau der lebenden Substanz.* Darmstadt Steinkopff.

Fisher, S. (1986) *Development and Structure of the Body Image.* Hillsdale, NJ, Lawrence Erlbaum, 1986. 2 vols.

Flexner, S, Flexner, J.T. (1941) *William Henry Welch and the Heroic Age of American Medicine.* New York, Viking Press.

Fliess, W. (1906) *Der Ablauf des Lebens – Grundlegung zur exakten Biologie.* Leipzig-Vienna, Franz Deuticke.

Fougerousse, A. (1992) L'approche bio-électronique de Vincent. *Sciences du Vivant*, **No.4** (2ème trimestre), 63-79.

Fox-Keller, E. (1983) *A Feeling for the Organism*. San Francisco W.H.Freeman.

Friedman, N. (1997) *The Hidden Domain*. Eugene OR, Woodbridge Group.

Fröhlich, F., Hyland, G. (1995) Fröhlich coherence at the mind-brain interface. In King, J. and Pribram, K.H. (eds.), *Scale in Conscious Experience; Is The Brain Too Important To Be Left To Specialists To Study*. Mahwah, N.J., Lawrence Erlbaum Associates, 405-438.

Fröhlich, H. (1968) Long range coherence and energy storage in biological systems. *International Journal of Quantum Chemistry*, **2**, 641-649.

Fröhlich, H. (1969) Quantum mechanical concepts in biology. In Marois, M. (ed.), *Theoretical Physics and Biology*, Amsterdam, North-Holland, 13-22.

Fröhlich, H. (1975) Evidence for Bose condensation-like excitation of coherent modes in biological systems. *Physics Letters*, **51A**, 21-22.

Gabler, R. (1978) *Electrical Interactions in Molecular Biophysics*. New York, Academic Press.

Gallagher, R. (1984) Riemann and the Göttingen school of physiology. *Fusion*, **6 (3)**, 24-30.

Garnier, G. (1959) *Wladislas Kopaczewski - le savant et son oeuvre*. Lunéville.

Gasan, A.I. / Maleev, V.Ya. / Semenov, M.A. (1990) Role of water in stabilizing the helical biomacromolecules DNA and collagen. *Studia Biophysica*, **136 (2-3)**, 171-178.

Geddes, P. (1930) Life and Work of Sir J.C.Bose. New York: Benjamin Blom 1971.

Genack, A.Z., Drake, J.M. (1994) Scattering for super-radiation. *Nature*, **368**, 400-401.

Gilbert, S.F., Opitz, J.M., and Raff, R.A. (1996) Resynthesizing evolutionary and developmental biology. *Developmental Biology*, **173**, 357-372.

Glansdorff, P, Prigogine, I., *Thermodynamics of Structure, Stability and Fluctuations*. London, Wiley, 1971.

Glasser, O. (ed.) (1944, 1950, 1960) *Medical Physics*. 3 vols. Chicago, Yearbook Publishers.

Glauber, R. J. (1963a) The quantum theory of optical coherence. *Physical Review*, **130 (6)**, 2521-2539.

Glauber, R. J. (1963b) Coherent and incoherent states of the radiation field. *Physical Review*, **131 (6)**, 2766-2788.

Glauber, R. J. (1964) Quantum theory of coherence. In Grivet, P. and Bloembergen, N. (eds.), *Quantum Electronics*. Paris, Dunod / New York, Columbia University Press, **1**, 111-120.

Goodwin, B.C. (1987) Developing organisms as self-organizing fields. In *Self-Organizing Systems*, 167-180, ed. Yates, F.E (ed.), New York, Plenum.

Goodwin, B.C. (1994) Toward a science of qualities. In *New Metaphysical Foundations for Modern Science*, Harman, W. (ed.), Sausalito, CA, Institute of Noetic Sciences, 215-250.

Gortner, R.A. (1938) *Outline of Biochemistry*. 2nd. ed. New York, Wiley & Sons.

Goswami, A. (1989) The Idealistic Interpretation of Quantum Mechanics. *Physics Essays* 2, 385-400.

Goswami, A. (1993) *The Self-Aware Universe*. J.P.Tarcher/Putnam.

Goswami, A. (1994) *Science Within Consciousness – Developing a Science Based on the Primacy of Consciousness*. Causality Issues in Contemporary Science, Research Report # CP-7, Sausalito CA, Institute of Noetic Sciences.

Gough, W.C., Shacklett, R.L. (1993) The science of connectiveness. *Subtle Energies* **4 (1)**, 57-76, **4 (2)**, 99-123, **4 (3)**, 187-214.

Grandpierre, A. (1997) The physics of collective consciousness. *World Futures* **48**, 23-56.

Grandpierre, A. (2000) The nature of man-universe connections. In Amoroso, R., Antunes, R., Coelho, C., Farias, M., Leite, A., and Soares, P. (eds.), *Science and the Primacy of Consciousness*, Orinda, CA., Noetic Press, 203-223.

Gray, J. (1992) Consciousness on the scientific agenda. *Nature* 358, 277.

Green, E. E. (1990) *Consciousness, Psychophysiology, and Psychophysics: An Overview*. Copper Wall Research Technical Note, No.1, November 21, 1990, Voluntary Controls Program, Topeka, Kansas, The Menninger Clinic.

Green, E. E. (1991) Copper Wall Research – Psychology and Psychophysics. *"Subtle Energy and Energy Medcine: Emerging Theory and Practice". Proc. 1st Ann. Conf. Int.Soc. for the Study of Subtle Energies and Energy Medcine (ISSSEEM), June 21-25, Boulder, Colorado.* Golden, Colorado.

Grinberg-Zylberbaum, J. (1987) Patterns of interhemispheric correlation during human communication. *International Journal of Neuroscience*, **36**, 41-53.

Grinberg-Zylberbaum, J., et al. (1992) Human communication and the electrophysiological activity of the brain. *Subtle Energies*, **3 (3)**, 25-43.

Grinberg-Zylberbaum, J., et al. (1994) The Einstein-Podolsky-Rosen Paradox in the brain: The transferred potential. *Physics Essays*, **7 (4)**, 422-428.

Gu, Q. (1998) Biophotons and nonclassical light. In Chang, J.J., Fisch, J., Popp, F.A. (eds.), *Biophotons*, Dordrecht, Kluwer Academic Publishers, 299-321.

Gulyaev, Yu.V.; Godik, E.E. (1987) The physical fields of biological objects. In *Cybernetics of Living Matter*, Makarov, I.M. (ed.), 244-250, Moscow, Mir Publishers.

Gurwitsch, A. (1964) *The Field of Consciousness*. Pittsburgh, Duquesne University Press.

Gurwitsch, A.G. (1923) Versuch einer synthetischen Biologie. *Schaxels Abhandlungen zur theoretischen Biologie*, **17**, 1-87.

Gurwitsch, A.G., Gurwitsch, L.D. (1959) *Die mitogenetische Strahlung*. Jena, Gustav Fischer.

Gutenbrunner, C., Hildebrandt, G., and Moog, R., (eds.) (1993) *Chronobiology & Chronomedicine: Basic Research and Applications*. Frankfurt, Peter Lang.

Hagelin, J.S. (1987) Is consciousness the unified field ? A field theorist's perspective. *Modern Science and Vedic Science* **1 (1),** 29-87.

Haken, H. (1978) *Synergetics*. New York, Springer.

Haken, H. (1980) *Dynamics of Synergetic Systems*. New York, Springer.

Hadjamu, J. (1974) *Professor Dr.med.Heinrich Schade, Begründer der Molekularpathologie, 1876-1935, Leben und Werk*. Düsseldorfer Arbeiten zur Geschichte der Medizin, Heft 39, Düsseldorf, Michael Triltsch Verlag.

Hagley, E. et al. (1997) Generation of Einstein-Podolsky-Rosen pairs of atoms. *Physical Review Letters* **79 (1)**, 1-5.

Halberg, F. (1953) Some physiological and clinical aspects of 24-hour periodicity. *Lancet (USA)*, **73**, 20-32.

Halberg, F. (1960) Temporal coordination of physiological function. *Cold Spring Harbor Symoposia on Quantum Biology*, **25**, 289-310.

Halberg, F. (1969a) Chronobiologie – rhythms et physiologie statistique. In Marois, M. (ed.), *Theoretical Physics and Biology*. Amsterdam, North-Holland, 347-393.

Halberg, F. (1969b) Chronobiology. *Ann. Rev. Physiol.*, **31**, 675-725.

Halberg, F. (1979) Physiologic 24-hour periodicity. *Zeitschrift für Vitamin-, Hormon-, und Fermentforschung*, **10**, 225-296.

Halberg, F. (1998) Chronomedicine. In: Armitage, P., Colton, T., (eds.), *Encycloedia of Biostatistics*, Vol.1. Chichester, Wiley, 642-649.

Harman, W. (1992) *Reconciling the experience of consciousness with the scientific worldview*. Presented at the HSRC Conference on Science and Vision, Pretoria, South Africa, January 31.

Harman, W., Sahtouris, E. (1998) *Biology Revisioned*. Berkeley, North Atlantic Books.

Haroche, S., Kleppner, D. (1989) Cavity Quantum Electrodynamics. *Physics Today*, **42, No.1**, 24-30.

Haroche, S. (1991) Cavity Quantum Optics. *Physics World*, **4 (3)**, 33-38.

Hatfield, E., Cacioppo, J.T., and Rapson, R.L. (1994) *Emotional Contagion*. Cambridge, England, Cambridge University Press.

Hauss, W.H., Losse, H. (1960) *Struktur und Stoffwechsel des Bindegewebes*. Stuttgart, Thieme.

Hauss, W.H., Junge-Hülsing, G. (1961) Über die universelle unspezifische Mesenchymreaktion. *Deutsche Medizinische Wochenschrift*, **86**, 763.

Hauss, W.H., Junge-Hülsing, G., and Gerlach, U. (1968) *Die unspezifische Mesenchymreaktion*. Stuttgart: Gustav-Thieme-Verlag.

Hay, E.D. (1983) *Cell Biology of Extracellular Matrix*. 2nd ed. Plenum Press, New York and London 1983.

Hazlewood, C.F., Nichols, B.L., Chang, D.C., and Brown, B. (1971) On the state of water in the developing muscle. *Johns Hopkins Medical Journal*, **178**, 117.

Hazlewood, C.F. (1979) A view of the significance of and understanding of the physical properties of cell-associated water. In Drost-Hansen, W., Clegg, J.S., (eds.), *Cell-Associated Water*, New York, Academic Press.

Hazlewood, C.F. (1991) Insight into the organization of water in living cells. In Tigyi, J., Kellermayer, M., and Hazlewood, C.F., (eds.) *The Physical Aspect of the Living Cell*. Budapest, Akademiai Kiadó, 107-118.

Heine, H., Anastasiadis, P., (eds.) (1992), *Normal Matrix and Pathological Conditions*. Stuttgart, Gustav Fischer.

Heine, H. (1997) *Lehrbuch der biologischen Medizin*. 2nd rev. ed. Stuttgart, Hippokrates.

Heisenberg, W. (1958a) *Physics and Philosophy*. New York, Harper & Row.

Heisenberg, W. (1958b) *Physikalische Prinzipien der Quantentheorie*. Mannheim, Bibliographisches Institut.

Heisenberg, W. (1976) Was ist ein Elementarteilchen ? *Naturwissenschaften* **63 (1),** 1-7.

Hellpach, W. (1911) Die *geopsychischen Erscheinungen*. Publ. from 4th ed. under the title *Geopsyche*, Leipzig, Wilhelm Engelmann.

Hellpach, W. (1924) Psychologie der Umwelt. In, E.Abderhalden (ed.), *Handbuch der biologischen Arbeitsmethoden*, Abt.VI, part C1, 109-218, Vienna, Urban & Schwarzenberg.

Henderson, L.J. (1909) Das Gleichgewicht zwischen Basen und Säuren im tierischen Organismus. *Ergebnisse der Physiologie*, L.Asher and K.Spiro (eds.), **8**, 254-325.

Henderson, L.J. (1913) *The Fitness of the Environment*. New York, Macmillan.

Henderson, L.J. (1913) The regulation of neutrality in the animal body. *Science*, **37 (950)**, 389-395.

Henderson, L.J. (1928) *Blood: A Study in General Physiology*. New Haven.

Héricourt, J. (1927) *Le Terrain dans les Maladies*. Paris, Flammarion.

Hess, W.R. (1948) *Die funktionelle Organisation des vegetativen Nervensystems*. Basel, Schwabe.

Hill, A.V. (1930) *Proceedings of the Royal Society (London)*. Ser.B., 106, 477.

Hill, A.V., Kupalov, P.S. (1930) *Proceedings of the Royal Society (London)*. Ser.B., 106, 445.

Ho, M.W., Popp, F.A., and Warnke, U. (eds.) (1994) *Bioelectromagnetics and Biocommunication*. Singapore, World Scientific.

Ho, M.W. (1993) *The Rainbow and the Worm - The Physics of Organisms*. Singapore: World Scientific.

Ho, M.W. (19) Toward an indigenous Western science: Causality in the universe of coherent space-time structures. In *New Metaphysical Foundations for Modern Science*, Harman, W. (ed.) Sausalito, CA, Institute of Noetic Sciences, 179-213.

Ho, M.W. , French, A., Haffegee, J., Saunders, P.T. (1994) Can weak magnetic fields (or potentials) affect pattern formation ? In *Bioelectrodynamics and Biocommunication*, Ho, M.W., Popp, F.A. and Warnke U. (eds.), Singapore World Scientific, 195-212.

Ho, M.W. (1996) Organisms as polyphasic liquid crystals. *Bioelectrochemistry and Bioenergetics*, **41**, 81-91.

Ho, M.W. (1997) Towards a theory of the organism. *Integrative Physiological and Behavioral Science*, 32 (4), 343-363.

Ho, M.W. (1998) Organism and psyche in a participatory universe. In Loye, D. (ed.) *The Evolutionary Outrider*, Westport, CT, Praeger, 49-65.

Ho, M.W. (1999) *Genetic Engineering – Dream or Nightmare ?* 2nd rev. ed. Dublin Gateway.

Holmes, F.L. (1963) Claude Bernard and the milieu interieur. *Archives Internationales d'Histoire des Sciences*, **16**, 369-376.

Hoppe, W., Lohmann, W., Markl, H., and Ziegler, H., (eds.) (1982) *Biophysics*. 2nd compl. rev. ed., New York-Berlin, Springer.

Huntington, E. (1915) *Civilisation and Climate*. New Haven, Yale University Press.

Huntington, E. (1923) *Earth and Sun*. New Haven, Yale University Press.

Huntington, E. (1930) *Weather and Health*. Bulletin of the National Research Council, Washington, National Academy of Science.

Huntington, E. (1945) *Mainsprings of Civilisation*. New York, John Wiley & Sons.

Ihle, G. (1962) Das "Praecoxgefühl" in der Diagnostik der Schizophrenie. *Archiv für Psychiatrie*, **203**, 385-406.

Inyushin, V.M., Grishchenko, V.S., Vorobyov, N.A., Shuyski, N.N., Fyodorowa, N.N. and Gibadulin, F.F. (1968) *On the Biological Character of the Kirlian Effect – The Concept of Biological Plasma* (in Russian). Alma-Ata Kazakh State University.

Inyushin, V.M. (1970) Biological plasma of human and animal organisms. *International Journal of Paraphysics,* **5 (1/2),** 50-53.

Inyushin, V.M. (1977) Bioplasma: The fifth state of matter ? In White, J., Krippner, S. (eds.) *Future Science*, Garden City, N.J., Anchor-Doubleday, 115-120.

Inyushin, V.M. (1983) Resonance, biostimulation and the problem of bioplasma. In Wolkowski, Z.W. (ed.) *Proceedings Int. Symposium of Wave Therapeutics,* Créteil, 123-129.

Jantsch, E. (1980) *The Self-Organizing Universe*. Oxford Pergamon Press.

Jibu, M.; Yasue, K. (1993) The basics of quantum brain dynamics. In Pribram, K.H., (ed.) (1993) *Rethinking Neural Networks, Quantum Fields and Biological Data*. Hilldale N.J., Erlbaum.

Jibu, M., Yasue, K. (1995) *Quantum Brain Dynamics and Consciousness: An Introduction*. Philadelphia, John Benjamins Publishing.

Jordan, P. (1934) Quantenphysikalische Bemerkungen zur Biologie und Psychologie. *Erkenntnis*, **4 (3)**, 215-252.

Jordan, P. (1938) Die Verstärkertheorie der Organismen in ihrem gegenwärtigen Stand. *Naturwissenschaften*, **26**, 537.

Jordan, P. (1942) Begriff und Umgrenzung der Quantenbiologie. *Physis* (Stuttgart), **No.1**, 13-26.

Jordan, P. (1948) *Die Physik und das Geheimnis des organischen Lebens*. Braunschweig, Friedrich Vieweg & Sohn.

Josephson, B.D.; Pallikara-Viras, F. (1991) Biological utilization of quantum nonlocality. *Foundations of Physics,* **21 (2)**, 197-207.

Kafatos, M., Nadeau, R. (1990) *The Conscious Universe – Part and Whole in Modern Physical Theory*. New York, Springer.

Kanitscheider, B. (1979) *Philosophie und moderne Physik*. Darmstadt, Wissenschaftliche Buchgesellschaft.

Katchalsky, A., Curran, P.F. (1967) *Nonequilibrium Thermodynamics in Biophysics*. Cambridge, Mass.,Harvard University Press.

Katz, J.R. (1917) The role of swelling. *Kolloidchemische Beihefte*, **9**, 1-182.

Kay, L.E. (1985) The secret of life: Niels Bohr's influence on the biology program of Max Delbrück. *Rivista di Storia della Scienza,* **2 (3)**, 487-510.

Kay, L.E. (1993) *The Molecular Vision of Life – Caltech, the Rockefeller Foundation, and the Rise of the New Biology.* New York, Oxford University Press.

Keller, E.F. (1990) Physics and the emergence of molecular biology: A history of cognitive and political synergy. *Journal of the History of Biology* **23**, 389-409.

Kollath, W. (1968) *Regulatoren des Lebens - vom Wesen der Redox-Systeme.* Heidelberg, Karl F.Haug Verlag.

Kopaczewski, M.W. (1921-22) La tension superficielle en biologie. Parts 1-3. *Archives de Physique Biologique,* **1 (4) (1921),** 145-167; **2 (2) (1922),** 1-20; **2 (3) (1922),** 1-12.

Kopaczewski, M.W. (1923) *Théorie et pratique des colloides en biologie et en médecine.* Paris , Vigot Frères.

Kopaczewski, M.W. (1926a) *Introduction à l'étude des colloides. L'état colloidal et ses applications.* Paris, Gauthier-Villars.

Kopaczewski, M.W. (1926b) *Les ions d'hydrogène. Signification, mesure, applications, données numériques.* Paris , Gauthier-Villars.

Kopaczewski, M.W. (1930-38) *Traité de Biocolloidologie.* 2eme éd. Paris, Gauthier-Villars. vol. 1: Pratique des colloides (1930), tome 2, Biocolloides, vol. 3: Phénomènes colloidaux (1932-33), vol. 4: État colloidal en biologie (1933-36), vol. 5: État colloidal en médecine (1937-38).

Kopaczewski, M.W. (1933) Role de la tension superficielle en biologie. *Protoplasma,* **19**, 255-292.

Kopaczewski, M.W. (1936) Le terrain, le microbe et l'état infectieux: Claude Bernard ou Pasteur? *Revue Scientifique,* **74 (14)**, 417-425.

Kopaczewski, M.W. (1938) Meteoropathologie. *La Nature* (Paris), **66 (3024)**, 272-276.

Kopaczewski, M.W. (1939) *Essai de météoropathologie - physique, clinique, thérapeutique.* Paris, Baillière.

Kopaczewski, M.W. (1947) *D'Arsonval et la Biophysique.* Rabat.

Kracmar, F. (1971) Zur Biophysik des vegetativen Grundsystems. *Physikalische Medizin und Rehabilitation,* **12 (6)**, 120-122.

Kraus, F. (1919) *Allgemeine und spezielle Pathologie der Person. Klinische Syzygiologie.* Thieme, Leipzig; 2nd ed.1926, Vol.1: Allgemeiner Teil. Vol.2: Besonderer Teil: Tiefenperson.

Kühnau, J. (1941) Redoxpotentiale und Redoxsysteme in der Medizin. *Therapie der Gegenwart,* **82**, 35 and 375.

Kuhnert, L., and Niedersen, U., (eds.) (1987) *Selbstorganisation chemischer Strukturen – Arbeiten von F.F.Runge, R.E.Liesegang, B.P.Belousov und A.M.Zhabotinsky.* Ostwalds

Klassiker der exakten Wissenschaften, 272, Leipzig, Akademische Verlagsgesellschaft Geest & Portig.

Lakhovsky; G. (1963) *The Secret of Life. Cosmic Rays and Radiations of Living Beings.* 3rd rev. ed. Rustington, Sussex, England, Health Science Press.

Lakhtakia, A., ed. (1993) *Essays on the Formal Aspects of Electromagnetic Theory.* Singapore, World Scientific Publishing.

Laszlo, E. (1995) *The Interconnected Universe – Conceptual Foundations of Transdisciplinary Unified Theory.* Singapore, World Scientific.

Laszlo, E. (1996) *The Whispering Pond – A Personal Guide to the Emerging Vision of Science.* Rockport, Mass., Element Books.

Laughlin, C.D. (1996) Archetypes, neurognosis and the quantum sea. *Journal of Scientific Exploration* **10**, 375-400.

Laville, C. (1925) *Electrodynamique du muscle.* Paris.

Laville, C. (1928) *Le cancer - dérangement électrique de la cellule.* Paris, Dunod, 1928.

Laville, C. (1932) *La négativation électrique.* Montrouge: Imprimerie de l'Industrie, Later ed. Paris, Masson, 1934.

Laville, C. (1934) De la notion du pH considérée comme révélatrice de l'intimité des mécanismes vitaux. *pH,* juillet 1934.

Laville, C. (1950) *Mécanismes Biologiques.* Paris, Dunod.

Lawandy, N.M., et al. (1994) Laser action in strongly scattering media. *Nature,* **368 (6470)**, 436-438.

Lawrence, C. and Weisz, G., (eds.) (1998) *Greater Than the Parts - Holism in Biomedicine 1920-1950.* New York, Oxford University Press.

Leggett, A.J. (1986) The superposition principle in macroscopic systems. In *Quantum Concepts in Space and Time*, Penrose , R. and Isham C.J. (eds.) Oxford, Clarendon Press, 228-240.

Leggett, A.J. (1992) *Quantum Tunnelling in Condensed Media,* Yu Kagan & Leggett, A.J. (eds). Elsevier Science.

Leggett, A.J. (1996) The current status of quantum mechanics at the macroscopic level. *Foundations of Quantum Mechanics in the Light of New Technology*, eds. Nakajima S., Murayama, Y., and Tonomura, A. (eds.), Singapore: World Scientific, 257-267.

Letokhov, V.S. (1968) Generation of light by a scattering medium with negative resonance absorption. *Soviet Physics JETP*, **26**, 835-839.

Lewin, K. (1936) *Principles of Topological Psychology.* New York, McGraw-Hill.

Lewin, K. (1951) *Field Theory in Social Science*. New York, Harper & Brothers.

Li, K.H. (1992) Coherence in physics and biology. In Popp, F.A., Li, K.H., Gu, Q. (eds.), *Recent Advances in Biophoton Research and its Applications*, Singapore, World Scientific Publishing, 113-155.

Li, K.H. (1994) Uncertainty Principle, coherence, and structures. In R.K.Mishra, D. Maass, and E.Zwierlein (eds.), *On Self-Organization*, Berlin, Springer, 245-255.

Li, K.H. (1995) Coherence - A Bridge between Micro- and Macro-Systems. *Biophotonics - Non-Equilibrium and Coherent Systems in Biology, Biophysics and Biotechnology*., ed. L.V.Belousov, and Popp, F.A. (eds.), 99-114, Moscow, Bioinform Services.

Lichtwitz, L., Liesegang, R.E., and Spiro, K. (1935) *Medizinische Kolloidlehre*. Dresden, Steinkopff.

Lieth, H.H. (1981) 25 years of International Society of Biometerology. *International Journal of Biometerology*, **25 (3)**.

Ling, G.N. (1960) The interpretation of selective ionic permeability and cellular potential in terms of fixed charge/induction hypothesis. *Journal of General Physiology*, **43**, 149.

Ling, G.N. (1962) *A Physical Theory of the Living State: The Association-Induction Hypothesis*. Waltham, Mass., Blaisdell.

Ling, G.N. (1992) *A Revolution in the Physiology of the Living Cell*. Malabar, Florida, Krieger Publishing.

Ling, G.N. (2001) *Life at the Cell and Below-Cell Level. The Hidden History of a Fundamental Revolution in Biology*. New York, Pacific Press.

Lipkind, M. (1998) Alexander Gurwitsch and the concept of the biological field. Part 1. *21st Century Science & Technology*, **11 (2)**, 36-51.

Lipkind, M. (1998) Alexander Gurwitsch and the concept of the biological field. Part 2. *21st Century Science & Technology*, **11 (3)**.

Loofbourow, J.R. (1940) Borderland problems in biology and physics, *Rev.Mod.Phys*., **12 (4)**, 267.

Luce, G.G. (1971) *Biological Rhythms in Human and Animal Physiology*. New York, Dover.

Lund, E.J. (1947) *Bioelectric Fields and Growth*. Austin/Texas University of Texas Press.

Mandoli, D.F., Briggs, W.R. (1982) Optical properties of etiolated plant tissues. *Proceedings of the National Academy of Sciences of the USA*, **79**, 2902.

Mandoli, D.F., Briggs, W.R. (1984) Fiber optics in plants. *Scientific American*, **251**, 90-98.

Mansfield, V. (1995) On the physics and psychology of transference as an interactive field. *http://lightlink.com/vic/field.htm*.

Manzelli, P., Masini, G., and Costa, M. (1994) *I Segreti dell'Acqua. L'opera scientifica di Giorgio Piccardi.* Roma, Di Renzo Editore.

Marois, M., ed. (1969) *Theoretical Physics and Biology.* Amsterdam, North-Holland Publishing.

Marois, M., (ed.) (1971) *From Theoretical Physics to Biology.* Paris, Editions du CNRS.

Marois, M., (ed.) (1973) *From Theoretical Physics to Biology.*Basel , S.Karger.

Marois, M., (ed.) (1975) *From Theoretical Physics to Biology.* Amsterdam, North-Holland.

Marois, M. (1997) *Documents of History: Life and Human Destiny. The Institut de la Vie.* Paris, Rive Droite.

McBroom, P. (1966) Body Dances to Speech. *Science News*, **89**, 483.

Meystre, P., Walls, D.F. (1991) *Nonclassical Effects in Quantum Optics.* Key Papers in Physics, Bristol, Adam Hilger, American Institute of Physics.

Michaelis, L. (1914) *Die Wasserstoffionenkonzentration.* Berlin, Julius Springer.

Michaelis, L. (1933) *Oxydations- und Reduktionspotentiale.* Berlin, Julius Springer.

Mickulecky, M., (ed.) (1993) The Moon and Living Matter. Bratislava, Slovak Medical Society.

Mickulecky, M., (ed.) (1994) *Sun, Moon and Living Matter.* Bratislava, Slovak Medical Society.

Mickulecky, M., (ed.) (1997) Chronobiology and its Roots in the Cosmos. Bratislava, Slovak Medical Society.

Milburn, M.P. (1994) Emerging relationships between the paradigms of oriental medicine and the frontiers of Western biological science. *American Journal of Acupuncture*, **22 (2)**, 145-157.

Milburn, M.P. (2001) *The Future of Healing – Exploring the Parallels of Eastern and Western Medicine.* Freedom, California: The Crossing Press.

Millay, J. (1981) Brainwave synchronization: A study of subtle forms of communication. *Humanistic Psychology Institute Review*, **3**, 9-40.

Mishra, R.K. (1975) Occurrence, fluctuations and significance of liquid crystallinity in living systems. *Molecular Crystals and Liquid Crystals*, **29**, 201-224.

Mishra, R.K., Bhaumik, K., Mathur, S.C., and Mitra, P.P. (1979) Excitons and Bose-Einstein condensation in living systems. *International Journal of Quantum Chemistry,* **16**, 691-706.

Mishra, R.K. (1990) The living state - the matrix of self-organization. In Mishra, R.K.(ed.), *Molecular and Biological Physics of Living Systems*, Dordrecht, Kluwer Academic Publishers, 215-237.

Mitman, G., Fausto-Sterling, A. (1992) Whatever happened to Planaria? C.M.Child and the physiology of inheritance. In Clarke A.E. and Fujimura J.H. (eds.), *The Right Tool for the Right Job: At Work in Tweentieth-Century Life Sciences.* Princeton, Princeton University Press, 172-197.

Moore, G., Roaf, H.E. (1908) *Biochemical Journal*, **3**, 55.

Morton, Michael E., Dlouhy, Carrie (eds.) (1989) *Energy Fields in Medicine. A Study of Device Technology Based on Acupuncture Meridians and Chi Energy.* Kalamazoo, Michigan, John E.Fetzer Foundation.

Murphy, G. (1945) Field theory and survival. *Journal of the American Society for Psychical Research*, **39 (4)**, 181-209.

Murphy, G. (1947) *Personality – A Biosocial Approach to Origins and Structure.* New York, Harper & Brothers.

Murphy, G. (1961) Toward a field theory of communication. *Journal of Consciousness*, **11**, 196-201.

Murphy, M.P., O'Neill, L.A.J., (eds.) (1995) *What is Life ? The Next Fifty Years. Speculations on the Future of Biology.* Cambridge, Cambridge University Press.

N.N. (1999) Can physics deliver another biological revolution ? *Nature* **397**, 476-77.

Nalimov, V.V. (1981) *In the Labyrinths of Language.* Philadelphia, ISI Press.

Nalimov, V.V. (1982) *Realms of the Unconscious.* Philadelphia, ISI Press.

Nalimov, V.V. (1989) *Spontaneity of Consciousness.* Moscow, Prometheus Publishers (in Russian).

Nassonov, D.H. (1959) *The Local Reaction of the Protoplasm and the Spreading of Excitation* (in Russian). Moscow, Academy of Sciences.

Nelson, R.D., Bradish, G.J., Dobyns, Y.H., Dunne. B.J., and Jahn, R.G. (1996) FieldREG anomalies in group situations. *Journal of Scientific Exploration*, **10 (1)**, 111-141.

Nelson, R.D., Jahn, R.G., Dunne. B.J., Dobyns, Y.H., and Bradish, G.J. (1998) FieldREG II: Consciousness field effects: Replications and explorations. *Journal of Scientific Exploration*, **12 (3)**, 425-454.

Newton, R., and Gortner, R.A. (1922) A method for estimating hydrophilic colloid content of expressed plant tissue fluids. *Botanical Gazette*, **74**, 442-446.

Nicolis, G., Prigogine, I. (1977) *Self-Organization in Non-Equilibrium Systems.* New York, Wiley.

Ninham, B.W. (1982) Surface forces in biological systems. In Franks, F., Mathias, S.F., (eds.), *Biophysics of Water*, Chichester: Wiley, 105-119.

Norretranders, T. (1998) *The User Illusion. Cutting Consciousness Down to Size*. New York, Viking.

Nuccitelli, R., (ed.) (1986) *Ionic Currents in Development*. New York, Alan R. Liss, 1986.

Olmsted, E.H. (1967) Historical phases in the influence of Bernard's scientific generalizations in England and America. In Grande, F. and Visscher, M.B. (eds.), *Claude Bernard and Experimental Medicine*. Cambridge, Massachusetts, Schenkman, 24-34.

Országh, J. (1990) Réactions d'oxydo-réduction et acido-basiques - vers une approche théorique et expérimentale plus cohérente. *Sciences du Vivant*, **No.1 (3ème trimestre)**, 23-35.

Országh, J. (1992) Quelques aspects physio-chimiques des coordonnées bioélectroniques. *Sciences du Vivant*, **No.4 (2ème trimestre)**, 45-62.

Oschman, J.L. (1996) The nuclear, cytoskeletal and extracellular matrices: a continous communication network. Center for Advanced Studies in the Space Life Sciences Workshop on "*The Cytoskeleton: Mechanical, Physical, & Biological Interactions*", Nov.15-17, 1996, Marine Biological Laboratory, Woods Hole, Mass., Poster Session. http://www.mbl.edu/CASSLS/Oschman.poster.html.

Oschman, J.L. (2000) *Energy Medicine – The Scientific Basis*. Edinburgh, Churchill Livingston.

Palmer, J.D. (1976) *An Introduction to Biological Rhythms*. New York, Academic Press.

Petersen, W.F., Levinson, S.A. (1930) *The Skin Reactions, Blood Chemistry and Physical Status of 'Normal' Men and of Clinical Patients,* Archives of Pathology, 9, published as a separate monograph.

Petersen, W.F. (1936) *The Patient and the Weather*. Ann Arbor, Michigan: Edwards. 4 vols.

Petersen, W.F. (1947) *Man Weather Sun*. Springfield, Ill., C.C.Thomas.

Piccardi, G. (1962) *The Chemical Basis of Medical Bioclimatology*. Springfield, Ill., C.C.Thomas.

Pienta, K.J., and Coffey, D.S. (1991) Cellular harmonic information transfer through a tissue tensegrity-matrix system. *Medical Hypotheses*, **34**, 88-95.

Pierce, G.J. (1927) Sir J.C.Bose and his latest book. *Science*, **66 (1721)**, 621-622.

Pike, E.R., Walther, H., (eds.) (1988), *Photons and Quantum Fluctuations*. Bristol and Philadelphia, Adam Hilger.

Pischinger, A. (1991) *Matrix and Matrix Regulation – Basis for a Holistic Theory in Medicine*. Brussels, Haug International.

Planck, M. (1931) *Nature*, April **18**, 1931.

Popp, F.A., Nagl, W., Li, K.H., Scholz, W., Weingärtner, O., Wolf, R. (1984) Biophoton emission, New evidence for coherence and DNA as a source. *Cell Biophysics*, **6**, 33-51.

Popp, F.A. (1986) *Bericht an Bonn*. Essen, Germany, VGM.

Popp, F.A., Warnke, U., König, H.L. and Peschka, W., (eds.) (1989) *Electromagnetic Bio-Information*. 2nd ed. Munich-Baltimore, Urban & Schwarzenberg.

Popp, F.A., Li, K.H., Gu, Q., (eds.) (1992) *Recent Advances in Biophoton Research and its Applications*. Singapore, World Scientific.

Popp, F.A. (1994) Electromagnetism and Living Systems. In Ho, M.W., Popp, F.A., and Warnke, U. (eds.), *Bioelectromagnetics and Biocommunication*. Singapore, World Scientific, 33-80.

Popp, F.A., Chang, J.J., Herzog, A., Yan, Z, and Yan, Y. (2002) Evidence of non-classical (squeezed) light in biological systems. *Physics Letters A*, **293**, 98-102.

Popper, K.R., Eccles, J.C. (1977) *The Self and Its Brain*. New York, Springer International.

Porter, K.R., Tucker, J.B. (1981) The ground substance of the living cell. *Scientific American*, **244**, 57-67.

Porter, K.R. (1984) The cytomatrix: A short history of its study. *Journal of Cell Biology*, **99**, 3s-12s.

Presman, A.S. (1970) *Electromagnetic Fields and Life*. New York and London, Plenum Press. (Original Russian edition: Nauka, Moscow 1968).

Pribram, K.H., (ed.) (1993) *Rethinking Neural Networks: Quantum Fields and Biological Data*. Hillsdale N.J., Erlbaum.

Prigogine, I. (1947) *Étude Thermodynamique des Phénomènes Irréversibles*. Liège, Desoer.

Prigogine, I. (1961) *Introduction to Thermodynamics of Irreversible Processes*. New York', Wiley.

Primas, H. (1981) *Chemistry, Quantum Mechanics, and Reductionism*. Lecture Notes in Chemistry, Vol.24, Berlin, Springer.

Primas, H. (1982) Chemistry and complementarity. *Chimia* **36**, 293-300.

Primas, H. (1985) Kann Chemie auf Physik reduziert werden ? *Chemie in unserer Zeit* **19 (4)**, 109-xx and **19 (5)**, 160-166.

Primas, H. (1990) Biologie ist mehr als Molekularbiologie. In Fischer, E.P., Mainzer, K., (eds.), *Die Frage nach dem Leben,* Piper, Munich, 63-92.

Primas, H. (1992) Umdenken in der Naturwissenschaft. *GAIA* 1 **(1)**, 5-15.

Primas, H. (1993) Ein Ganzes, das nicht aus Teilen besteht – Komplementarität in den exakten Naturwissenschaften. In *Mannheimer Forum 92/93,* ed. E.P.Fischer. Mannheim: Boehringer.

Primas, H., Atmanspacher, H. and Amann, A. (eds.) (1999) *On Quanta, Mind and Matter. Hans Primas in Context.* Lecture Notes in Chemistry, 24, Dordrecht, Kluwer.

Radin, D., Rebman, J.M. and Cross, M.P. (1996) Anomalous organization of random events by group consciousness: Two exploratory experiments. *Journal of Scientific Exploration,* **10 (1)**, 143-168.

Radin, D. (1997) The Conscious Universe - The Scientific Truth of Psychic Phenomena. San Francisco, Harper, San Francisco.

Rashevsky, N. (1960) *Mathematical Biophysics.* 3rd. ed. New York, Dover.

Rashevsky, N. (1962) *Physicomathematical Aspects of Biology.* New York, Academic Press.

Rein, G. (1989) Effect of non-hertzian scalar waves on the immune system. *Journal of the U.S. Psychotronics Association,* **1**, 15.

Rein, G. (1991) Utilization of a cell culture bioassay for measuring quantum potentials generated from a modified caduceus coil. *Proceedings of the 26th Intersociety Energy Conversion Engineering Conference, August 4-9, 1991, Boston*, **4**, 400-403.

Rein, G. (1993) Modulation of neurotransmitter function by quantum fields. In Pribram, K.H., ed. *Rethinking Neural Networks: Quantum Fields and Biological Data,* Hillsdale N.J., Erlbaum, 377-388.

Rein, G. (1997) A bioassay for negative Gaussian fields associated with geometric patterns. In *Proceedings of the Fourth International Symposium of New Energy, Denver, Colorado, May 23-26, 1997.* Fort Collins, Colorado, International Association for New Science.

Rein, G. (1998) Biological effects of quantum fields and and their role in the natural healing process. *Frontier Perspectives* **7 (1)**, 16-23.

Reiss, P. (1926) *Le pH intérieur cellulaire.* Paris.

Reiss, P. (1940) L'action du potentiel d'oxydation-réduction du milieu sur l'autolyse protéique du cristallin et du corps vitré. *Archives de Physique Biologique,* **15 (4)**, 39-40.

Reiss, P. (1942/43) Actions du potentiel d'oxydation-réduction du milieu sur l'activité de differentes protéinases: Hydrolyse et condensation. *Archives de Physique Biologique,* 16, suppl.

Reiss, P. (1943/44) Les mesures de potentiels d'oxydation-réduction dans le sang. Revue bibliographique. *Archives de Physique Biologique,* 17, suppl.

Reiss, P., Lemair, R. (1943/44) Évolution du potentiel d'oxydo-réduction du sang humain in vitro. *Archives de Physique Biologique,* 17, suppl.

Richards, T.L., Standish, L.J. (2000) EEG coherence and visual evoked potentials: Investigation of neural energy transfer between human subjects. Abstract No.393. *Tucson 2000 Consciousness Conference*, http://www.imprint.co.uk/Tucson2000.

Ricker, G. (1905) *Entwurf einer Relationspathologie*. Jena, Gustav Fischer.

Ricker, G. (1924) *Pathologie als Naturwissenschaft. Relationspathologie*. Berlin, Julius Springer.

Rosen, R. (1958-59) A relational theory of biological systems. *Bulletin of Mathematical Biophysics*, **20**, 245-260, and **21**, 109-128.

Rosen, R. (1967) *Optimality Principles in Biology*. New York, Plenum Press / London, Butterworth.

Rosen, R. (1970) *Dynamical Systems in Biology*. New York, Wiley-Interscience.

Rosen, R. (1972) *Relationale Biologie*. Fortschritte der experimentellen und theoretischen Biophysik (ed.), W.Beier,Vol.15. Leipzig, Georg Thieme.

Rosen, R. (1974) The role of quantum theory in biology. *International Journal of Quantum Chemistry: Quantum Biology Symposia,* **No.1**, 229-232.

Rowlands, S. (1985) Condensed matter physics and the biology of the future. *Jourrnal of Biological Physics,* **13**, 103-105.

Rubik, B. (1996) *Life at The Edge of Science*. Philadelphia, Institute for Frontier Science.

Rudder, B. de (1931) *Grundriss einer Meteorobiologie des Menschen*. Berlin, Springer.

Rudder, B. de (1937) *Über sogenannte « kosmische » Rhythmen beim Menschen*. Stuttgart, Georg Thieme.

Sargent, F. II, Shimkin, D.B. (1965) Biology, society and culture in human ecology. *BioScience*, **15**, 512-516.

Sargent, F. II (1974) *Human Ecology*. Amsterdam, North-Holland / New York, American Elsevier.

Sargent, F. II (1982) *Hippocratic Heritage – A History of Ideas About Weather and Human Health*. New York, Pergamon Press.

Sargent, F. II (1983) *Human Ecology - A Guide to Information Sources*. Detroit, Gale Research.

Sassaroli, E., Srivastava, Y., Swain, J. and Widom, A., (eds.) (1998) *Macroscopic Quantum Coherence*. Singapore, World Scientific.

Saunders, S., Brown, H.R., (eds.) (1991) *The Philosophy of Vacuum*. Oxford, Clarendon Press.

Savva, S. (1999) Biofield and a cybernetic model of the organism: sauggestion for empirical study. *National Geophysical Data Center Public Hypernews*, http://hypernews.ngdc.noaa.gov/hnxtra/savva_paper.html.

Schade, H. (1909) Kolloidchemie und Balneologie. *Medizinische Klinik*, **No.29**, 1070 and **No.30**, 1116.

Schade, H. (1912a) Physikochemische Beiträge zur Öedemfrage. *Verhandlungen des Deutschen Kongresses für Innere Medizin* (Wiesbaden), **No.29**, 526-535.

Schade, H. (1912b) Untersuchungen zur Organfunction des Bindegewebes. I.Mitteilung: Die Elasticitätsfunction des Bindegewebes und die intravitale Messung ihrer Störungen. *Zeitschrift für experimentelle Pathologie und Therapie*, **11 (3)**, 369-399.

Schade, H. (1913) Untersuchungen zur Organfunction des Bindegewebes. II.Mitteilung: Das Quellungsvermögen des Bindegewebes in der Mannigfaltigkeit seiner Erscheinungen. *Zeitschrift für experimentelle Pathologie und Therapie*, **14, (1)**, 1-29.

Schade, H. (1921a) *Die physikalische Chemie in der inneren Medizin. Die Anwendung und die Bedeutung physikochemischer Forschung in der Pathologie und Therapie*. Dresden, Theodor Steinkopff Verlag.

Schade, H., Neukirch, P., and Halpert, A. (1921b) Über lokale Acidosen des Gewebes und die Methodik ihrer intravitalen Messung, zugleich ein Beitrag zur Lehre der Entzündung. *Zeitschrift für experimentelle Medizin*, **24**, 11.

Schade, H. (1922) Die Physikochemie des Bindegewebes und ihre Bedeutung für die Lymph- und Ödembildung. *Verhandlungen der Deutschen Gesellschaft für Innere Medizin*, **34**, 283-287.

Schade, H. (1923a) Über die Gesetze der Gewebsquellung und ihre Bedeutung für klinische Fragen (Wasseraustausch im Gewebe, Lymphbildung und Ödementstehung). *Zeitschrift für Klinische Medizin*, **96**, 279-327.

Schade, H. (1923b) Von der klinischen Bedeutung des Bindegewebes. *Jahreskurse für Ärztliche Fortbildung*, **14, part III**, 10-17.

Schade, H. (1923c) Die Physikochemie der Entzündung. *Verhandlungen der Deutschen Pathologischen Gesellschaft*, 19th meeting, 69-80. Jena, Gustav Fischer Verlag.

Schade, H. (1926) Die Bedeutung der H-Ionenkonzentration in der Pathologie. *Kolloid-Zeitschrift*, **40**, 252-258.

Schilder, P. (1950) *The Image and Appearance of the Human Body*. London, Kegan, Paul, Trench, Trubner.

Schiller, J. (1967) *Claude Bernard et les Problèmes Scientifiques de son Temps*. Paris, Editions du Cèdre.

Schnitzler, H., Lieth, H., (eds.) (1983), *25 years activities of the International Society of Biometeorology and 25 years publication index, International Society of Biometeorology*. Lisse, Netherlands, Swets & Zeitlinger.

Schrödinger, E. (1926) Der stetige Übergang von der Mikro- zur Makromechanik. *Naturwissenschaften*, **28**, 665.

Schrödinger, E. (1944) *What is life ? The Physical Aspect of the Living Cell.* Cambridge, Cambridge University Press.

Schutz, A. (1975) *Collected Papers.* 3 vols. The Hague, Martinus Nijhoff.

Schwartz-Salant, N. (1988) *The Borderline Personality – Vision and Healing.* Wilmette, Illinois, Chiron Publications.

Sedlak, W. (1967) Elektrostaza i ewolucja organiczna (Electrostasis and organic evolution). *Roczniki Filozoficzne*, **3**, 31.

Sedlak, W. (1976) Bioplasma - a new state of matter. In *"Bioplasma". Proceedings of the 1st Bioplasma Conference, May 9, 1973, Catholic University, Lublin/Poland*, W.Sedlak, (ed.), Lublin (English translation 1978).

Sedlak, W. (1979) *Bioelektronika: 1967-1977.* Aleksandrowicz, Julian (ed.), Warsaw, Poland: Instytut Wydawniczy Pax.

Sedlak, W. (1980) *Homo Electronicus.* Warsaw, Poland, Instytut Wydawniczy Pax.

Sedlak, W. (ed.) (198x) *Bioelektronika - Materialy i Krajowego Sympozjum.* Catholic University, Lublin, Poland.

Sedlak, W. (1984) *Postepy fizyki zycia.* Warsaw, Poland: Instytut Wydawniczy Pax.

Segal, J. (1958) *Die Erregbarkeit der lebenden Materie.* Jena, Gustav Fischer.

Segal, J., Körner, U., Leiterer, K.P. (1983) *Die Entstehung des Lebens aus biophysikalischer Sicht.* Jena, Gustav Fischer.

Selleri, F. (ed.) (1988) *Quantum Mechanics versus Local Realism – The Einstein-Podolsky-Rosen Paradox.* New York, Plenum Press.

Selye, H. (1936) A syndrome produced by diverse nocuous agents. *Nature*, **148**, 84-85.

Selye, H. (1946) The general adaptation syndrome and the diseases of adaptation. *Journal of Clincial Endocrinology*, **6**, 117-196.

Selye, H. (1950) *Stress: The Physiology and Pathology of Exposure to Stress.* Montreal, Acta Medica.

Selye, H. (1967) *In Vivo – The Case for Supramolecular Biology.* New York, Liveright.

Shacklett, R.L. (1991) The physics behind the mind-matter link. In *"Subtle Energies and Energy Medicine: Emerging Theory and Practice", conference proceedings of the First Annual Conference of the International Society for the Study of Subtle Energies and Energy Medicine.* June 21-25, Boulder, Colorado, 92-95.

Sherrington, C.S. (1940) *Man on His Nature*. Harmondsworth, Middlesex, Penguin Books, 69-98.

Shimony, A. (1963) Role of the observer in quantum theory. *American Journal of Physics* **31 (10)**, 755-773.

Shipov, G.I. (1998) *A Theory of the Physical Vacuum – A New Paradigm*. Moscow, International Institute for Theoretical and Applied Physics RANS.

Shnol', S.E., Smirnov, B.R., Sadonsky, G.I. (1981) in Grechova, M.T. (ed.) *Autowave Processes in Systems with Diffusion* (in Russian). Gorky, 187.

Shnol', S.E., Smirnov, B.R., Sadonsky, G.I., Rovinsky, A.B. (1982) *Khimiya i Zhisn'*, **7**, 68.

Shnol', S.E., (ed.) (1996) *Relations of Biological and Physico-Chemical Processes with Space and Helio-Geophysical Factors*. Abstracts of the 4th International Pushchino Symposium, dedicated to the centennial of helio-biology founder A.L.Chizhevsky (1897-1964), September 23-28. Pushchino, Academy of Sciences of Russia, Pushchino Research Centre.

Sigel, F. (1975) *Schuld ist die Sonne*. Thun-Frankfurt am Main, Harri Deutsch (Russian original ed. Moscow 1972).

Sinz, R. (1978) *Zeitstrukturen und organismische Regulationen*. Berlin, Akademie-Verlag.

Sinz, R. (1980) *Chronopsychophysiologie, Chronobiologie und Chronomedizin*. Berlin, Akademie Verlag.

Sit'ko, S.P., Gizhko, V.V. (1991) Towards a quantum physics of the living state. *Journal of Biological Physics*, **18 (1)**, 1-10.

Smith, C.W. (1994) Electromagnetic and magnetic vector potential bio-information and water. *Ultra-High Dilution – Physiology and Physics*, Endler, P.C. and Schulte, J. (eds.), Dordrecht, Kluwer Academic.

Smuts, J.C. (1926) *Holism and Evolution*. New York, Macmillan.

Sollberger, A. (1965) *Biological Rhythm Research*. Amsterdam, Elsevier.

Stapp, H.P. (1997) Nonlocal character of quantum theory. *American Journal of Physics,* **65 (4)**, 300-304.

Susskind, C., Bose, Jagadis Chunder (1970) in Gillispie, C.G. (ed.) *Dictionary of Scientific Biography*. New York, Scribner's, 325.

Szent-Györgyi, A. (1941) Energy levels in biochemistry. *Nature*, **148**, 157.

Szent-Györgyi, A. (1941) Towards a new biochemistry. *Science*, **93 (1941)**, 609.

Szent-Györgyi, A. (1957) *Bioenergetics*. New York, Academic Press.

Szent-Györgyi, A. (1960) *Introduction to a Submolecular Biology*. New York, Academic Press.

Szent-Györgyi, A. (1969) Charge-transfer and cellular activity. In *Theoretical Physics and Biology*, Proceedings lst Int. Conf. on Theoretical Physics and Biology, Versailles, June 26-30, 1967, Marois, M. (ed.), 192-193, Amsterdam-London, North-Holland.

Szent-Györgyi, A. (1971) Biology and pathology of water. *Perspectives in Biology and Medicine*, **14 (2)** 239-249.

Takata, M., Murasugi, T. (1941) Flockungszahl-Störungen im gesunden menschlichen Serum, "kosmoterrestrischer Sympathismus". *Bioklimatische Beiblätter*, **8**, 17.

Takata, M. (1951) Über eine neue biologisch wichtige Komponente der Sonnenstrahlung. *Archiv für Meteorologie, Geophysik und Bioklimatologie*, **486**.

Tart, C. (1969) Psychedelic experiences associated with a novel hypnotic procedure, mutual hypnosis. *Altered States of Consciousness*. New York, Wiley, 291-308.

Taub-Bynum, E.B. (1984) *The Family Unconscious – An Invisible Bond*. Wheaton, Illinois, Quest Books.

Taylor, R. (1996) Scalar fields, subtle energy and the multidimensional universe (in English). *Soznanye i Fizicheskaya Realnost'* **1 (3)**, 79-

Taylor, R. (1998) A gentle introduction to quantum biology. *Consciousness and Physical Reality* **1(1)**, 64-72.

Tchijevsky, A.L. (1936) *Les Phénomènes Éléctrodynamiques dans le Sang*. Éditions Hippocrate, Paris.

Tchijevsky, A.L. (1940) Cosmobiologie et rhythme du milieu extérieur, in Holmgren, H.J. (ed.), *Verhandlungen der zweiten Konferenz der Internationalen Gesellschaft für biologische Rhythmus-Forschung am 25. und 26. August 1939 in Utrecht*. Stockholm, Acta Medica Scandinavica, 108, Suppl., 212-226.

Tettinger, L., Doljansky, F. (1992) On the generation of form by the continuous interactions between cells and their extracellular matrix. *Biological Reviews of the Cambridge Philosophical Society*, **67**, 459-489.

Thaheld, F.H. (1998) A proposed experiment concerning nonlocal correlations between a quantum observer and another person. *Physics Essays*, **11**, 422-425.

Thaheld, F.H. (2001a) A preliminary indication of controllable biological quantum nonlocality ? *Apeiron*, **8 (1)**.

Thaheld, F.H. (2001b) Proposed experiments to determine if there is a connection between biological nonlocality and consciousness. *Apeiron*, **8 (4)**, 53-66.

Thiele, H. (1947) Richtwirkung von Ionen auf anisotrope Kolloide - Ionotropie. *Naturwissenschaften*, **34**, 123.

Thiele, H. (1954) Ordered coagulation and gel formation. *Discussions of the Faraday Society*, 18, 294-301.

Thiele, H., Schacht, E. (1957) Über Ionenreaktionen bei Polyelektrolyten, Vorstufen bei der Bildung von Gelen. *Zeitschrift für physikalische Chemie*, **208**, 42-58.

Thiele, H. (1967) *Histolyse und Histogenese. Gewebe und ionotrope Gele - Prinzip einer Strukturbildung*. Frankfurt am Main, Akademische Verlagsgeselllschaft.

Thompson, D'Arcy, W. (1917) *On Growth and Form*. Cambridge, Cambridge University Press.

Tigyi, J., Kellermayer, M and Hazlewood, C.F. (1991) *The Physical Aspect of the Living Cell*. Budapest, Akademiai Kiadó.

Tiller, W. (1977) Towards a future medicine based on controlled energy fields. *Phoenix*, **1 (1)** 5-16.

Tiller, W. (1985) Energy fields and the human body, in White, J. (ed.), *Frontiers of Consciousness. The Meeting Ground between Inner and Outer Reality*, New York, Julian Press, 229-242.

Tiller, W. (1993) What are subtle energies ? *Journal for Scientific Exploration*, **7 (3)**, 293-304.

Tiller, W. (1995) Subtle energies in energy medicine. *Frontier Perspectives*, **4 (2)**, 17-21.

Tiller, W.A. (1999a) Towards a predictive model of subtle domain connections to the physical domain aspect of reality: The origins of wave-particle duality, electric-magnetic monopoles and the mirror principle. *Journal of Scientific Exploration*, **13 (1)**, 41-67.

Tiller, W.A., Dibble, W.E., and Kohane, M.J. (1999b) *Exploring robust interactions between human intention and inanimate/animate systems*. Excelsior, MN, USA, Ditron, LLC.

Tiller, W.A., Dibble, W.E., and Kohane, M.J. (2001) *Conscious Acts of Creation – The Emergence of A New Physics*. Walnut Creek, California, Pavior Publishing.

Tocquet, R. (1951) *Cycles et Rhythmes*. Paris.

Tomassen, G.J. (eds.) (1990) *Geo-Cosmic Relations; the Earth and its Macro-Environment*. Proceedings of the First International Congress on Geo-Cosmic Relations, Amsterdam, Netherlands, 19-22 April 1989. Wageningen, Pudoc.

Trincher, K.S. (1965) *Biology and Information: Elements of Biological Thermodynamics*. New York, Consultants Bureau.

Tromp, S.W. (1949) *Psychical Physics*. New York, Elsevier.

Tromp, S.W. (1961) Significance of border sciences for the future of mankind. In Boyko, H. (ed.), *Science and the Future of Mankind*, Den Haag, Uitgeverij Dr.W.Junk, 83-120.

Tromp, S.W. (19 63) *Medical Biometeorology*. New York, Elsevier.

Tromp, S.W. (1972) Possible effects of extra-terrestrial stimuli on colloidal systems and living organisms. In Biometeorology, 5, part II. Suppl. to *Intenational Journal of Biometeorology*, **16**, 239-248.

Troshin, A. S. (1966) *Problems of Cell Permeability*. Rev. & supplem. (ed.) Oxford, Pergamon Press. (Russian original ed.: Moscow: Academy of Sciences, 1956).

Usa, M., Kobayashi, M., Scott, R.Q., Maeda, T., Hiratsuka, R., Inaba, H. (1989) Simultaneous measurement of biophoton emission and biosurface electric potential from germinating soybean (*Glycine max*). *Protoplasma* , **149,** 64-66.

Uexküll, T. et al. (1997) *Subjektive Anatomie*. Stuttgart , Schattauer.

Vanable, J.W. (1991) A history of bioelectricity in development and regeneration, in Dinsmore, C.E. (ed.), *A History of Regeneration Research*, Cambridge, Cambridge University Press, 151-178.

Vernadsky, V.I. (1954-60) *Izbrannye Sochineniya* (Selected Works, in Russian). Vols.1-5. Moscow, Academy of Sciences.

Vernadsky, V.I. (1998) *The Biosphere*. With introduction and annotations by Mark A.S. McMenamin and Jacques Grinevald. Copernicus Books (first published in Russian in 1926).

Vincent, L.-C. (1954) Aperçu sur la bio-électronique. *Revue de Pathologie Générale et Comparée*, **54 (663)**, 121-130.

Vincent, L.-C. (1956a) Bio-Electronique. Définition des trois facteurs prhoniques pH, rH^2 et ρ. Bulletin de la Société de Pathologie Comparée, Séance du Mardi 14 Juin 1955, *Revue de Pathologie Générale et de Physiologie Clinique*, **56 (677)**, 643-656.

Vincent, L.-C. (1956b) Potentiel d'oxydo-réduction et rH^2. *Revue de Pathologie Générale et de Physiologie Clinique*, **56 (677)**, 657-678.

Vlès, F. (1927) *Cours de Physique Biologique*. Paris, Vigot Frères.

Vlès, F. (1929) Revue des notions actuelles sur un problème de physico-chimie pathologique: Les propriétés des points isolelectriques et du terrain physico-chimique dans l'organisme normal ou pathologique; leur application à l'étude des tumeurs. *Archives de Physique Biologique*, 7, fasc. suppl. **No.5**, 1-64.

Vlès, F., Reiss, P., and Deloyer, L. (1931) Le potentiel de platine et le rH du sang circulant des mammifères. *Comptes Rendus de la Société de Biologie*, **108**, 37.

Vlès, F. (1936a) Recherches sur les propriétés physico-chimiques des électrolytes. *Archives de Physique Biologique*, Vol.13, **No.1 (1936)**, 57-73 and 88-107.

Vlès, F. (1936b) Recherches sur les electrolytes. II. Les conditions de cohérence dans les solution. III: Remarques sur le rH de Clark. Comptes rendus des séances de la réunion de physique biologique de Strasbourg. Supplément aux *Archives de Physique Biologique*, **13**, 191-193.

Vlès, F., and Coulon, A. de (1936c) Recherches sur les propriétés physico-chimiques des tissus en relation avec l'état normal ou pathologique de l'organisme. 22e partie. Suite des expériences sur la cancérisation spontanée des souris au sol et isolées. *Archives de Physique Biologique*, **13 (2)**, 150-176.

Vlès, F. (1936d) L'eau colloidale. Comptes rendus des séances de la réunion de physique biologique de Strasbourg. *Supplément aux Archives de Physique Biologique*, **13**, 192.

Vlès, F. (1936e) Les données actuelles sur la constitution et les propriétés physico-chimiques de l'eau. *Archives de Physique Biologique*, **15 (1)**, 33-85.

Vlès, F. (1942) *Introduction à la photochimie biologique – radiations, analyse spectrale, photochimie*. Paris, Vigot Frères.

Vogelman, T.C. (1989) Penetration of light into plants. *Photochemistry and Photobiology*, **50 (6)**, 895-902.

Waddington, C.H. (1968-72) *Towards a Theoretical Biology*. Edinburgh, Edinburgh University Press.

Walker, E.H. (1970) The nature of consciousness. *Mathematical Biosciences* **7**, 131.

Walker, E.H. (1974) Consciousness and quantum theory. In *Psychic Exploration,* White, J. (ed.), New York, Putnam's Sons, 544-568.

Walker, E.H. (2000) *The Physics of Consciousness*. Cambridge, Mass., Perseus Books.

Watson, A. (1997) Quantum spookiness wins, Einstein loses in photon test. *Science,* 277, 481.

Weiner, H (1992) *Perturbing the Organism – The Biology of Stressful Experience*. Chicago, University of Chicago Press.

Weiss, P., Garber, B. (1952) Shape and movement of mesenchyme cells as functions of the physical structure of the medium. Contributions to a quantitative morphology. *Proceedings of the National Academy of Sciences (USA)*, **38**, 264-280.

Welch, G. R. (1992) An analogical "field" construct in cellular biophysics: history and present status. *Progress in Biophysics and Molecular Biology*, **57**, 71-128.

Whipple, H.E., (ed.) (1965) Forms of Water in Biological Systems. *Annals of the New York Academy of Sciences*, **125**, Art.2, 249-772.

Wiener, N. (1948) *Cybernetics*. New York, Wiley.

Wiggins, P.M. (1971) Water structure as a determinant of ion distribution in living tissue. *Journal of Theoretical Biology*, 32, 131-146.

Wiggins, P.M. (1972) Intracellular pH and the structure of cell water. *Journal of Theoretical Biology*, **37 (2)**, 363-371.

Wiggins, P.M. (1990) Role of water in some biological processes. *Microbiological Reviews*, **54 (4)**, 432-449.

Wijk, R. van, Linnemans, W.A. (1993) The basic regulatory system - a system theoretical concept behind chronical diseases. In Lamoen, G.J. van (ed.), *Biologische Information und Regulation*, Heidelberg, Karl F.Haug Verlag, 36-62.

Williams, R.J. (1956) *Biochemical Individuality*. New York, Wiley.

Wnuk, M.J., Bernard, C.D. (2001) The electromagnetic nature of life – The contribution of W.Sedlak to the understanding of the essence of life. *Frontier Perspectives*, **10 (1)**, 32-35.

Wolf, E. (1963) Spatial coherence of resonant modes in a maser interferometer. *Physics Letters*, **3 (4)**, 166-168.

Wolkowski, Z.W., Sedlak, W. and Zon, J. (1983) The utility of bioelectronics and the bioplasma concept in the study of the biological terrain and its equilibrium. In *Proceedings of the International Symposium on Wave Therapeutics, Versailles 1979*, Wolkowski, Z.W. (ed.), 114-122, Créteil, Université de Paris-Val-de-Marne.

Wolkowski, Z.W. (1985) Le concept de champ: de la physique à la biologie. In *Synergie et Cohérence dans les Systèmes Biologiques*, Wolkowski, Z.W. (ed.), Paris, École Européenne d'Été d'Environnement.

Wolkowski, Z.W. (1988) Sur l'évolution de certain concepts physiques dans les sciences de la vie. *Revue Internationale de Systémique* **2 (4)**, 459-477.

Wolkowski, Z.W. (1995) Recent advances in the phoron concept: An attempt to decrease the incompleteness of scientific exploration of living systems. In *Biophotonics – Non-Equilibrium and Coherent Systems in Biology, Biophysics and Biotechnology*, Beloussov, L.V. and Popp, F.A. (eds.), Moscow, Bioinform, 33-51.

Wu, T.T. (1975) Concept of nonintegrable phase factors and global formulation of gauge fields. *Physical Review D* **12 (12)**, 3845-3857.

Wu, T.T. and Yang, C.N. (1975) Some remarks about unquantized non-Abelian gauge fields. *Physical Review D*, **12 (12)**, 3843-3844.

Yagodinskii, V.N. (1987) *Aleksandr Leonidovich Chizhevskii* (in Russian). Moscow, Nauka.

Zeiger, B.F. (1998) Photon emission of cereal seeds, "biophotons", as a measure of germinative ability and vigour. In Chang, J.J., Fisch, J., and Popp, F.A. (eds.), *Biophotons*. Dordrecht, Kluwer

Zeiger, B.F. and Bischof, M. (1998) The quantum vacuum and its significance in biology. Paper given at *the Third International Hombroich Symposium on Biophysics,* Neuss, Germany, August 20-24, 1998.

Zhang, C.L., Popp, F.A., and Bischof, M. (eds.) (1996) *Current Development of Biophysics.* Hangzhou, China, Hangzhou University Press.

Ziegler, E. (1960) *Messung und Bedeutung des Redoxpotentials im Blut in vivo und in vitro* (Habilitationsschrift, Universität Freiburg i.Br.). Arzneimittel-Forschung, 10.Beiheft. Aulendorf/Württemberg, Verlag Editio Cantor.

Zon, J.R. (1980) The living cell as a plasma physical system. *Physiological Chemistry and Physics,* **12 (4)**, 357-364.