FIELD CONCEPTS AND THE EMERGENCE OF A HOLISTIC BIOPHYSICS

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ABSTRACT

Due to recent advances in several disciplines, the basic features of a holistic biophysics are now emerging. It is proposed that the postulates for such a field must include that it will be based on the intrinsic holism of quantum theory and the properties of macroscopic quantum effects, that it should include the principles of nonlocality, nonseparability, and interconnectedness, that it will be based on a field picture of reality and the organism, and finally must include consciousness.

The paper attempts to show why field models are appropriate tools for the holistic modeling of the organism, proposes a hierarchy of regulation systems based on fields, gives a review of field models proposed in biology, biophysics, consciousness research and social science, and discusses the possible role of fields in bridging the mind-body gap.

Finally, a discussion of the perspectives that may be opened up for biophysics by some recently proposed extensions of electromagnetic theory leads the author to suggest a role for the physical vacuum in the organism.

INTRODUCTION

"Can Physics deliver another biological revolution ?" asked an editorial in the journal *Nature* of January 1999[1]. However, the so-called "new physics-biology agenda" which several U.S. universities, foundations and government agencies intend to fund heavily, is actually a very old agenda going back to the 1930's, namely that of molecular biology, which now in a gigantic effort of total genetic mapping, called by some *"the New Manhattan Project of Biology"*, strives to bring the molecular biology project of total technological control over life to a final fulfillment.

Is this the kind of "new biophysics" we want to be supported with all that money and effort ? I am certainly not alone in asking this question, and with the growing dissatisfaction about the reductionist, molecular-genetic approach to biology the number of those who develop and support an entirely different kind of biophysics is increasing [2-16].

A look into the history of biology and biophysics shows that there always have been alternative traditions to the molecular-reductionistic approach now dominant in these fields. In biology, during some periods, e.g., in the first half of this century – holistic or organismic approaches have been far from marginal, in some disciplines, such as developmental biology, even constituting the dominant trend. Biophysics itself, although a relatively young field of science, has already experienced several changes in emphasis in the course of its history[17,18]. The German founders of biophysics at the beginning of the 19th century, people like H.Helmholtz, E.Du Bois-Reymond, E.Brücke, C.Ludwig, E.H.Weber and G.T.Fechner, usually are depicted by historians of science as staunch reductionists and opponents of vitalistic and idealist ideas in biology. However, as Culotta has shown[19], 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. Likewise, in the 1930s when molecular biology started its rise that has made it the dominant approach in biology and biophysics, there were a number of other viable biological programs, some of them holistic, that could have been chosen for promotion by the Rockefeller Foundation[20]. The reason why the officers and scientific advisers of the Foundation chose to promote the molecular vision of life was that they sought to develop, under the influence of Jacques Loeb's engineering standpoint[21] aimed at controlling life, a mechanistic

biology as a central element of a new science of man whose final goal was social engineering.

Originally, the Rockefeller Foundation had intended to promote its goal of social control by eugenics, supporting several research projects concerned with eugenic selection. When eugenics lost its scientific validity amd social acceptance, the molecular biology program of creating a new biology grounded in the physical sciences and able to rigorously explain and eventually control the fundamental mechanisms governing human behaviour, promised a surer, if slower, way toward social control by eugenic selection based on the more readily accepted principles of genetics and protein science. Even within the scientific developments that stood at the origin of molecular biology[22], before it definitely took the reductionist turn leading to the present situation, at least one also forms an important element in the foundation of a modern holistic approach in biophysics: the quantum philosophy of Bohr, Schroedinger, Jordan and Delbrück.

BIOPHYSICS AND THE QUANTUM REVOLUTION

The philosophical contribution to the rise of molecular biology originated in Niels Bohr's speech *„On Light and Life"* at the International Congress on Light Therapy at Copenhagen, August 15, 1932 [23] where he postulated that a new physics was required for interpreting life; life was not reducible to atomic physics. A few of the key figures in molecular biology, mainly M.Delbrück and E.Schrödinger, were strongly influenced by Bohr's views [24], which Schrödinger took up in his book *„What is Life ?"* [25]. The book 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 [26].

However, the book certainly was more influential by interpreting the genetic viewpoint of H.J.Muller, T.H.Morgan and M.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[27]. These 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 as the manageable project of refashioning life and redirecting the course of evolution that the Rockefeller Foundation and some of its early pioneers like H.J.Muller and W.Weaver had envisioned. 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 many weak points in genetic and evolution theory[28], does not prevent it to carry us into such immature and dangerous projects as genetic engineering biotechnology in agriculture and medicne, 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[29,30]. 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 [31] 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"* .

For Primas[29], 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 [29,30,32-36], the atomistic-molecular view of matter and the reductionist-mechanist philosophy have no more 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 possiblities 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*. For quantum mechanics, the scientific theory most widely recognized as fundamental and best confirmed by experiment, material reality forms and 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[14]. 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 [37, 38], while quark physics as founded by M.Gell-Mann continues to cultivate democritean atomism with their clinging to the concept of elementary particles[39]. Similar holistic views of quantum theory are the *„bootstrap theory"* of G.Chew [40], D.*Bohm's „Causal Quantum Theory" or „Holographic Theory of Reality"* [41, 42], and others advocated by H.Stapp[43], A.Goswami [44-46], Kafatos & Nadeau[47], Friedman[48], D.Peat, F.Capra, H.Atmanspacher[49], 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[50-54]. 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 therefore emphasizes that we will have to learn to work simultaneously with several complementary descriptions of nature[29] .

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 ist 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

distiction only makes sense for irreversible processes. As to the existence of the hypothetical vitalistic forces, modern physics is well able to integrate new forces into its system.

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, interdepences, on processes, fields, and wholes. Quantum theory is a nonlocal theory[43]. It is important to see that we cannot 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 diomensions of reality. The holistic interpretation of quantum theory in fact may also be taken as implying a multidimensional structure of reality [48,55]**.** 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[56], or of the „noumena“, the realm behind the phenomena according to 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 [48]. 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[51]. 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 [41,44-46,48,55,57,58,59-61]. 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 [62,63] seems obvious to us, as we will explain later. Therefore we postulate the development of a *„vacuum biophysics"* (see last chapter) .

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[64-68]. Biological systems obviously possess the characteristics of macroscopic quantum systems.

THE REDEFINITION OF BIOPHYSICS

From what we have just heard, we can conclude that traditional biophysics, based up to now on classical physics and equilibrium thermodynamics, needs a redefinition in terms of the revolution brought by the last few decades of quantum-mechanical experiments and interpretations. As there is still no agreement on the definition of the field, we are free to attempt such a redefinition. In the following I will try to determine what the postulates for such a new biophysics could be, as it actually is already in development since about ten or fifteen years.

First of all, 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. Thus, 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. Its basis must be the insight into the fundamental interconnectedness *within* the organism as well as *between* organisms, and that of the organism *with the environment*.

Therefore it must be inter- or transdisciplinary and truly integrate biological, biochemical and medical expertise into its physical models, but also connect to knowledge from fields such as geophysics, biometeorology, heliobiology etc.

It 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 of the new biophysics, related to the latter, will be coherence and macroscopic quantum states.

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 sythesize the wealth of its details, and 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. However, 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.

HISTORICAL ANTECEDENTS OF HOLISTIC

BIOPHYSICS

Not only theoretical considerations as those of Primas, but also the history of biology and of biophysics show clearly that the reductionistic concept of molecular biology is not the only possible concept for biological science; there even have been several periods in which holistic approaches have been dominating biology, or at least parts of it[69]. Even in biophysics proper, there have always been holistic schools of thought, although they usually are not mentioned in contemporary reviews of the field, or not thought of belonging to biophysics.

An early instance of holistic thought in biology is the school of rational or transcendental morphologists of the late 18th and early 19th centuries, such as G.de Cuvier, E.Geoffrey St-Hilaire, and R.Owen, who deduced, from their detailed studies of organismic morphology, the existence of principles or laws of form operating in the biological realm[70]. Similarly, the holistic biology and medicine of the Romantic period, including J.W.Goethe, A. v. Humboldt, C.G.Carus, K.E. von Baer and J. Müller, regarded the ideal form

of a species as a transcendental guiding principle in morphogenesis[71]. A strong tradition of antireductionistic physiology starting with F.Magendie was mainly created by Claude Bernard[72]. Bernard's concept of *"internal environment" ("milieu interne")* developed in 1857, stood at the beginning of the research in physiological regulation, to which E.Starling, L.J.Henderson, J.Barcroft, and W.B. Cannon *("homeostasis")* have been contributing; other holistic physiologists were J.S.Haldane, H. Selye, R. Dubos and A. Carrel.

In the period of 1900-1950, the main thrust of developmental biology, especially in the work of H.Driesch, H.Spemann, P.A.Weiss, A.Gurwitsch, R.Harrison, C.M.Child, J.v.Uexküll, J.Needham, E.S.Russell, J.H.Woodger, A.Meyer-Abich, and A.Müller, has been holistic and centered around the concept if biological fields [69,73-74].

Very much fallen into oblivion has today the important work done during this century in the German tradition of holistic physiology, pathology and medicine, represented by names like G.v.Bergmann, H.Schade, F.Kraus, F.Buttersack, A.Bier, Th.Brugsch, B.Aschner, L.R.Grote, F.Hoff, R.Rössle, G.Ricker, H.Eppinger, W.Petersen, H.Pischinger, O.Bergsmann. Holistic schools of medical thought have also been active in Britain, the USA, and France, mainly in the interwar period[75].

Important contributions to holistic science came from Gestalt theory and other holistic theories in psychology, neurobiology, and psychiatry, as exemplified by W.James, Chr.v. Ehrenfels, M.Wertheimer, W.Köhler, K.Goldstein, K.Lewin, C.v.Monakow, C.S.Sherrington, K.Lashley, G.Murphy, V.v. Weizsäcker, A.Maslow, K.Pribram [74-78].

The work of the Austrian-Canadian biologist L.v.Bertalanffy is particularly significant for the emerging holistic biophysics; Bertalanffy's "organismic" conception of life, which also was the starting point of his *"General System Theory",* actually constitutes a first attempt to create a holistic picture of the organism based on physical laws and detailed biological knowledge, and ist still a valuable guide for our contemporary efforts [79-84]. The German school of Beier [85-86] has continued this tradition in biophysics.

An early tradition of holistic biophysics developed from Claude Bernard's school in France, represented by A.d'Arsonval, W.Kopaczewski, F. Vlès, and G.Lakhovsky.

Russia has its own tradition of holistic biology, biophysics and bioelectromagnetics with the work of V.I.Vernadsky, A.L.Chizhevsky, A.G.Gurwitsch, E.Bauer, and A.S.Presman, among others.

An important contribution to holistic thinking comes from the tradition of mathematical biophysics with its concepts of optimality, and relational and similarity principles, represented by D'Arcy W.Thompson, N.Rashevsky, R.Rosen, and R.Thom.

Holistic concepts in philosophy of relevance to biology and biophysics have been developed by J.Smuts, A.N.Whitehead, O.Spann, A.Meyer-Abich, H.Conrad-Martius, H.Plessner, H.Friedmann, among others.

Last but not least, the contributions of psychosomatic medicine, such as those by V.v.Weizsäcker, F.Alexander, Flanders Dunbar, G.Groddeck, and G.R.Heyer, must be mentioned.

In the time of 1900 to 1950, holistic approaches in biology, usually connected to field concepts (see next chapter), far from being marginal, have formed one of the dominant schools of thought, at least in developmental biology[69,73,74]. For various reasons, the plausibility of this approach has strongly decreased from the 1950's[87]. The main reason was the rise of genetics as an alternative program to explain development.

Much of this work is anything but obsolete, but it is now necessary to actualize the fundamental observations and concepts developed by these pioneers of holistic science with the up-to-date knowledge in the respective fields.

FIELD CONCEPTS AS A NECESSARY BASE OF HOLISTIC BIOPHYSICS

Modern physical field theories, such as those developed by Faraday and Maxwell, have their origin in metaphysical concepts arising from the participatory consciousness of archaic man[88]. Field and particle theories arise from complementary modes of human self- and world-experience rooted in

bodily awareness, with the field perception of reality probably being much older than particle theories, which could only arise when the participatory world-view slowly gave way to individual consciousness and the perception of an objective world, by way of an increasing differentiation between inside and outside, I and the world, the subjetive and the objective, and matter and consciousness. This objectivation of the world has reached its climax in the worldview of the classical physics of the late 19th century, with the assumption that all there is to reality is solid particles assembled in various degrees of complexity.

The electromagnetic field theories of Faraday and Maxwell proposed in the second half of the last century have inspired biologists already from 1900 to the development of the first field theories, but it was only with Einstein's General Relativity, quantum mechanics and quantum field theory, that physics overcame the mechanical world picture and conceived reality as a field phenomenon.

Biology still bases its picture of the organism on the building-stone view of classical physics which physics itself has already given up since a couple of decades. One of the first and most fundamental steps in the development of a holistic biology must therefore be not only to complement the classical view with the field aspect, but even to build its model of the organism on the field picture.

As I have shown elsewhere, the concept of the field has alraedy occupied a central place in the school of "organismic" or "holistic" biologists in the first half of this century[69].

Leading biologists such as H.Spemann, R.Harrison, P.A.Weiss, J.Needham, and C.H.Waddington, A.G.Gurwitsch used the hypothesis of a biological, or morphogenetic, field, introduced by Weiss and Gurwitsch in the early 1920's, as a tool for understanding the phenomena of development, regeneration and morphogenesis and to make predictions for experimental testing. Although their field concepts referred to the model of physical, especially electromagnetic fields, the organicists 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.

ELECTROMAGNETIC FIELD THEORIES IN BIOLOGY

At this time, there was not enough experimental evidence for the existence of bioelectromagnetic fields nor for the biological effects of EM fields. Thus, the various electromagnetic (EM) field concepts proposed since the first decades of the 20th for biology, as those by Keller, Burr, Burr & Northrop, Crile, Lund, and Lakhovsky[89], were premature. The breakthrough and beginning of modern EM field theories in biology came only in 1970, with A.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[90]. Since then, there is ample evidence for bioeffects of EM fields and endogenous EM fields. 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 fierlds 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.

A number of further developments have contributed to the full development of modern biological field theories. They include the work of A.Szent-Györgyi on the excitation-deexcitation dynamics in biochemistry and the role of charge transfer in the organism[91-93]; the work on open, non-equilibrium systems and the coordinated collective behaviour of particles culminating in Prigogine's theory of "dissipative systems"; H.Fröhlich's work on coherence of the EM fields coupled to these particles and connecting them [94-97]; the Dicke theory of the coherent emission of coupled multiatomic emitters [98]; the theory of quantum coherence developed by R.J.Glauber [99-101]; and several recent developments in quantum optics, such as the work on non-classical light and Cavity Quantum Electrodynamics [102,103].

MODERN BIOELECTROMAGNETIC FIELD THEORIES

These achievements became important elements in the *"biophoton theory"* developed by Popp and his group[104-106]. Like most modern field-theoretical proposals, it tries to reconcile particle and field approaches. Based on the

evidence for the coherent emission of ultraweak luminescence by organisms, 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, holographical 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 the regulation of biochemical and morphogenetic processes.

A related approach, *"bioplasma theory"*[107-114], 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[115, 116], has 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[41]. 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.[117,118] 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 [119-124].

BIOPHYSICS AND CONSCIOUSNESS: ON THE POSSIBLE ROLE OF FIELDS IN BRIDGING THE MIND-BODY GAP

The German founders of biophysics in the early 19th century 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[19]. Today, the situation is different. Since around the turn of the 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[127-128]. An increassing number of authors are emphasizing the necessity of introducing consciousness into the scientific worldview, and some believe it should even become its very foundation [41,44-46,49,57,131-135]. As to the consequences of a

„biology without consciousness“, Efron[136] 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[137,129-130] has certainly been a significant influence. As can be seen from the new discipline of *„Quantum Neurodynamics“* [138-140], 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[141], 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 [88].

It was probably W.James who first introduced the concept of a field of consciousness into modern psychology in 1890. C.G.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 Chr.v.Ehrenfels and W.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. In the 1930's K.Lewin proposed in his field theory of social psychology that social interactions are best understood by a field model. In the 1940's G.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 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. In 1964, Aron Gurwitsch proposed a field theory of experiential organization in the

tradition of Gestalt theory, Lewin and Husserl's phenomenology. The Russian mathematician and philosopher, V.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.

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 70's K.H.Pribram has proposed that coherent holographic fields mediate between consciousness and neurological processes; J.Eccles has 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. H.Margenau in 1984 suggested mind may be a unique type of non-material field, analogous to quantum probability fields; this suggestion was taken up in 1986 by J.Eccles who proposed that this field may modify the probability of emission of neurotransmitters at the dendritic synapse. 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. 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.

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.

OBSERVATIONS AND EXPERIMENTAL STUDIES OF INTERPERSONAL FIELDS OF UNKNOWN NATURE

The existence of electromagnetic fields emitted by living organisms, including humans, is now well established, even if there is not much established 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 [88].

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, which probably serves to establish empathic resonance. A related phenomenon is the well established phenomenon of *"emotional contagion"*. 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. 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"*. In *"mutual hypnosis"* two persons create a common psychic field which in the deeper stages can turn into a shared hallucinatory or dreamlike reality. Families may, according to some psychotherapists, possess a common unconscious and shared emotional field.

A number of recent experimental studies give evidence that such interpersonal field effects may have some physical basis. Studies of empathically bonded pairs by J.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. 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 events generators (REG) that suggest the presence of a field within such groups. 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.

While these experiments suggest the possible non-electromagnetic nature of the studied fields, the measurements of the "Copper-Wall Project" performed by E.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 electromaters attached to the four highly polished copper walls surrounding them in some distance.

BIOLOGICAL FIELDS IN THE LIGHT OF SOME PROPOSED EXTENSIONS OF ELECTROMAGNETIC THEORY

In some of these experiments showing the existence of interpersonal field phenomena (Grinberg-Zylberbaum, DMILS) electromagnetic fields have been excluded; therefore we must use the hypothesis 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[63,142-147], 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 [147-153]. 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 [142, 145,146].

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 [154], 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 [155,156]. Aharonov & Bohm [154] have shown that in certain cases the potentials act as real physical fields and must even be consdered 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[157,158]. Barrett [159,160] 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 Tiller[142] 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[159,160] 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“*[161-166] and the B(3) „ghost field“ of longitudinal magnetic polarization [167-173].

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 the recent attempts at developing unfied theories of all physical interactions.

In the various unification programs 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)[174]. We postulate that it also merits such a central place in biophysics [62,63,147]. It has in fact already been used in a number of recent models, e.g. by Conrad[175,176], Grandpierre[58], Laughlin[177], Laszlo[59,60], Jibu & Yasue[139,140], Shacklett [55], and Tiller[142-144]. 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. 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“* [178].

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.

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 [179-180].

More recently, Zeiger[62-63] 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 endowes 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 proving 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 Bearden[181-183] 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.

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, between the solid body on the one hand, and consciousness on the other hand, the intermediate levels of holitic regulation systems and physiological-biochemical regulation, bioenergetic (EM) fields, and finally bioinformation fields.

<table>
<tr><th colspan="3">HIERARCHY OF LEVELS OF BIOLOGICAL FUNCTION</th></tr>
<tr><td></td><td colspan="2">• Solid body (tissues)</td></tr>
<tr><td></td><td>• Holistic regulation systems
(nervous system, hormonal system, extracellular matrix, immune system etc.)</td><td>• Physiological-biochemical regulation
(acid-base balance, redox potential, bioelectronics (electronic excitation , electron flows, proton flows), etc.</td></tr>
<tr><td>EM FIELDS</td><td colspan="2">• Bioenergetic fields (EM fields)</td></tr>
<tr><td rowspan="2">DOMAIN OF THE

VACUUM</td><td colspan="2">• Bioinformation fields „subtle energies“ (potentials etc.)</td></tr>
<tr><td colspan="2">• Unified field, consciousness</td></tr>
</table>

CONCLUSION

Can physics deliver another biological revolution ? There is good evidence it indeed can and will, but it is not the further perfection of the reductionist program of molecular-biological control of life devised in the 1930's that will produce the much needed revolution, but rather the renewal of the alternative tradition of holistic understanding in biophysics whose features are now beginning to emerge more clearly. It will draw on the still valid findings of the various holistic approaches in physics and the biomedical sciences of the first half of the last century which it will actualize by linking them to the many recent advances in physics and molecular biology, and it will incorporate the interaction of consciousness with biological matter as a key element in understanding the phenomena of life. The new holistic biophysics will be based on a field model of the organism and its interactions with other living systems and the environment; besides electromagnetic fields it will also consider the possible role of novel, non-electromagnetic fields and of the physical vacuum in biological processes.

REFERENCES

(1) Can physics deliver another biological revolution ? *Nature* 397 (1999), 89.

(2) Williams, N. (1997) Biologists cut reductionist approach down to size. *Science* 277, 476-77.

(3) Albrecht-Buehler, G. (1990) In defense of ‚nonmolecular' cell biology. *International Reiew of Cytology* 120, 1-21.

(4) Elsasser, W.M. (1982) The other side of molecular biology. *Journal of Theoretical Biology* 96, 67-76.

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

(6) Sermonti, G. (1995) The inadequacy of the molecular approach in biology. *Frontier Perspectives* 4 (2), 31-34.

(7) Petukhov, S.V. (1999) *Biosolitons* (in Russian). Moscow: Kimrskaya Tipographia.

(8) Jerman, I; Stern, A. (1996) *The Gene in Waves – The Forming of A New Biology* (in Slovenian). Lyublyana, Slovenia: Scientific Publishing Center.

(9) Savva, S. (1998) Toward a cybernetic model of the organism. *Advances* 14 (4), 287-301.

(10) Schwartz, G.E.R.; Russek, L.G.S. (1999) *The Living Energy Universe*. Charlottesville, VA: Hampton Roads Publishing.

(11) Rubik, B. (1996) Toward an emerging paradigm for biology and medicine. In: *Life at The Edge of Science*. Philadelphia: Institute for Frontier Science, 147-167.

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

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

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

(15) Ho, M.W. (1998) Organism and Psyche in a Participatory Universe. In: *The Evolutionary Outrider*, ed. D.Loye. Westport, CT: Praeger, 49-65.

(16) Zhang, C.L.; Popp, F.A.; Bischof, M. (1996) *Current Development in Biophysics*. Hangzhou: Hangzhou University Press.

(17) Bischof, M. (1995) Vitalistic and mechanistic concepts in the history of bioelectromagnetics. In: *Biophotonics – Non-Equilibrium and Coherent Systems in Biology, Biophysics and Biotechnology*, eds. L.V.Beloussov and F.A.Popp. Moscow: Bioinform, 3-14.

(18) Bischof, M., Some remarks on the history of biophysics and its future. In: *The Current Development of Biophysics*, eds. C.L.Zhang, F.A.Popp, and M.Bischof. Hangzhou, China: Hangzhou University Press, 10-21, 1996.

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

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

(21) Pauly, P.J., *Controlling Life – Jacques Loeb and the Engineering Ideal in Biology*. New York: Oxford University Press, 1987.

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

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

(24) 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.

(25) Schroedinger, E., *What is Life ?*

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

(27) 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.

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

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

(30) Primas, H.; Atmanspacher, H., and Amann, A., eds. (1999) *On Quanta, Mind and Matter: Hans Primas in Context*. (Fundamental Theories in Physics, 102). Dordrecht: Kluwer.

(31) Rosen, R. (1967) *Optimality Principles in Biology*. New York: Plenum Press.

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

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

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

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

(36) 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.

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

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

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

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

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

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

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

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

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

(46) 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.

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

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

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

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

(51) Shimony, A. (1988) The reality of the quantum world. *Scientific American* 258, 36-43.

(52) 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.

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

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

(55) Shacklett, Robert 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 Medicne, June 21-25, 1991, Boulder, Colorado*, pp.92-95.

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

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

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

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

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

(61) 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.

(62) Zeiger, B.F. (1998) Photon emission of cereal seeds, „biophotons“, as a measure of germinative ability and vigour. In: Chang, J.J.; Fisch, J.; Popp, F.A. (eds.): *Biophotons*. Dordrecht: Kluwer, 251-297.

(63) Zeiger, B.F.; 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*.

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

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

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

(67) 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.

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

(69) Bischof, M. (1998a) Holism and field theories in biology – Non-molecular approaches and their relevance to biophysics. In: *Biophotons*, eds. J.J.Chang, G.Fisch, and F.A.Popp. Dordrecht: Kluwer, 375-394.

(70) Goodwin, B. (1981) A structuralist view of biological origins. In: *The Study of Time IV*, eds. J.T. Frazer, N.Lawrence, and D.Park. New York: Springer, 73-89.

(71) Meyer-Abich, A. (1949) *Biologie der Goethezeit*. Stuttgart: Hippokrates.

(72) Virtanen, R. (1960) *Claude Bernard and his Place in the History of Ideas*. Lincoln: University of Nebraska Press.

(73) Haraway, D.J. (1976) *Crystals, Fabrics, and Fields: Metaphors of Organicism in Twentieth-Century Developmental Biology*. New Haven: Yale University Press.

(74) Harrington, A. (1996) *Reenchanted Science: Holism in German Culture from Wilhelm II to Hitler*. Princeton: Princeton University Press.

(75) Lawrence, C.; Weisz, G. (1998) *Greater Than The Parts – Holism in Biomedicine, 1920-1950*. Oxford: Oxford University Press.

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

(77) Taylor, E. (1996) *William James on Consciousness Beyond the Margin*. Priinceton: Princeton University Press.

(78) Taylor, E. (1999) *Shadow Culture – Psychology and Spirituality in Aamerica*. Washington, D.C.: Counterpoint.

(79) Bertalanffy, L.v. (1933) *Modern Theories of Development: An Introduction to Theoretical Biology*. London: Oxford University Press.

(80) Bertalanffy, L.v. (1952) *Problems of Life*. New York: Wiley.

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

(82) Bertalanffy, L.v. (1975a) New Patterns of Biological and Medical Thought. In: *Perspectives on General System Theory*. New York: Braziller, 40-52.

(83) Bertalanffy, L.v. (1975b) The Organismic Conception. In: *Perspectives on General System Theory*. New York: Braziller, 97-102.

(84) Bertalanffy, L.v.; W.Beier; R.Laue (1977) *Biophysik des Fliessgleichgewichts*. Braunschweig: Vieweg.

(85) Beier, W. (1960) *Biophysik*. Leipzig: Thieme.

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

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

(88) Bischof, M. (1998) *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, 1998.

(89) Bischof, M. (1994) The history of bioelectromagnetism. In *Bioelectrodynamics and Biocommunication*, eds. Ho, M.W.; Warnke, U., and Popp, F.A. Singapore: World Scientific, 1-30.

(90) Presman, A.S. (1970) *Electromagnetic Fields and Life*. New York: Plenum.

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

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

(93) 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, edited by M.Marois, 192-193. Amsterdam-London: North-Holland.

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

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

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

(97) Fröhlich, H. (1981) Coherence in biological systems. *Collective Phenomena* 3, 139-146.

(98) Benedict, M.G.; Ermolaev, A.M.; Malyshev, V.A.; Sokolov, I.V.; Trifonov, E.D. (1996) *Super-Radiance – Multiatomic Coherent Emission*. Bristol and Phildadelphia: Institute of Physics Publishing.

(99) Glauber, R.J. (1963a) The quantum theory of optical coherence. *Physical Review* 130 (6), 2529-2539.

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

(101) Glauber, R.J. (1970) Quantum theory of coherence. In: *Quantum Optics*, eds. Kay, S.M. and Maitland, A. New York: Academic Press, 53-125.

(102) Meystre, P.; Walls, D.F., eds. (1991) *Nonclassical Effects in Quantum Optics*. New York: American Institute of Physics.

(103) Berman, P.R. (1994) *Cavity Quantum Electrodynamics*. Boston: Academic Press.

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

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

(106) Chang, J.J., Fisch, J., Popp, F.A. (1998) Biophotons. Dordrecht: Kluwer.

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

(108) Inyushin, V.M. (1970) Biological plasma of human and animal organisms. *International Journal of Paraphysics* 5 (1/2), 50-73.

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

(110) Sedlak, W. (1967) A model of a system radiating the biological field and electrostasis (in Polish). *Kosmos A* 2, 154-159.

(111) Sedlak, W. (1969) ABC of the electromagnetic theory of life (in Polish). *Kosmos A* 18, 164-174.

(112) Sedlak, W. (1976) Bioplasma - a new state of matter (in Polish). In*: Bioplasma – Proceedings of the First Bioplasma Conference, May 9, 1973*, held at the Catholic University of Lublin, Poland. Lublin: Catholic University (English translation in 1978).

(113) Wolkowski, Z.W.; Sedlak, W; 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*, ed. Z.W.Wolkowski. Créteil, 114-122.

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

(115) Pribram, K. (1971) *Languages of the Brain*. New York: Prentice-Hall.

(116) Pribram, K., Nuwer, M., Baron, R.J. (1974) The holographic hypothesis of memory structure in brain function and perception. In: D.H.Krantz, R.C.Atkin son, R.D.Luce and P.Suppes, eds., *Measurement, Psychophysics, and Neural Information Processing*. San Francisco: W.H.Freeman, 416-457.

(117) Miller, R.A.; Webb, B.; Dickson, D. (1979) A holographic concept of reality. In: *Psychoenergetic Systems*, ed. S.Krippner. New York: Gordon and Breach, 231-237.

(118) Miller, R.A.; Webb, B. (1992) Embryonic Holography. *Pychedelic Monographs and Essays*, 6. Boynton Beach, Florida: PM&E Publishing Group.

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

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

(121) Dossey, L. (1992) Era III medicine: The next frontier. *ReVision* 14 (3), 128-139.

(122) Welch, G.R.; Smith, H.A. (1990) On the field structure of metabolic space-time. In *Molecular and Biological Physics of Living Systems*, ed. R.K.Mishra. Dordrecht: Kluwer, 53-85.

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

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

(125) 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.

(126) 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*, eds. L.V.Beloussov and F.A.Popp. Moscow: Bioinform, 33-51.

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

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

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

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

(131) Jahn, R.G.; Dunne, B.J. (1987) *Margins of Reality – The Role of Consciousness in the Physiucal World*. Harcourt, Brace, Jovanovich.

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

(133) 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, 1992.

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

(135) Radin, D. (1997) The Conscious Universe - The Scientific Truth of Psycic Phenomena. San Francisco: HarperSanFrancisco.

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

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

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

(139) 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.

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

(141) 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.

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

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

(144) Tiller, W.A. (1999) 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.

(145) Taylor, R. (1996) Scalar fields, subtle energy and the multidimnensional universe. *Soznanye i Fizicheskaya Realnost'* 1 (3), 79-82.

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

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

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

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

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

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

(152) 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.

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

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

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

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

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

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

(159) 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.

(160) 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.

(161) 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).

(162) 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.

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

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

(165) 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.

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

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

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

(169) 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.

(170) 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.

(171) 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.

(172) 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.

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

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

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

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

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

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

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

(180) Bischof, M. (1995a) *Biophotonen – das Licht aus unseren Zellen* (in German). Frankfurt/Main: Zweitausendeins.

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

(182) 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.

(183) 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.