GSI CLASSROOM

Book Review and Commentary:

BIOLOGICAL COHERENCE AND RESPONSE TO EXTERNAL STIMULI

Edited by Herbert Fröhlich

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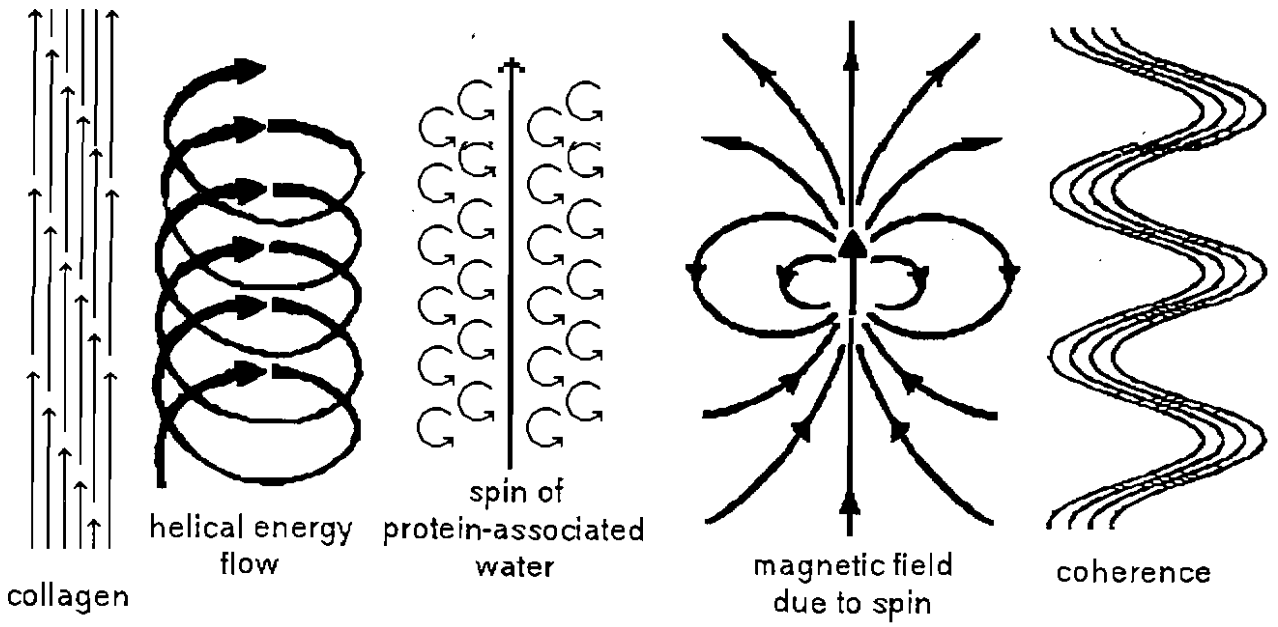

Review and commentary

by

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Introduction

For those of us who are interested in the human body as an energetic system, there is no recent literature that is more significant than that published by Herbert Fröhlich and his colleagues. One of the foremost physicists in the study of crystalline or highly ordered non-living materials, Fröhlich has recently turned his attention to the cooperative or coherent phenomena displayed by biological systems. The book reviewed here provides a deep and rich source of insight and stimulation. Each reading enhances our understanding of an important new model that is emerging in the field of biophysics. This is a model that may eventually validate many of the energetic experiences in bodywork.

A line of thought that began in the late 1960's has led to the realization by Fröhlich that molecular systems must produce giant coherent or laser-like oscillations that will move about within the organism and that will be radiated into the environment. Fröhlich predicts that these signals have important roles in the regulations that lead to unity of function, wholeness, in the organism.

The ability of molecules to vibrate and produce strong oscillations at visible and near-visible light frequencies goes hand in hand with the great sensitivity of living systems to external energy fields of all kinds. The book contains fascinating essays by Fröhlich as well as by his various colleagues around the world who have confirmed and elaborated upon his predictions.

Study of these phenomena is likely to enlighten us about a number of seemingly esoteric observations that bodyworkers make on a regular basis. For those who are sensitive to radiations (light, colors, sounds, electric and magnet-like sensations, etc.) in the spaces around their clients, the material reviewed here is worthy of careful study. Coherent vibrations recognize no boundaries, at the surface of a molecule or of a cell or of an organism--they are collective properties of the whole and they radiate their messages into the environment.

We have attempted to keep to a minimum the use of technical terms and mathematics, and have defined those concepts that may be new to you and that are essential for an understanding of the subjects covered. We have written this review because it forms the basis for a series of articles we are publishing on the scientific basis of bodywork.

We interpret the main points of each chapter from the perspective of the bodyworker. While the concepts apply to a variety of sorts of molecular arrays in living systems, our comments are mainly in reference to collagen, connective tissue, and fascia, as well as the cells that produce and nourish them. Statements in parentheses, references, and drawings are our own additions.

Non-linear systems are mentioned frequently. Non-linearity, chaos theory, and fractals are related phenomena that are attracting lots of attention in scientific circles at the present time. They form the basis of a "new science" that reveals order and pattern in phenomena that previously seemed to be random, erratic, and unpredictable. The radiations and communications discussed in the book are primarily of the non-linear type.

H. Fröhlich, Liverpool
Theoretical Physics and Biology

The two approaches, reductionist, or working with the properties of individual parts, and holistic, working with properties of large systems, supplement each other. An understanding of systems involves different and new principles that are not simply extensions of the behavior of parts. Study of energetics in living systems has elucidated some striking effects, but sometimes these are not reproducible. This is due to the non-linear or chaotic properties of such systems. A very small change in an initial condition may lead to a large change in the outcome.

F. Kaiser, Darmstadt
Theory of Non-Linear Excitations

Non-linear excitations can result in a single frequency becoming strongly excited and then stabilized because of the high degree of order present in the surrounding matrix. In fact, an entire system (such as a particular fascial layer or an entire tendon) may react as a unit, and transform as a whole. When this happens the system may emit a coherent signal much like a laser beam.

This approach helps us understand the very great sensitivity of living systems to extremely weak environmental electromagnetic fields. Energy applied from the outside of the organism can couple to coherent signals inside that are involved in whole-body regulations. The existence of coherent signaling systems in organisms has important consequences for the establishment of temporal (time) and spatial (structural) order.

One important type of coherent wave is the soliton or solitary wave. This is a wave that preserves its shape and speed, even when it collides with another soliton. Solitons are capable of loss-free energy transport--they do not dissipate or lose their energy as they move through tissues.

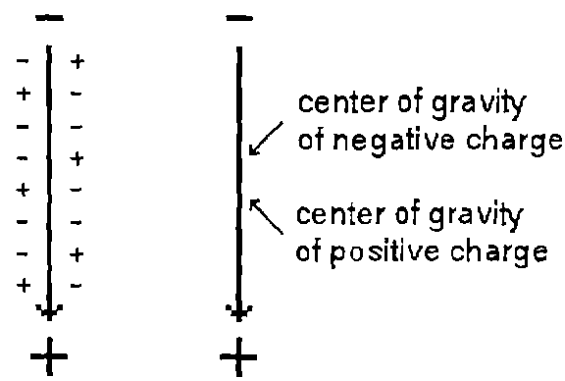
Solitons can carry a variety of messages, but they are non-linear. This means that a very weak external field, containing very little energy, can destabilize a soliton. When this happens, the soliton can collapse, releasing a large amount of energy. In this way a strong effect can be produced by a minute external field.

(We shall see later, in the chapter by Smith, that such effects may be involved in allergic reactions. In a separate article [Oschman, 1993], we have suggested that bodywork may sometimes stimulate the production of palpable soliton waves that flow through a client's tissues. This wave is in the form of a ripple that spreads away from the place where you are working. The soliton wave provides a good example of the difference between a linear and non-linear system. Linear waves spread out and disperse. Their energy becomes disorganized and lost. In contrast, the non-linear soliton wave remains localized and self-sufficient--it holds itself together. The velocity of a soliton is slow compared with the speed of sound [Hyman and others, 1981]).

E. Del Giudice and colleagues, Milano
Structures, Correlations and Electromagnetic Interactions in Living Matter: Theory and Applications

Quantum mechanics provides a method for predicting the properties of complex systems. In essence it is a statistical study of assemblies of parts. Order can arise in sets of seemingly non-ordered microscopic components. Physicists have accounted for the behaviors of crystals, ferromagnets, superconductors, and plasmas using these methods. (With some outstanding exceptions, physicists generally shy away from living systems because they think cells and tissues are too complicated and therefore too "messy" for the application of basic physical principles. Few physicists seem to realize that living systems consist primarily of regions, such as the connective tissue, fascia, cell membranes, and cytoskeleton, that are highly ordered because of the crystalline packing of the constituent molecules. "Living crystals" are therefore describable by many of the well-established approaches used in solid state physics).

Fröhlich made a big advance in the analysis of living systems in 1968, when he recognized that the electrical polarity of a molecular component can be taken as a basic "order parameter." (A parameter is a numerical value that remains constant for a member of a population). Once this step was taken, it became possible to study and predict the effects of a wide range of influences, all of which modify the basic parameter. (The electrically polarized collagen molecule is one of the "building blocks" of living matter. Fröhlich's studies provide a basis for understanding the behavior of many of such units when they are arrayed together to form a larger structure, such as a collagen fibril, collagen bundle, tendon, ligament, cartilage, or fascial plane).

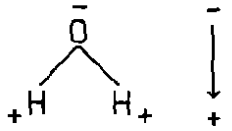


The collagen molecule (tropocollagen) is a stiff rod, shaped like a knitting needle. Positively and negatively charged groups are distributed along the length of the molecule (left). Because charges are grouped asymmetrically, gravitational centers of positive and negative charge do not coincide but are instead a certain distance apart along molecular axis (right). As a result, collagen has a permanent electric dipole moment, or polarity, along its axis. For simplicity, the dipole is represented as an arrow pointing toward the positive end.

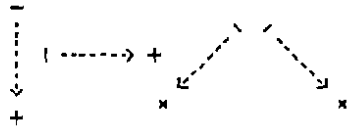
Del Giudice and colleagues present a detailed mathematical application of quantum field theory (QFT) to living systems. Then they develop a scheme for living systems that is based on the idea that life is the final step in an evolutionary process involving the assembly of electrically polarized molecules.

An array of collagen dipoles forming a collagen fibril. The molecules are not packed each one on top of the other. Instead, they are staggered or off-set from each other. The polarities of the individual molecules add together, so that the fibril as a whole has an electrical polarity. It is an electret, i.e. it has a long-lasting electric polarization along a specific direction. Electrets are usually piezoelectric, i.e. they generate electric fields when they are compressed or stretched. The formation of the electret is the first step in the self-organization of the living system. Since the bulk of the collagen fibrils in the vertebrate body are oriented vertically, the organism as a whole has an overall electrical polarity, with the head negative with respect to the tail or feet (Athenstaedt, 1974).

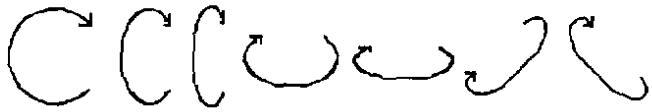
There is a detailed treatment of filamentary units (such as collagen molecules in connective tissues and microtubule filaments in cells) that can orient water molecules.



The water molecule is electrically polarized because the oxygen is strongly electronegative with respect to the hydrogens. As with the collagen molecule, the water electric dipole can be represented as an arrow.

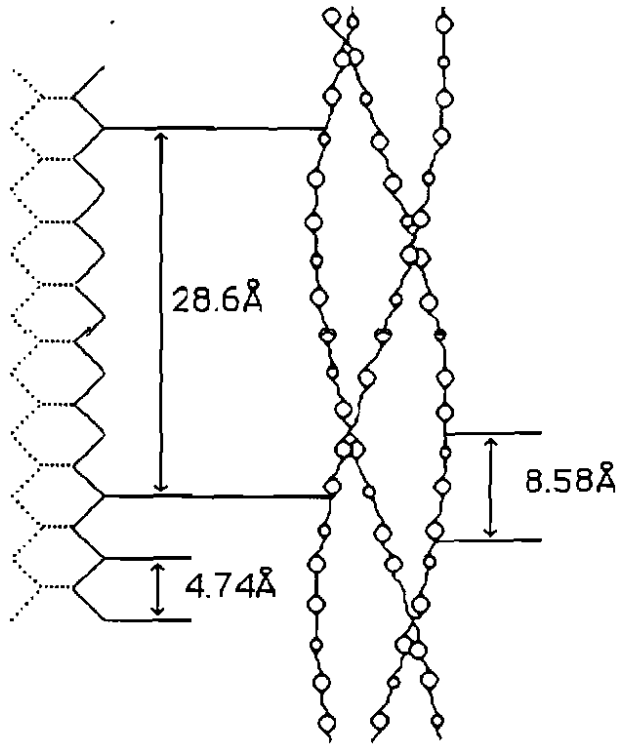


The water molecule can vibrate or oscillate in various planes.



The water molecule can also spin or tumble in different planes.

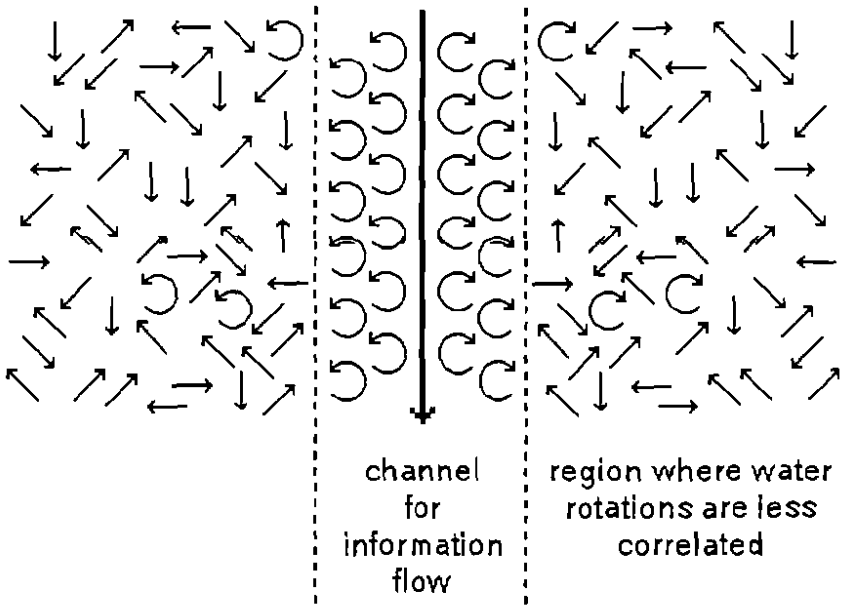
(Previous work showed that the spacing of charges along the collagen molecule is ideal for orienting nearby water molecules, which associate with the collagen in hydrogen bonded chains, as shown below. The water molecules form hydrogen-bonded filaments that stabilize the three-dimensional structure of the collagen fibrils).



The regular array of water molecules (left) associated with a collagen molecule (right). Here the triple helix of the collagen is shown. The dotted lines at the left represent the ice-like hydrogen bonds between adjacent water molecules in the chain. Based on Berendsen, 1962.

Filamentary structures and their associated water molecules can confine and channel electromagnetic signals, and can protect or shield them from outside influences.

(The structure of these systems includes water that is closely associated with the protein, and more distant water molecules whose orientation is much less affected by the presence of the protein. When a wave of energy, in the form of an electric, magnetic, or electromagnetic pulse, passes along the protein, it will cause adjacent water molecules to vibrate or to spin about their axes ([Davydov]). The vibrations or spins of water molecules a distance away from the protein will be less influenced by the wave).



When a wave of energy passes along a protein such as collagen, water molecules surrounding and closely associated with the protein will spin about their axes. The protein and coherently spinning water molecules provide an information channel that confines electromagnetic signals. The spins of water molecules some distance away from the protein will be less influenced by signals passing through the channel. The interface between ordered and disordered water phases, shown with the dashed lines, has a steep electrical gradient across it. The disordered or uncorrelated water layer protects or shields or insulates the information channel from outside influences. The extent of this shielding depends on the degree of spin correlation, which can be calculated on the basis of quantum field theory (this is known as the Goldstone correlation among dipoles).

Of great importance is the fact that such systems will have interfaces between highly ordered structures and associated water molecules (such as collagen fibrils) and less organized regions (such as the extracellular fluid) where the rotations of water molecules are far less correlated. These interfaces have very steep electrical gradients across them. "Life then appears to be possible only on the interface between order and disorder or between differently ordered domains."

Detailed mathematical treatment of this system leads to a startling result in relation to cancer. Cancer cells and cells infected with viruses have a higher than normal microscopic order. The cytoskeleton of the cancer cell contains a few thick filaments instead of the distributed fibrillar network found in healthy cells. The excessively strongly correlated structure in the cancer or virus-infected cell would prevent external electromagnetic fields from penetrating into the system. In essence, the cells would be shut off or insulated from environmental stimuli. (We find this to be a most intriguing concept because of its relation to the concept in acupuncture that cancer is caused by "stagnant Ch'i, and Albert Szent-Györgyi's concept that cancer is caused by a breakdown in electronic communications).

Living systems are dominated by coherent vibrations. The coherence or structural order, "the matter field," triggers the coherence of the electromagnetic field. In the technical language of physics, the coherent field arises because of spatial variation of the condensation of Goldstone bosons. Again, detailed mathematical treatment of this system leads to the conclusion that biological systems will exhibit phenomena that are usually associated with superconductors, including influences of weak magnetic fields

and Josephson effects (Brian D. Josephson, Nobel Prize in 1971, predicted that certain kinds of currents, called supercurrents, would pass between two superconductors separated by a thin insulating layer. The effect was demonstrated experimentally in 1963. Josephson junctions are now widely used in electronics and computers because they can detect and amplify weak fields, switch signals from one circuit to another at extremely high speed, and store information, all with extremely low power dissipation and in very small spaces).

(The Josephson effect is particularly interesting because it provides the basis for the ultra-sensitive magnetometer known as the SQUID [superconducting quantum interference device]. A SQUID instrument is capable of detecting the magnetic fields produced in the spaces around the body as a consequence of physiological processes such as muscle contractions, glandular secretions, and brain activity).

The SQUID consists of two superconductors separated by a thin insulating barrier. Josephson effects have already been predicted and investigated by others. (This discussion is pointing toward a mechanism by which living systems may be able to detect biomagnetic fields, which is, in fact, the basis for certain unconventional approaches such as aura balancing and magnetic healing). As biocircuit elements, Josephson junctions, and extended arrays of such junctions, could be used for information storage and processing. They also provide another means by which living systems could sense exceedingly weak electromagnetic fields present in the environment).

As with the previous chapter, solitons are discussed. An event such as a deformation or a chemical reaction at a particular site along a molecular chain will trigger solitons, which will propagate along the chain. The lengths of molecular chains in living systems and the velocities of soliton propagation imply soliton lifetimes up to a few seconds.

A soliton can trap an electric charge and carry it along. Once the soliton is formed, this charge transfer does not require further input of energy. Thus a sort of "supercurrent" is created. As the soliton wave passes along the molecular chain, electromagnetic fields may be radiated into the space around the chain. Dipolar molecules close to the molecule and in the surrounding space will cooperate by oscillating (or spinning) coherently.

W. Grundler and colleagues, Neuherberg
Resonant Cellular Effects of Low Intensity Microwaves

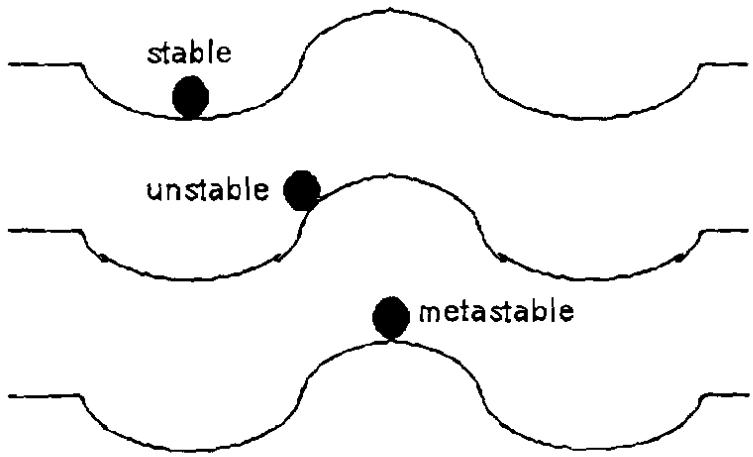
This chapter concerns the effects of microwaves on living systems. Resonant interactions between microwaves and living systems are well documented, but the results are not always reproducible. There are other, as yet unidentified, parameters that need to be taken into consideration.

F. Kremer and colleagues, Mainz
The Influence of Low Intensity Millimetre Waves on Biological Systems

This study documented both thermal and non-thermal influences of low intensity millimeter waves on selected biological systems. The authors provide a detailed set of criteria for establishing such effects.

J. B. Hasted, London
Metastable States of Biopolymers

(Dictionary definition of metastable: marked by only a slight margin of stability). Consider a sphere in a bowl that has a convex spherical bump in the center. The stable configuration is with the sphere in the lowest part of the "valley." If the sphere is placed on the side of the bump, it is unstable--it will roll down into the valley. If the sphere is balanced on top of the bump, it is metastable--it is temporarily stable but will roll off if it's balance is even slightly disturbed. Physicists refer to such a disturbance as a "perturbation."



(Collagen is an example of a biopolymer. A biopolymer is a chain-like molecule formed by the polymerization or chemical linking of small biomolecules, each of which is called a monomer).

In the case of vibrations within biopolymers, a metastable state can occur for a limited period of time if sufficient energy is supplied to the system to get it to a balance point. A perturbation or input of extra energy can then destroy the metastable state and release the energy that was used to create the metastable state in the first place.

The ability of the metastable state to withstand slight perturbations depends on its environment. For example, in nature proteins are wet. The water molecules associated with a protein can absorb a certain amount of the energy of a perturbation and therefore protect the metastable state.

Halsted presents a detailed technical discussion of the relationship between a protein and its aqueous film in relation to the absorption of perturbations of different kinds (heat, vibration, electromagnetic fields) and at different frequencies. An assembly of electric dipoles with a permanent or semipermanent polarization, such as the collagen fibril, will be a stable or metastable electret. (Recall from above that an electret it has a long-lasting electric polarization along a specific direction and is usually piezoelectric.

We also mentioned the idea that the formation of the electret is the first step in the self-organization of the living system). In an electret, polar molecules are oriented in a way that enables the dipoles to reinforce each other.

Electromagnetic fields interact with biomolecules by both resonant and non-resonant processes. (Resonance occurs when a relatively strong vibration is produced in an electrical or mechanical system by applying a much smaller periodic stimulus which is at or near the natural frequency of the larger system). Radiofrequency interactions are dominated by non-resonant interactions because the wave lengths are quite long with respect to the molecular lengths. Only at Gigahertz (giga=billion=10^9 Hz), frequencies with millimeter and less wavelengths (microwaves, infrared, etc.), do resonance processes begin to dominate the absorption of electromagnetic signals. Some preliminary work on such resonances has been reported.

F. Drissler. Stuttgart
Physical Aspects of Plant Photosynthesis

The primary physical event in photosynthesis is of great interest because it is the first step in the production of all biological energy from solar radiation. Remarkable transport mechanisms convey energy trapped by chlorophyll molecules to reaction centers, where the energy is converted into chemical bonds. If the excitation does not reach a reaction center within a short period, it is re-radiated (this is called delayed fluorescence). This study examined the possibility that coherent vibrational states in the chloroplast membrane may be involved in these energy transfers.

J.K. Pollock & D.G. Pohl, Milledgeville, Georgia
Emission of Radiation by Active Cells

Fröhlich's original suggestion was that the highly ordered molecular arrays in living systems could cooperate under certain conditions to set up high frequency electrical oscillations in the range of 10^{11} to 10^{12} cycles per second. This article summarizes evidence that such signals exist and are radiated into the cellular environment. Particular emphasis is given to the studies of Pohl using microdielectrophoresis. This is a method in which cells are suspended in a solution containing tiny charged particles that are attracted to areas where there is a strong electric field. It was repeatedly found that cells produced the strongest fields at or near mitosis (the stage in cell division in which the chromosomes and nuclei divide). They studied bacteria, fungi, algae, and mammalian cells. The method revealed patterns around the cells, suggesting that the radiation is from certain parts of the cell surface.

W.R. Adey, Loma Linda, California
Physiological Signaling Across Cell Membranes and Cooperative Influences of Extremely Low Frequency electromagnetic Fields

Originally the cell membrane was regarded as a boundary between the cytoplasm and the environment. Emphasis has shifted to the role of the membrane as a window through which the living material senses its environment. Of great interest are studies showing that there are proteins that span the membrane, joining the inside and outside environments. These proteins are energetic and signaling pathways, conveying external stimuli to the cell interior.

The huge voltage across the cell membrane should prevent weak, very low frequency electromagnetic fields from influencing cellular processes. However, we now know that minute low frequency signals do profoundly influence cellular events, and this implies some form of cooperative communication processes along the lines that Fröhlich proposed some years ago.

Adey and his colleagues have used low frequency signals to identify the steps involved in coupling information flows from the outside to the inside of the cell. Cell membranes seem to act as powerful amplifiers, boosting minute electromagnetic fields as the first step in a series of long-range quantum processes. He likens the cell surface, with its protruding proteins, to "a field of waving corn, responding to an infinite variety of faint electrochemical breezes that blow along the membrane surface."

The inward and outward flows of signals are related to pathological problems including cancer, and there is a prospect of distinguishing between normal and abnormal signal streams.

The way calcium binds with brain tissue provides an example of an amplifying effect such as just described (and also alluded to in the chapter by Kaiser, in which a small external signal produces a much stronger internal influence). Very weak low frequency electromagnetic fields at strengths comparable to those produced by normal brain waves (as measured with the electroencephalogram) have profound cooperative effects on calcium and hormone binding in brain tissues. The effects depend on signal strength and frequency.

The pineal gland is sensitive to the orientation of the head with respect to the earth's geomagnetic field. The earth's field also influences calcium fluxes in response to applied electromagnetic fields.

There is a discussion of cellular events involved in bone healing and the ways external fields can be used to stimulate fracture therapy. A lot of attention is also being given to epidermal growth factor (EGF) and nerve growth factor (NGF) and their receptors in cell membranes. Both extend across cell membranes, and have a similar sequence of 23 amino acids that reside inside the membrane. This segment is not well adapted as a mechanical linkage, or as an ion transfer system. Adey suggests that transmembrane signaling may instead be accomplished by Davydov-Scott soliton waves (see the paper by Hyman and others that we have cited at the end of this review).

Adey and his colleagues have also discovered three examples of hormonal responses

inside cells that can be triggered with electromagnetic fields only, independently of the presence of the hormones.

Adey next discusses the possibility that external electromagnetic fields can initiate cancers by mechanisms that do not involve direct effects on the genetic material. Instead, harmful fields may distort inward signal streams directed toward the nucleus and other cell organelles. Several examples are given.

Next, Adey discusses models of organization in physiological systems with respect to cooperative phenomena. **Assemblies of many components can develop dynamic patterns as a result of complex flow patterns. "These flow patterns can undergo sudden transitions to new self-maintaining arrangements that will be relatively stable over time."** The flow patterns referred to are energy flows. Two or more different interactions can give rise to the same dynamic pattern. What makes this possible is cooperativity, which is defined as the way the components of a system act together to switch from one stable state to another. These transitions can involve phenomena that physicists refer to as phase transitions, hysteresis, and avalanche effects. (A phase is a state or a condition or an aspect of a system. The conversion of water to ice is an example of a phase change, as is a change from disorganized or diseased to organized or healthy. Hysteresis is a situation in which the relationship between two quantities is not linear but depends on their prior history. Avalanche effects, as the name suggests, occur when a small disturbance becomes multiplied to cause a rapid and regenerative flow of something such as a current). Very weak signals can trigger such transformations. When this happens, we refer to the situation as an amplification effect. Classical linear systems respond slowly to large stimuli. In cooperative systems, large transitions can take place sharply and rapidly in response to minute inputs of energy. The extreme sensitivity of living systems, and the biological responses we already know about to remarkably minute signals, remind us of how much we have yet to learn about the couplings that cooperative systems are capable of. (We must be careful of the artificial energy fields we create in our environment).

Sustained oscillations are an essential component of living systems. Every process in the organism that can be measured shows rhythmic variations. Adey discusses the theory of how environmental rhythms may entrain internal oscillations. He then considers chaotic models and how they may interact with strongly structured rhythms, to the advantage of the organism.

Again, the possible role of solitons in signaling and control of molecular states is discussed. When the energy applied to a system is raised, a certain sharp threshold is reached and soliton waves are formed. If the applied energy is increased further, another threshold is reached, above which solitons will not form.
The focus is on the cell membrane, which acts as an amplifier of natural or imposed environmental fields in the extremely low frequency (ELF, below 3000 Hz) range, which is referred to as the "biological spectrum." The low frequency oscillations can readily couple to rhythms in the polarization state of macromolecular arrays. (A macromolecule is a large molecule such as a biopolymer. A macromolecular array is a crystalline assembly of such large molecules. A tendon, bone, or a sheet of fascia are examples of macromolecular arrays in the human body). The macromolecular array would swing from a highly excited and strongly polarized state to a weakly polar ground state. Slow chemical oscillations could be coupled to these slow rhythms of

electrical polarization. The strongly polarized state would oscillate at 10^{11} Hz. (Hz is the abbreviation for Hertz, a measure of frequency equivalent to cycles per second. A frequency of 10^{11} Hz is in the microwave portion of the electromagnetic spectrum). Slow chemical and electrical oscillations would have frequencies around 10 Hz (this is an interesting frequency for healers because it is the frequency of the Schumann resonance in the earth's electric and magnetic field. In separate articles, we have discussed evidence that various types of traditional healers may couple their brain waves and their bodily biomagnetic fields to the Schumann resonance when they are in their "healing state).

Also relevant to the ELF "biological spectrum" is the fact that the strength of the geomagnetic field is ideal for inducing cyclotron resonances in free calcium ions and gyro-frequencies in both singly and doubly charged ions of biological significance. (Cyclotron resonances are situations in which charged particles develop a collective helical motion in an magnetic field. At resonance, large amounts of energy can spiral through a conductor or a semiconductor). In other words, the large magnetic field of the planet could transfer large amounts of energy into the various ions found in living tissues.

(All of this evidence points to a wide spectrum of previously unsuspected energetic relations between the components within the organism and between the components and the environment). There is even some evidence that biological systems may exhibit superconductivity.

In conclusion, Adey discusses the various hierarchies of order in living systems and the new concepts of communication that are emerging from physical studies at the atomic and molecular levels. Electromagnetic fields applied to cells can be used to probe the sequences of events involved in hormonal regulations. A dramatic component of these sequences is the amplification that takes place at the cell surface. This amplification enables fields millions of times weaker than the membrane potential to modulate cellular activities.

S. Rowlands, Calgary, Canada
The Interaction of Living Red Blood Cells

It has been recognized for over a century that clotting red blood cells form stacks. This is called roleau-formation. In 1972, Rowlands observed that when cells and roleau were a short distance apart, they seemed to move rapidly towards each other. At the time he considered this to be an illusion, particularly since the outer surface of the membrane of each red cell is negatively charged and erythrocytes should therefore repel each other.

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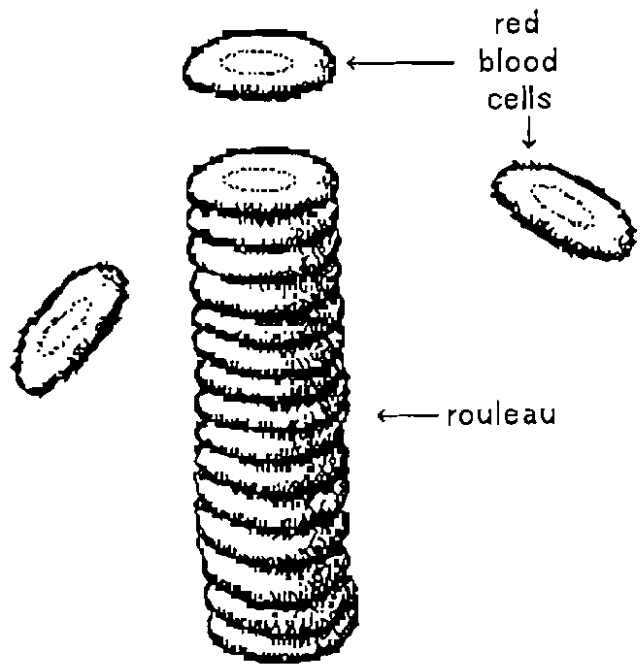

A review of coherent excitations published by Fröhlich in 1980 theorized that long range attractive forces would be exerted between cells as a consequence of coherent oscillations of polarized membrane molecules. Upon reading of Fröhlich's work, Rowlands immediately recognized that red blood cells provide an ideal system to test the long range attraction idea. Red blood cells are very simple in structure, and have no intrinsic motility. A series of studies confirmed Fröhlich's hypothesis.

Roleau do not form in normally circulating blood in healthy people, although in some diseases, particularly connective tissue diseases, roleau-formation can be observed in the small blood vessels in the retina and conjunctiva of the eye.

According to Fröhlich's theory, long range interactions require an intact cell membrane, an electrical potential across the membrane that polarizes the membrane macromolecules, and a supply of metabolic energy to maintain coherent waves of membrane polarization. Rowlands and his colleagues tested and confirmed each of these postulates of Fröhlich's theory for the interaction of human erythrocytes.

Polarized macromolecules in cell membranes may also polarize nearby water molecules. Multiple layers of these ordered water molecules may provide an ideal medium for the transmission of Fröhlich's coherent polar waves from cell to cell.

In conclusion, Rowlands points out that the usual biochemical view of molecules wandering about inside cells by random motion until they happen to bump into the correct enzyme is inconceivable. Much more logical is the idea that long-range coherent Fröhlich interactions bring about the orderly and efficient movements and actions of molecules and cells that constitute life.

H. Fröhlich, Liverpool
The Genetic Code as Language

Geneticists have identified a significant portion of DNA that does not code for the amino acid sequence in proteins. This "nonsense," imprecisely sequenced component of the genetic material has been called "selfish" or "junk" DNA. The existence of such DNA presents a paradox, in that the evolutionary forces of natural selection and "survival of the fittest" should long ago have weeded out any random or functionless DNA.

In this exceptionally fascinating chapter, Fröhlich suggests broadening the genetic code to include more of the functions of language. Specifically, he suggests the junk or selfish DNA may function to regulate higher levels of complexity.

The genetic code as it is usually viewed does not account for the collective aspects of chromosomal functioning, the "planetary genome," that might have analogies with language. Specifically, Fröhlich constrasts the inactive, one-dimensional structure of a protein, which is determined by its amino acid sequence, and its active, three-dimensional form. This three-dimensional form gives proteins their remarkable specificity for interacting with particular substrates. In order to become active, a protein must assume a single correct shape out of the infinite variety of configurations that are possible. Such specificity is usually considered to arise "spontaneously" a consequence of "self-organization." Fröhlich regards these as concepts that "mask many difficulties."

One of the pieces of information that may reside in the "junk" DNA is involved in the chromosomal replication process. A chromosome is a huge molecule that, during mitosis, unhelixes, separates, finds its appropriate partner with which to pair, and then folds up again without becoming tangled up. All of this happens in a very small space. The process illustrates the essential difference between the concept of a code and the concept of a language. Corresponding chromosomes may have the same resonant frequency which enables them to communicate over some distance, drawing like to like.

At higher levels of order, developing cells take on particular forms and functions, sometimes moving considerable distances to join with specific neighbors. Perhaps the extra DNA is used for organizing such collective behavior. Fröhlich suggests that collective coherent oscillations in the "junk" region of the DNA may produce resonant vibrations that help the cell select which proteins will be produced at particular times during development, so they may take up their functional positions in tissues and organs. This model would explain why a young kidney cell, for example, when transplanted into a liver, adapts to that organ because it is overwhelmed by the resonance of the surrounding liver cells. And, when an organ becomes large enough, the collective conversations would reach a level that would stop further proliferation. Without such control, a sort of cancer would result.

Fröhlich goes on to discuss auto-immune diseases and the problem of self-recognition. The conventional dogma is that all cells of an organism have "self-markers" that differentiate self-cells from foreign cells, which are attacked by the immune system. But what causes this, and how does it come about? The answer must involve some collective property of the entire genome.

C.W. Smith, Salford, England
Electromagnetic Effects in Humans

C. W. Smith has developed some of the most important applications of biological coherence to human health. He begins with an historical review of coherence and electromagnetic effects in humans. He then discusses a fascinating range of related topics.

Our reliance on clocks and calendars shows that we order ourselves in a coherent fashion with the coherent motions of the celestial bodies. In spite of the obvious manner in which we link our behavioral and physiological rhythms with natural and astronomical cycles, the subjects of biological rhythms and electrical phenomena in living systems have been vigorously and acrimoniously debated by scientists.

Tesla, who invented much of our modern electrical technology, became the first well-documented case of electromagnetic hypersensitivity. In his experiments he exposed himself to massive electrical and magnetic fields which led to an illness similar to an allergy. (There are now many people who have mysterious electromagnetic illnesses that conventional medicine is unable to diagnose. Those who are hypersensitive to 60 cycle electricity may become dizzy or nauseous or develop migraine headaches that are triggered by walking past a hidden transformer or by standing next to an appliance such as a toaster. Sometimes these patients are given drugs to treat their symptoms, the drugs produce side-effects, and more drugs are given to treat those side-effects).

Lakhovsky used high frequency fields to treat cancer. His theory (1939) was that health involved a balance or equilibrium in the electrical oscillations in living cells, and disease arose from oscillatory disequilibrium. (This idea not only coincides with the concepts that are now emerging from Fröhlich's work, but they fit well with the ancient concepts that form the basis of acupuncture. Health involves the harmonious balance between pulsating energy flows and communications within the various meridians).

Piccardi studied the correlations between rates of chemical and biological processes and extraterrestrial influences. Gauguelin reviewed biological rhythms which are highly coherent and which become "phase-locked" to environmental fluctuations.

There are many advantages to the use of coherent signals for biological communications. Smith discusses the advantages of serial vs. parallel data processing channels and the ways coherence can reduce interference from natural and artificial fields in our environment. Just as harmful chemicals can disrupt the genetic material and cause disease, harmful coherent signals can sensitize and disrupt electronic signals within the organism. (Our long-term survival as a species may depend upon how well our internal communication systems are able to carry out essential functions in an environment that we are increasingly "polluting" with artificial coherent energy fields of various kinds. Robert O. Becker [1990] believes electromagnetic pollution may eventually have more significant health effects than air and water pollution).

Smith also makes a profoundly important but rarely appreciated point that the widely studied chemical signaling processes (e.g. hormonal regulations) are really

interchangeable with electrical signals. The whole field of chemical analysis by spectroscopy shows that there is a "fundamental duality between chemical structure and coherent oscillations." (Spectroscopy is the main method physicists and chemists and even astrophysicists use to study the structure of matter of all kinds. When energy is applied to atoms or molecules, they vibrate and produce luminescence or radiation. Spectroscopists study these radiations to determine the precise structure of matter that is too small or too far away to be examined directly).

Smith makes the additional point that survival in predator-prey situations has forced living systems to evolve sensors that operate at the limits of the laws of physics. These sensors enable biological rhythms to be entrained with variations in the geomagnetic field. The geomagnetic field, in turn, varies from moment to moment in relation to an intricate fabric of extraterrestrial cycles including solar and lunar rhythms, sunspots, the rotation of the sun about its axis, solar winds, the aurorae, oscillating currents in the upper atmosphere, magnetic storms, etc. (We are reviewing this topic in a separate book).

Important work of Wever is reviewed next. Influences of environmental signals on human physiological rhythms were studied by isolating subjects underground in shielded rooms. Twenty years of German research involved 325 subjects who were placed in isolation for 1 to 3 month periods. There were 52 experiments in which bodily rhythms were altered or desynchronized by a constant environment. Applying a 10 Hz field via electrodes hidden in the walls of the isolation chamber could prevent or reduce rhythm desynchronization. The pineal gland is sensitive to both light and minute magnetic field variations. A number of investigators think the pineal is the time-keeping organ in humans.

Homing pigeons have large pineals that may serve as their geomagnetic "compass." Honeybees also have a compass sense, but insects do not have pineal glands. It appears that the whole insect body may be cooperatively involved in detecting variations in magnetic field strength.

Experiments regarding the possible involvement of magnetic fields in dowsing is also discussed, but we are not sure at this stage of how to interpret the findings.

Submarine crews experience physiological changes that have been attributed to the fact that they are shielded from geomagnetic variations and ELF fields by the steel hull and surrounding salt water. Astronauts orbiting the earth may have different responses because they experience each day's geomagnetic cycle during a much shorter time period. There are indications from studies of cultured cells that effects of shielding from the geomagnetic field may not show up until many generations after the experiment is performed.

The frequency range 1 Hz to 30 Hz is particularly important physiologically and is also the frequency of the normal variations in the geomagnetic field. Of particular importance is the 8-12 Hz range of the brain alpha rhythm. The geophysical rhythms are strong enough to influence living tissues. Of particular interest are the ELF frequencies present in all human subjects and that resonate with homeopathic remedies. Ludwig has reported on the resonant frequencies of particular physiological functions in man.

Smith turns next to puzzling aspects of enzyme chemistry. Enzymes are catalysts of chemical reactions--they are not consumed during the reaction but they stimulate the reaction to progress at a very high rate. Enzyme-catalyzed reactions can be compared to electronic devices such as high-gain amplifiers in which the gain is regulated by feedback mechanisms.

The great specificity of enzyme action (the enzyme will act upon one and only one substrate) has been compared to a mechanical "lock and key" arrangement. However, what chemists do not usually consider is the manner by which the "key" finds its way to the "keyhole." (The problem is comparable to the attraction of the HIV virus to its receptor on a lymphocyte). Fröhlich developed a model for this type of situation in which strong attractions arise because of giant dipole oscillations of the two molecules involved. The appropriate frequency for such attractions is around 10^{13} Hz, which corresponds closely to the frequency of cell membrane electrical oscillations at body temperature.

Other studies have shown that water is important in determining the way proteins behave, and the way the water is added to a protein powder is important. Water can be added as vapor or as liquid water, and different results are obtained. This was the first indication that water might maintain a sort of "memory" of its recent history, and this effect turned up later in connection with studies of allergies.

Biomolecules are not supposed to have magnetic interactions with water, but show the presence of effects that were 10,000 larger than expected. There are a number of detailed technical matters that must be taken into consideration for these studies to be repeatable. Enzyme activities may be sensitive to the light beam used in a spectrophotometer, and even to the geomagnetic field. Solutions of enzymes even seem to "remember" for a long time the frequencies they are exposed to. Chemists often use magnetic stirrers to mix solutions being studied, and Smith points out that this could mask any magnetic influences that might be present.

Enzymes and other biological processes show responses to weak magnetic fields that decrease or disappear if stronger fields are used. Biological systems are nonlinear. The idea that the absence of a biological response to a strong field means that a weaker field will surely have an even smaller effect is not valid.

There are indications that Josephson effects may take place in biological systems. If so, the various electronic and computational tricks (switching, amplification, information processing) that are possible with Josephson junctions are probably available to living cells and used by them for communication and information processing.

Studies on bacteria and yeasts indicate that specific coherent frequencies can trigger proliferation. This may be a part of the *Candida* problem. For example, the clocks in computers operate at high frequencies that may be biologically active. One of Smith's allergy patients had attacks of colitis that seemed to be triggered by working next to a computer with an 8 MHz (8 million cycles per second) clock frequency. Smith and

others have shown that this frequency affects the growth of yeasts.

All of this information provides a basis for examining allergies, which are now recognized as disturbances of regulatory systems. About 15% of the population is debilitated to some degree by allergies. In extreme cases, an individual may respond to as many as a hundred different substances.

Since 1982, Smith has studied more than 100 electrically sensitive multiple-allergy patients. The sensitivities can be triggered by specific electromagnetic frequencies in the range of a few thousandths of a Hertz to a gigahertz. New allergic responses can be acquired when a patient is exposed to a previously innocuous substance while reacting to an allergen. A coherent electromagnetic signal at a particular frequency can become an allergen and trigger a specific set of symptoms. "....the pattern of of allergic responses is the same whether the trigger is chemical, environmental, nutritional or electrical."

Traditional therapy for allergies has involved pricking the skin with a diluted allergen. The result is a wheal on the skin. As the allergen is taken through a series of dilutions, the wheal gets smaller, then larger, then smaller, etc., until a dilution is reached where no wheal is produced. If the allergen was taken through a further series of dilutions, the wheal would again cycle through the pattern of response and no-response. Eventually a dilution is reached at which no response occurs. This is known as the patient's "neutralizing dilution" and could be injected to protect the patient from subsequent exposure.

Work by Monro and colleagues showed that extremely sensitive allergic patients only needed to hold a glass tube containing a dilution of the allergen to show symptoms or neutralizing effects. The most sensitive patients could even distinguish tubes of allergen that were merely brought into the same room with them. On the basis of this, it was discovered that the pin prick was unnecessary--dilutions could simply be dropped on the patient's skin, and then wiped off.

Smith and his colleagues used a similar method for testing and treating electrically hypersensitive allergy patients. Increasing the frequency has the same effect as diluting the allergen. Eventually a frequency is reached that has the same effect as the "neutralizing dilution."

In conducting these studies, care must be taken to keep the strength of the field low. If the field is too strong at a frequency that causes an allergic reaction, the system becomes over-stimulated and saturated, and further testing must be put off for some hours or days. The studies are begun with the signal generator in the adjacent room to see if the patient can tell whether the signals are on or off.

For sensitive patients, the signal generator does not even need to have an antenna attached to its output terminals. For less sensitive patients, a short length of wire is adequate. In no case is the wire physically connected to the patient. The amounts of radiation are no larger than that leaking from a television set or home computer.

Not only can the patients be extremely sensitive to electromagnetic fields, they can emit signals during their reactions. These signals can be large enough to produce malfunctions in electronic equipment. Computers, factory robotic systems, electronic