EXPLORING THE BIOLOGY OF PHOTOTHERAPY

By James L. Oschman, Ph.D.

This essay is affectionately dedicated to the memory of John Searfoss, O.D., a distinguished pioneer in phototherapy and a very warm and enthusiastic colleague.

There exists a relationship which is largely predictable between light frequency, environment, and the restoration of health following departures from normal, which are still within the physiologic limits....

H.R. Spitler, M.D., O.D.

Dr. Spitler's observation that, within limits, health can be restored with specific light frequencies, poses a profound biological question: How can light "jump start" the healing process for a wide range of clinical problems, involving tissues throughout the body? An answer to this question would obviously have much medical significance.

Gottlieb, discussing the research of Tiina Karu in Russia, states the problem this way:

> *How does light find the right places to work to heal the body? Normal tissue is much less affected by light than out-of-balance tissue. Starving cells are far more sensitive than well-fed ones.*[1]

Recent research is beginning to answer this question. This essay summarizes relevant discoveries and then follows a light stimulus through the network within the body to the places where structure and function have been compromised. The goal is a logical explanation of how the appropriate application of light can reach and benefit any part and any process in the organism.

UNSOLVED PROBLEMS

Modern biomedical research has achieved many milestones, and given us crisp images of our internal structure and physiology. In spite of this, a number of important theoretical and clinical problems remain virtually untouched. Our academic struggles and our intellectual myopias stem from our basic approach, which is to take the organism to pieces and study the parts, one-by-one. While much has been learned this way, there is a tendency to lose sight of the big picture. There is a tendency to focus on phenomena that are easy to study or measure, leaving more difficult areas unexplored. And textbook explanations are often taken as complete answers, even though they are not.

Research on consciousness is a good model for discussing whole-system inquiries such as ours, because simplistic and reductionistic hypotheses have only led to limited progress. Models of consciousness are also of interest to phototherapists who observe beneficial behavioral or psychological changes in their clients. Of key importance is the realization that what we have referred to as *mind* and *body* are one and the same, indistinguishable, inseparable, intertwined. The idea that mind and body are *connected* is erroneous and misleading. It is impossible to connect something to itself. While we might agree on this point, it is only recently that we have begun to understand its real significance.

In terms of phototherapies, the eye is obviously the window to the brain. It has therefore seemed logical to focus on neurophysiological models as a basis for phototherapy. But the nervous system actually plays only minor roles in injury repair and defense against disease. The real actors are cells and the medium in which they reside, the connective tissues.

Our obsession with the brain and neurons has been addressed brilliantly and concisely in a recent paper by Stuart Hameroff: *The neuron doctrine is an insult to neurons.*[2]

> *The neuron doctrine, currently in vogue, is based on the assumption that brain = mind = computer. This view leaves us almost completely ignorant about how the brain produces mental life. The expectation is that consciousness emerges at some critical level of computational complexity in the self-organizing networks of synaptically connected neurons. However, there are no testable predictions arising from such an emergence model. We can only wait for consciousness to happen.*

The neuron doctrine is a bluff.

These problems are recapitulated at the cellular level:

The neuron doctrine, currently in vogue, is too watered-down to explain how the brain gives rise to mental life. Neuroscience is not being applied deeply enough. The neuron doctrine considers only certain activity at neuronal surfaces, ignoring internal features, including the fact that neurons are living cells. Each neuron is treated as a "black box," ignoring internal activities. The present characterization of the neuron is a cartoon, a skin-deep portrayal that simulates a real neuron much as an inflatable doll simulates a real person.

A TURNING POINT

A British biophysicist, Mae-Wan Ho, has taken us to an important turning point in our inquiries:

I believe that the impasse in brain science is the same as that in all of biology: we simply do not have a conceptual framework for understanding how the organism functions as an integrated whole.

Ho has developed a *quatum coherence* model that is simultaneously the basis of living structural and functional organization and the key features of conscious experience.[3] Her work gives a framework for approaching many unsolved problems related to the biology of the healing process and the mechanisms involved in phototherapies.

WHAT CELLS DO

Hameroff implies that there is more to a neuron than we have been led to believe. So let us open the cellular "black box."

In terms of injury repair, the neuron is not very important. The nervous system is a marvel of communication and musculoskeletal control, but it actually plays a small role in injury repair and defense against disease. Its main role in healing is in the conduction of pain, a process that is poorly understood.

We begin our consideration of cells with a basic biology lesson that is often overlooked. If we trace the cells that make up the human body back through evolutionary history, we arrive at the primitive motile bacteria and protozoa. The biology lesson is that such single-celled organisms, lacking any trace of nerves or brains or muscles, can swim gracefully, avoid predators, find food and mates, and have sex.[4]

In terms of injury repair and defense against disease, the evolutionary descendants of these remarkable organisms are our white blood cells, fibroblasts, pericytes, stem cells, satellite cells, and so on. These cells are capable of sensing where they are needed in the body to make repairs or remodel tissues or destroy unwanted pathogens or cancerous growths. These cells move about swiftly, silently, and intelligently, without the benefit of what we usually think of as nerves, brains, or muscles.

Some of these cells, such as the satellite cells in muscle, are relatively fixed in position, and can remain in a quiescent or resting state for many years, until they are called upon to replace or repair damaged tissues. Others continuously wander about within the body, following prescribed routes, on patrol and ready to act quickly when and where needed.[5] Still others, called myofibroblasts, differentiate from fibroblasts and are responsible for wound contraction.[6]

REGULATING REPAIR

The repair process is a marvel of regulation:

Any disease or trauma sets off an intricate cascade of physiological activities and adjustments. If the disturbance is severe, both local and systemic responses are initiated, and all of the systems in the body can be involved. Each organism and each injury and each disease is unique, and the body's response must be precisely appropriate if full restoration is to be achieved.

A variety of kinds of cells migrate toward a site of trauma. For example, platelets release clotting factors; waves of white cells move in to fight infection or resorb "non-self" materials; epithelial cells, fibroblasts, and osteoblasts crawl into position to replaced damaged tissues and to form scar tissue. These events are triggered by a variety of messages, both chemical and electrical, that radiate from a site of disorder.

A range of stimulating and inhibiting factors activate and integrate repair, and then wind down the process when healing is complete. An intricate web of whole-body feedback and feed-forward regulatory pathways can be involved. Some activities persist for weeks after an injury. Vital processes must be maintained during repair. This may require temporary shifting of functions to other parts or systems or pathways.[7]

Given the intricate matrix of regulations involved in restorative processes, it is not surprising that some injuries or diseases heal slowly. All of clinical medicine aims to understand this and provide interventions that accelerate the healing process. In some cases, the repair mechanisms themselves, or the communication systems that integrate them, are in need of repair.

CELLS HAVE TO BE SENSITIVE, INTELLIGENT, AND HIGHLY MOBILE

Cells sense their surroundings with receptor molecules extending from their surfaces. On the inside of the cell, these receptor molecules connect with the *cytoskeleton*. This is a system of relatively stiff elements called microtubules (the "bones" of the cell), contractile filaments called microfilaments (the "muscles" of the cell), and a connecting system microtrabeculae, intermediate filaments and other fibers (the "connective tissue" of the cell).

Taken together, the continuous network within the cell can act as a sophisticated microscopic cellular "nervous and musculoskeletal system." The cytoskeleton processes information, responds to stimuli, makes decisions based on past experiences, initiates movements, and carries out a variety of activities such as protein synthesis, secretion, contraction, and phagocytosis.

One of the most important realizations in the history of cell

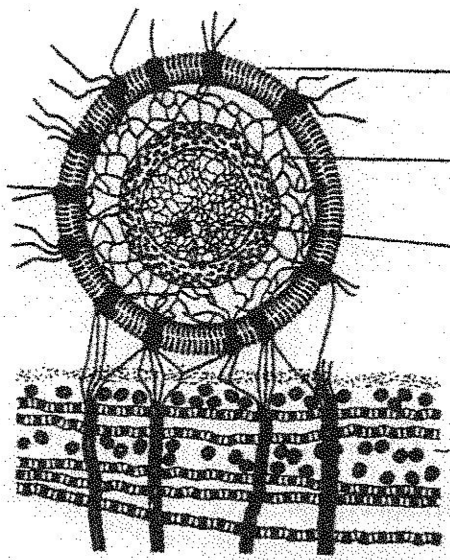

Figure 1
The living matrix is the continuously interconnected network of extracellular, membranous, cytoskeletal, and nuclear fabrics. Many components of the living matrix are highly ordered, liquid crystalline arrays of molecules. Every fiber is associated with water molecules that play a key role in conduction of information throughout the matrix. From Oschman, J.L., 2000. *Energy Medicine: the scientific basis*. Harcourt Brace/Churchill Livingstone, Edinburgh.

biology is that the cytomatrix or cytoskeleton of every cell in the body is linked to specific membrane molecules called *integrins* that extend across the cell surface and into the immediate cellular environment, where linkages are formed with the connective tissue or with neighboring cells (Figure 1). Also, deep within each cell, the cytoskeleton binds in specific ways with the nuclear envelope, nuclear matrix, and genetic material.

The whole arrangement, connective tissue, cytoskeletons, and nuclear matrices, is a structural, mechanical, energetic, and informational *continuum*. I call the whole assembly *the living matrix*. It is a semiconductor network, an integrated circuit.[8]

In many parts of the body the molecules are locally organized into highly ordered arrays that resemble crystals.[9] Technically they are liquid crystals, materials that have properties of both liquids and solids. The retina is a virtually crystalline arrangement of cells, the lamellae within the outer segments of the rods and cones are organized in crystalline arrays, cell membranes and connective tissues are liquid crystals, as are the arrays of actin and myosin within muscle cells.

Key links in the system, the integrins, regulate most functions in the body at a fundamental level.[10] Integrins are being recognized as focal points in disease processes. It is the integrins that anchor cells to each other and to the substrate. These anchorings can be labile--under appropriate conditions they dissolve to allow cells to detach and move about.

To summarize, the basic work of injury repair and defense is done by individual cells that must sense where they are needed, move there, and then carry out specific activities. When repair processes are impaired, for whatever reason, it is either because the relevant cells are not functioning properly, because they are not receiving important messages, or because they have difficulty moving through the terrain through which they must migrate. The terrain, of course, is mainly the connective tissue in its various forms: fascia, tendon, ligament, bone, cartilage, basement membranes.

Ultimately, if light is to activate injury repair, the light must in some way affect these cells. There are two obvious choices. Either light stimulates the cells directly, or it opens up the channels by which the cells communicate with each other. The information to be presented next points toward the second mechanism as being a primary effect.

FOLLOWING A PHOTON

The retina is the most remarkable and thoroughly studied sensor in nature. The standard picture of photoreception begins with the interaction of a photon with the visual pigment, rhodopsin. The 1967 Nobel Prize research of George Wald and others showed precisely how rhodopsin in the retinal rod cell can absorb the energy of a single photon.[11] A conformational change in the rhodopsin molecule initiates a cascade of chemical reactions, the flow of millions of sodium ions across the rod cell membrane, and an electrical signal that is transmitted by the optic nerves to the brain. In essence, the energy contained in a single photon is amplified many times to produce a nerve impulse.[12] From many such impulses the brain constructs our image of the world around us.

But there is another story to be told. This other story is not meant to replace the standard textbook description of photoreception and visual image formation. The neurobiology texts are not wrong. But when we look inside the rod cells, the nerves, and the other cells associated with them, we find another pathway by which the body becomes "aware" of the photon. This pathway *includes* the nervous system, but is not limited to it. This pathway conducts information far faster than nerves. This pathway is not slowed by synaptic delays. The pathway is inside the cellular "black boxes" and connects to the connective tissue in which the cells are embedded.

We will look at this pathway to see if it can help us understand how phototherapies have their remarkable system-wide effects.

CILIA, FLAGELLA, AND MICROTUBULES

In 1973, Jelle Atema from the Woods Hole Oceanographic Institution published an important theoretical paper about the cilia and flagella that are components of many mammalian and invertebrate sensory cells.[13] Cilia and flagella occur in mammalian retinal rod cells. They are also present in olfactory receptors and in the acoustico-lateralis system that senses gravity and sound.

In both rods and cones, light absorption occurs in the outer segment, which contains hundreds of flattened membrane discs or lamellae that store the light-absorbing pigments. The outer segment is connected to rest of the photoreceptor cell by a narrow stalk containing a typical ciliary axoneme (Figure 2). Careful study of the development of photoreceptors has revealed that the lamellae are formed from the ciliary membranes.[14]

Cilia and flagella enable single-celled organisms to sense their environments and respond by moving appropriately (Figure 3). To understand how this is possible, Atema and others have suggested that *sensory systems may be movement systems working in reverse.* The same molecular mechanisms that convey sensory information *into* cells can also *produce* movements, and *vice versa*.

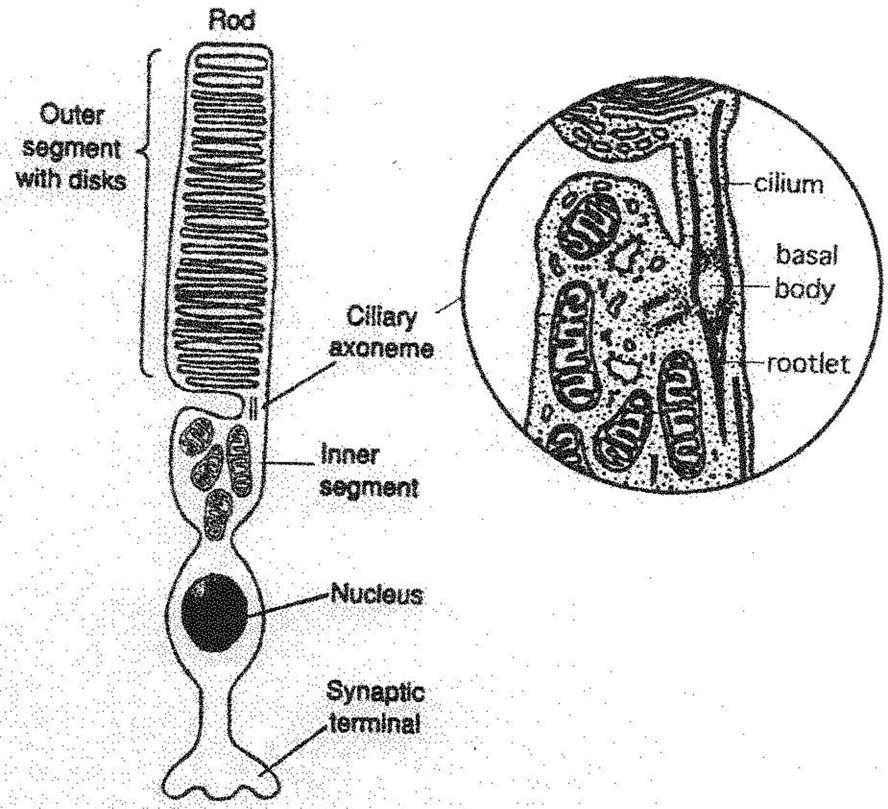

Figure 2
In both rods and cones, the outer segment is connected to the inner segment by a narrow stalk containing a ciliary axoneme. Developmental studies have shown that the photoreceptor lamellae are derived from the ciliary membranes. The illustration of the rod cell is modified from Kleinsmith, L.J. and V.M. Kish, 1995. *Principles of cell and molecular biology.* Harper Collins, New York, P. 768. The inset is modified from Lentz, T.L., 1971. *Cell fine structure. An atlas of drawings of whole-cell structure.* W.B. Saunders Company, Philadelphia PA. p. 381.

This is a truly remarkable concept. It provides a simple mechanism for sensation and movement in single-celled organisms and in the cells responsible for repair of tissues, and has many implications for mammalian sensory and motor physiology.[15]

To be specific, the sensory cilium in the retina and in sensory receptors found throughout nature may act as *motile* structures working in *reverse*, responding to stimuli by initiating structural changes that are propagated through the cytoskeleton and thence through the entire living matrix. In principle, such structural changes could be propagated *anywhere* in the body.

In other words, sensitivity to the environment, i.e. the *reception* of energy/information, evolved in close functional relationship with locomotor mechanisms, i.e. the *production* of movement or kinetic energy. Therefore when we apply a stimulus to any cell, we are speaking to an evolutionarily ancient and intelligent system designed for sensing the environment and producing actions appropriate for survival. This system evolved *before* nerves and muscles.

Cilia and flagella in mammalian and invertebrate sensory endings have in common a 9 + 2 core arrangement of microtubules (Figure 4). In sensory cells of higher animals, the microtubules connect within the cell to the cytoskeletal matrix, which is composed of additional microtubules as well as microtrabeculae and microfilaments. This living matrix pathway is described in Chapters 3 and 4 in *Energy Medicine.*[16]

Atema proposed that the ciliary microtubules in sensory cells receive environmental information and transmit it via *propagated conformational changes* in the microtubule proteins.

The microtubules, and the entire living matrix are thus active, functional components in the reception and transmission and processing of sensory information. Waves of conformational change initiated in the *retinal lamellae,* for example, can be propagated into the the microtubules and thence through the cytoskeleton of a rod or cone cell, across the cell surface via specific membrane molecules (integrins), and thence into neighboring cells and the fibrous system of the connective tissue.

obvious architectural role in keeping the photoreceptors in position. The junctions are composed of particular set of proteins that form an intricate and novel kind of cell-cell junction.[18]

Now we look closely at the nature of the conformational changes conducted through the living matrix continuum.

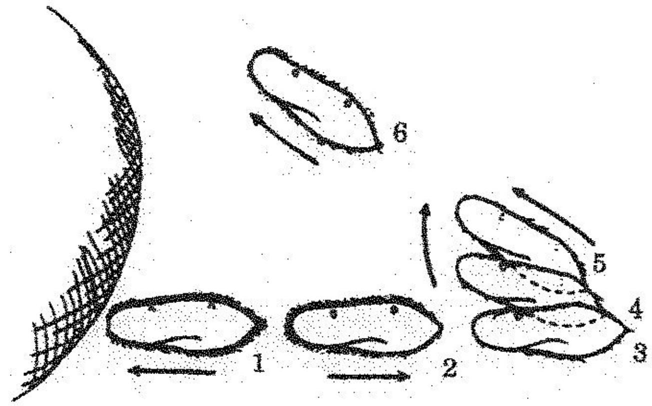

Figure 3
Cilia and flagella enable single-celled organisms to sense their environments and respond by moving appropriately, even though these organism lack structures resembling nerves, brains, or muscles. From the website of Stuart Hameroff, http://www.hameroff.com

A DIRECT ROUTE FROM THE RETINA TO EVERY PART OF THE ORGANISM

The main point is that there is a theoretical basis for sensory information being conveyed rapidly and *directly* into the body, bypassing or parallel to the neuronal circuitry. This provides for a very rapid response to light, *a response that reaches into every part of the body.*

In terms of phototherapy, the actual sensation of a color may not be the most important part of the process. I am proposing that healing responses are initiated by mechanisms that involve the *entire* living matrix, not just the neuromatrix. Light transduced by the retina into nerve impulses is processed by specific optic fibers in the nervous system, whereas light-induced waves of conformational change entering the living matrix are, in principle, capable of being rapidly conducted to every nook and cranny of the body, even to the nuclear matrices and genes located in *every* cell, not just nerve cells. It is a way for light to generate a message that reaches everywhere, not just where nerves go. This makes sense because, as we have seen, the most important cells involved in any repair process are not in direct communication with neurons.

A dramatic application of phototherapy is in brain injury. This gives rise to a question: how can the application of light to the retina revitalize or regenerate neural pathways? To answer this question, it is important to recognize that the organization of the neuromatrix is primarily determined by activities of the perineural connective tissues, composed of astrocytes, glia, oligodendrocytes, and so on. Recently it has been discovered that these "supporting cells" actually form a communication system of their own, with synapse-like connections to the neurons proper.[17] Light produces signals that reach all of these cells--it affects all parts of the matrix.

A look at the anatomy of the retina reveals a likely site for photoreceptor signals to connect to the perineural connective tissue system and thence to all parts of the body. Light microscopists identified a dense-staining line called "the outer limiting membrane" lying between the photoreceptor layer and the outer nuclear layer of the retina. Electron microscopy has revealed that this is not a membrane at all. Instead, it is a precisely aligned planar array of densely spaced plaque-bearing junctions with bundles of actin filaments attached to them. This distinctive row of adhering junctions, now called "the outer limiting zone," attaches the photoreceptor cells to the Müller cells, which are neuroglial connective tissue cells. The junctions have an

THE SOLITON

At the time Jelle Atema was suggesting that sensory information is conducted by conformational waves in microtubules, little was known about how these waves could be propagated. However, in a series of important studies beginning in the same year that Atema wrote his theoretical paper, 1973, A.S. Davydov and his colleagues, at the Institute for Theoretical Physics in Kiev, developed an explanation of energy transfer along α-helical protein molecules. Conformational changes are conducted as a special collective excited state called a *soliton*.[19] The soliton is a singular or solitary wave.

Our familiar experience of solitons in nature is the tsunami or tidal wave, which can be propagated for long distances across the ocean without loss or dispersion. Solitons have enabled the development of modern high speed multiwavelength optical networks used in the telecommunications industry--the internet for example. Soon all of the major inter-city fiber-optic links will be soliton-based.

The soliton is a robust coherent wave with remarkable "self-focusing" properties that enable the propagation of a narrow, stable pulse over long distances without any distortion or energy loss. Solitons are self-sufficient carriers of energy and information--they hold themselves together as they travel through cells and tissues. Rapid advances in the speed of fiber optic communications have been due mainly to learning how to manipulate solitons. There is an opinion, which makes sense, that all successful technologies were actually "invented" by living systems long ago in our evolutionary history. The soliton is one of these biological inventions.

The soliton is not an esoteric or ephemeral or theoretical academic

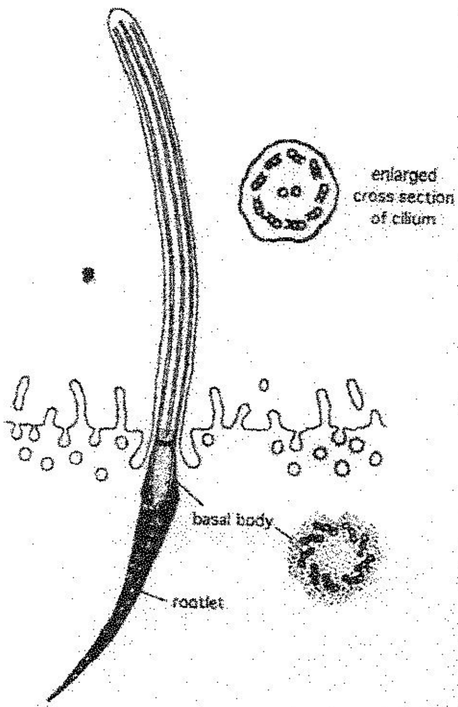

Figure 4
Cilia and flagella in mammalian and invertebrate sensory endings have in common a 9 + 2 core arrangement of microtubules. From Lentz, T.L., 1971. *Cell fine structure. An atlas of drawings of whole-cell structure.* W.B. Saunders Company, Philadelphia PA. p. 4.

or new age construct--it is a phenomenon that is widely recognized in physics, biology, and engineering. For example, a dozen leading experts from the U.S.A., USSR, Japan and Western Europe held a week-long international symposium on solitons. The proceedings were published in *Physica Scripta.*[20] Solitons have been utilized to explain many phenomena in different fields of nonlinear optics, the physics of the condensed state, field theory, gravitation theory, plasma physics, and other sciences. The biomedical importance of solitons is documented in 503 papers listed at PubMed, the database of the National Library of Medicine. Sixty eight of those papers were published in the year 2000.

Davydov proposed a role of solitons in muscle contraction.[21] Soliton conduction through proteins is at least 10 to 20 times faster than nerve conduction. By utilizing fast soliton transfer, which can approach or even exceed the speed of sound[22] movements could be generated *prior to perception* by classical neuronal cognitive processes. I have referred to this as a *Continuum Pathway* from sensation to action. It is a continuous pathway in living systems for sensory, energy, information and action that includes but is not limited to nerves.[23]

Exploration of the soliton concept has major clinical significance for brain and spinal cord injury as well as for human performance, the study of cognition and consciousness, and for understanding a variety of phenomena in energy medicine and the martial arts.

QUANTUM COHERENCE

What is emerging is a biophysical model that encompasses both light and related processes taking place throughout the organism. In her brilliant paper, *Quantum coherence and conscious experience*, Mae-Wan Ho describes this system:

> *The extracellular, intracellular, and nuclear matrices together constitute a noiseless excitable electronic continuum for rapid intercommunication and energy flow permeating the entire organism, enabling it to function as a coherent and sentient whole.*[24]

Now we summarize the phenomenon of quantum coherence. For a detailed and readable account, see Mae-Wan Ho's book, *The Rainbow and the Worm: The Physics of Organisms*:[25]

> *Coherence in ordinary language means correlation, a sticking together, or connectedness; also, a consistency in the system. So we refer to people's speech or thought as coherent, if the parts fit together well, and incoherent if they are uttering meaningless nonsense, or presenting ideas that don't make sense as a whole. Thus coherence always refers to wholeness. To appreciate the implications of coherence for the living system, we have to look at its quantum physical description.*

An important step in the application of quantum mechanics in biology came about when Herbert Fröhlich, a leading quantum physicist, became fascinated with the huge electrical fields across cell membranes. Cell membranes are extremely thin (10^{-6} cm), yet support enormous electrical fields, amounting to some 10^5 volts per centimeter. Ordinary materials will not sustain such a huge voltage--they will break down and sparks will jump across them. For cell membranes to maintain such enormous fields they must be made of an extraordinary material with remarkable properties. They are liquid crystals.

In the late 1960's, Fröhlich realized that highly organized molecular systems such as those found in cell membranes, connective tissues, and muscles will develop high frequency electrical oscillations. Because of their high degree of structural uniformity and regularity (e.g. Figure 5b), bioelectric fields will cause the components of these molecular arrays to vibrate strongly and emit stable coherent or laser-like electromagnetic radiation at specific frequencies. The oscillations are in the near visible and visible parts of the spectrum. These signals will move about within the organism and will be radiated into the environment.

This important prediction has been confirmed by a variety of researchers around the world.[26] Moreover, during the period when Fröhlich was developing his ideas about biological coherence, Davydov was studying the ways energy and information are conducted in proteins, and Atema and his colleagues were following sensory information through microtubules.

Hameroff has been a leader in recognizing that coherent signals moving through the cellular matrix have key roles in communication, memory, and information processing (intelligence). He has reviewed 13 models of cytoskeletal information processing.[27] Soliton waves traveling through neural and non-neural cells would leave in their

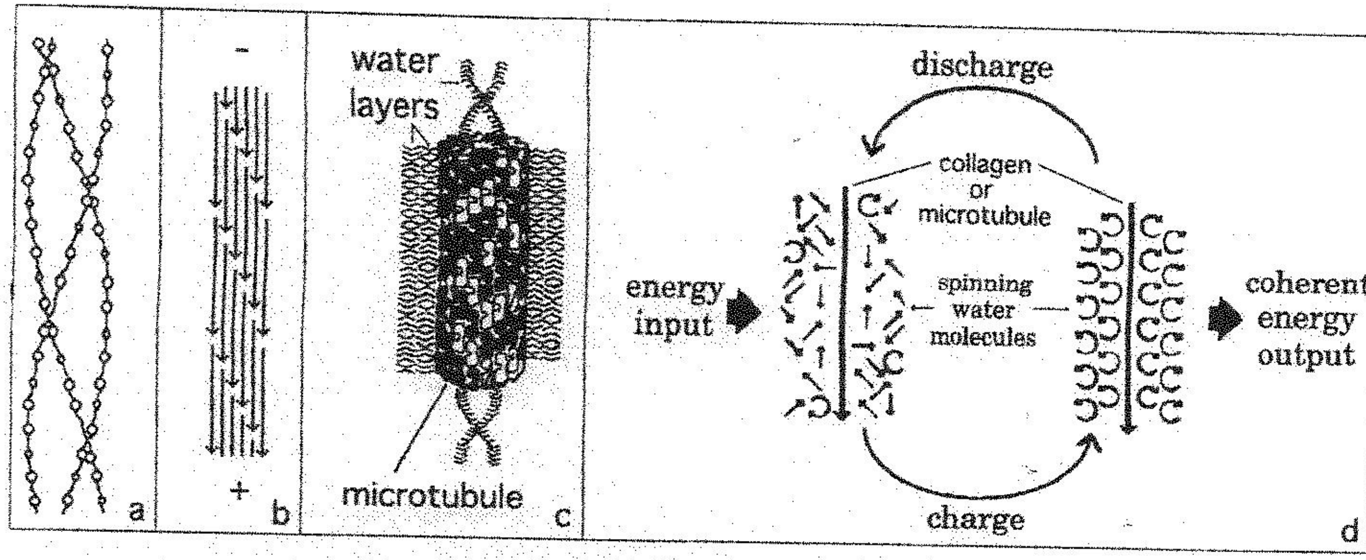

Figure 5

a) the collagen triple helix. b) an array of collagen molecules forms connective tissue. The whole system is electrically polarized, with the head end negative relative to the tail (Athenstaedt, H., 1974. Pyroelectric and piezoelectric properties of vertebrates. *Annals of the New York Academy of Sciences* 238:68-94). c) a portion of a microtubule showing the layers of water both inside and outside. d) the energetic structure of the microtubules and other proteins forming the living matrix oscillates back and forth between a highly excited and strongly polarized state to a weakly polar ground state. The formation of the polarized state (Davydov soliton) involves progressive coherence of the spins of the water molecules.

wakes *memories* in the form of patterns of cytoskeletal structure and/or vibrations. This information could be subsequently read out and utilized to make informed decisions for the regulation of cellular processes.

All of these phenomena come together in the following way.

THE LIVING MATRIX IS AN EXCITABLE MEDIUM

The entire living matrix, including the cytoskeletons of all cells and the fibers in the connective tissues, form a continuous excitable medium.

When we think of excitable media, we usually think of the neuronal membrane. But as Hameroff has pointed out, this is a "skin-deep portrayal" that leaves out what takes place *within* neurons.

Excitable materials oscillate between different states. The nerve membrane has a *resting state* with a large membrane potential. A stimulus electrically depolarizes the membrane, resulting in an action potential that propagates non-decrementally along the cell surface as a wave. In the wake of the wave, the membrane potential is restored back to the resting level.

There are many kinds of excitable media, they are extremely important, and they have been widely studied.[28] Let us look at the living matrix as an excitable medium capable of conducting electromechanical waves.

Consider the Davydov soliton wave that can propagate without degradation along a protein molecule. Water plays a vital role in the process. Water molecules are able to *spin* about their axes. As a portion of a protein becomes energized or excited, there is a build-up of order in the spins of the water molecules. The water spins become organized, coherent, and aligned. This order in water structure coincides with the propagation of energy along the protein. In living systems, as in oceanic tidal waves, the soliton is a coherent *spin-wave*.

In the wake of the soliton is a collapse back to a less ordered or chaotic state. When the collapse takes place, a Fröhlich wave is emitted. The proteins forming the living matrix oscillate between a highly excited and strongly polarized state and a weakly polar ground state.[29] I have summarized the oscillation between the soliton build-up and the Fröhlich wave emission in Figure 5d.

MORPHIC FIELDS AND PHYSIOLOGICAL REGULATIONS

The coherent Fröhlich emission has two components, an electromagnetic field with a frequency at or near that of visible light, and a massless particle called a Goldstone Boson.[30] This is a disturbance in the quantum vacuum that can be propagated everywhere virtually instantaneously. According to del Guidice and his colleagues in Milan,[31] what we see as "structure" is, in fact, a consequence of coherent focusing of polarized waves of energy. What we observe as ordered liquid crystal networks arise, in part, because of the alignment of rotating components such as water.

Fröhlich has described how light emitted by this process can be used to communicate between different cells and tissues, regulating cell division and a host of other vital processes. Coherent Fröhlich interactions regulate the orderly and efficient movements and actions of enzymes throughout the body. Fröhlich has developed a theory of cancer based on this.[32] His work provides a basis for endogenous light playing a key role in a host of regulatory processes.

There are many advantages to the use of coherent light signals for biological communications and regulations. This has become a topic of intense research.[33] Cyril Smith, for example, discusses the ways coherence can protect electromagnetic communications within the body from interference from natural and artificial fields in the environment.[34]

A FIBER-OPTIC SYSTEM?

Some researchers have envisioned the protein fabric in the body as a fiber-optic system. Fascinating evidence has been published by Pankratov in Moscow.[35] Pankratov projected light on acupuncture points and found that it reemerged from other points along the same meridian. This fascinating discovery suggests that the meridians are the main channels through which light is preferentially conducted in the body. Pankratov cites work on plants that showed that they, too, have light channels.[36]

From the information available, the analogy between proteins and fiber optic wave guides may be an over simplification. It is true that microtubules and collagen fibers are long thin hollow tubes, and therefore capable, in principle, of serving as light pipes. However, we have seen that light probably gives rise to solitons, and these are the entities that are conducted through the tissues. Soliton propagation follows nonlinear rules as opposed to ordinary linear optics. Soliton conduction allows far more sophisticated signal processing to take place within the matrix.

So a testable explanation for the Pankratov results, as well as the effects of phototherapies including colorpuncture, is that light is converted into solitons in sensory cells. Since the light absorbing reactions are reversible, it is likely that solitons arriving at the ends of microtubules, such as in retinal cells, can be converted back into light. These hypotheses are worthy of further study.

CONCLUSIONS

The goal of this essay is to develop a set of hypotheses that can provide a basis for the Syntonic Principle. We would like to know how light can activate the healing process in diverse clinical conditions, and in tissues throughout the body. What has been presented is a non-neural explanation of how light applied at one place, say the retina or at an acupuncture point, can produce effects that reach into every part of the body. The body consists of some 100 trillion cells, and the overall health of the organism, and its ability to heal itself, reflect the health and interconnectedness of all of those cells.

To summarize, the basic work of injury repair and defense is done primarily by individual cells that must sense where they are needed, move there, and then carry out specific activities. Ultimately, if light is to activate healing processes, the light must in some way speak to these cells directly, or to the pathways that enable the cells to "whisper" to each other, or both.[37]

From the biology of the situation, I suggest that the immediate effect of light is on the communication pathways. Specifically, it is proposed that light stimulates the flow of solitons, which are waves of energy and information that travel rapidly through the protein fabric of the body. The flow of solitons opens gates and switches and organizes dynamic living matrix pathways. Cells can then "whisper" to each other using their own "languages." These whisperings orchestrate the repair of traumas of all kinds. Light, electromagnetic fields, sounds, solitons, bosons, and chemicals are all part of vital communications, but there are undoubtedly others.

The soliton concept can therefore be added to the list of explanations for Syntonic effects summarized by Gottlieb in reference 1.

The manner by which light-stimulated soliton transmission can open up communications throughout the body is a topic for further research. Perhaps it is an effect on the integrins spanning cell membranes. Integrins are essential components of the living matrix communication pathway and have been implicated in a wide range of disorders. Another hypothesis has arisen from the work of Guenter Albrecht-Buehler, who has developed concepts of "vision" at the cellular level, involving the microtubules acting as the "nerves" of cells. Albrecht-Buehler found that light alters the stability of the radial array of microtubules surrounding the centrosomes, which therefore appear to be the light "detectors" within cells. The centrosomes, in turn, are important in regulating cell division and other cytoplasmic processes. In any case, the diversity of clinical problems that approachable through phototherapy seem to indicate system-wide biological effects on the communications vital to the healing process.

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