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Coherent Energy, Liquid Crystallinity and Acupuncture

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Talk presented to British Acupuncture Society, 2 October, 1999

A medical physicist in the United States, Cho Zang-Hee, who pioneered the proton emission tomography (pet) scanner, had his curiosity aroused 6 years ago, when he injured his back and found almost instant relief with acupuncture treatment. So he started carrying out experiments with functional magnetic resonance imaging (fmri) on the usual human guinea-pigs -- volunteer medical students. He flashed a light in front of them and, as expected, the visual cortex of the brain lit up on the fmri. Then, Cho had an acupuncturist stick a needle into one of the acupoints at the side of the little toe, which are supposed to be connected with the eye. In one person after another, the visual cortex lit up, just as if they had been stimulated with a flash of light. Inserting the needle into a non-acupoint in the big toe had no effect (see Dold, 1998).

Cho also found that on repeated stimulation of the same acupoints, some subjects gave increasing response in the visual cortex, while others gave decreasing response. One of the acupuncturist said it was due to yin and yang, and without seeing the data, correctly identified which subjects had an increase (yang) and which had a decrease (yin) in 11 out of 12 cases.

The only explanation for acupuncture in the west is that the nerves underlying the muscles are stimulated by the needle, which then sends impulses to the limbic system of the brain, the mid-brain and the pituitary, leading to the release of endorphins and monamines, chemicals which block pain perception. This is the accepted basis for anaethesia induced by acupuncture. But it does not explain other effects. It certainly does not explain what connects the acupoints in the foot directly to the visual cortex of the brain.

The meridian theory of traditional Chinese medicine recognizes a vital energy, qi, circulating in nature and in our body. Within the body, qi is said to circulate through channels known as meridians. The meridians interconnecting the viscera and limbs, the deeper and superficial layer of the body in a branching network of increasingly fine mesh. The meridians and their acupoints have no known relationship with anatomical systems in western medicine, despite many attempts to search for correlations (see Ho and Knight, 1998).

Until quite recently, I have thought little about acupuncture. Instead, I have been involved, since 1985, in trying to understand living organisation from the perspective of contemporary physics, especially of non-equilibrium thermodynamics and quantum theory. At the same time, I was developing and using new experimental approaches to investigate organisms non-destructively, as they are living and developing. As a result, I have now come to an understanding of the organism that is beginning to connect with the meridian theory, and, I hope, in due course, with holistic health systems of all other cultures. I have outlined a tentative theory of the organism in the second edition of my book, *The Rainbow and The Worm, The Physics of Organisms* (Ho, 1998). Let me briefly describe it and then show how it may link up with the meridian theory.

Many physicists have puzzled over how organisms seem able to resist the second law of thermodynamics which says all systems tend to evolve towards thermodynamic equilibrium -- a state of maximum disorder in which all useful energy has degraded into a random, useless form referred to as entropy. Instead, organisms can summon energy at will in a perfectly coordinated way, and to maintain and reproduce its exquisite organisation. Everyone knows that because the organism is an open system, it does not actually *violate* the second law, because the environment provides raw materials and useful energy and becomes more disordered as organisation is built up and maintained in the system, and entropy exported out of it. But how does the organism actually do it?

It turns out that the key to living organisation is not so much energy flow as energy storage under energy flow. Furthermore, the organism has somehow managed to close the loop of energy storage to become a self-maintaining, self-reproducing life-cycle (see Figure 1).

Figure 1

The organism is thus a system in which energy is *stored* in a *coherent* form, the energy remaining coherent as it is mobilized throughout the system. Notice that I have substituted ‘coherent energy’ for the usual concept of ‘free energy’. Coherent energy, as I shall explain presently, is stored in a range of space-times in which it remains coherent, and is tied to the characteristic space-times of natural processes. I say ‘characteristic space-time’ instead of the usual ‘characteristic time’ because in the new physics since Einstein’s relativity theory, space and time are no longer separable. (Indeed, organic space-time is very different from

the linear, homogeneous, space and time of Newtonian physics (see Ho, 1998). 'Free energy', on the other hand, has no relationship to space or time, and is a notoriously vague concept.

Coherent energy is energy that comes and goes together so it can do work, as opposed to incoherent energy which cancels itself out. Anyone ever hit by a wave on the seashore will know what coherent energy is as opposed to the random motion of say, molecules of air in this room. Coherent energy is mobilised within the organism with minimum dissipation, which means it generates minimum entropy. This depends on a *symmetrical coupling* of energy yielding and energy requiring processes within the living system. Symmetrical coupling involves a complete reciprocity, so that the effects of one process on the other are the same, and furthermore, they can reverse roles so the giver of energy becomes the receiver and *vice versa*. How is that achieved?

Practically all living processes are organised in cycles. The organism is thick with biological rhythms ranging from periods of split seconds for electrical activities of brain cells to seconds such as the heart-beat and respiration, to periods which are circadian and circannual. But no one has ever been able to explain why that should be. The answer is provided by thermodynamics. It turns out that symmetrically coupled cycles are the key to *both* the conservation of coherent energy and compensation (or cancelling out) of entropy within the system so that living organisation is maintained. I have represented a miniscule fraction of all the coupled cycles in the living system intuitively in Figure 2, the sum total of which make up the life-cycle. The way to think about it is that as one cycle of activity is running down, it is charging up a second cycle, so that the role can be reversed later. Similarly, as disorder is created in some part of the system, a kind of superorder appears in elsewhere, which can restore order to the first part.

Figure 2

Each cycle of activity has a characteristic space-time and together, they span all space-times from the very fast to the very slow, the global to the local. Each cycle is hence a domain in which coherent energy is stored, as said earlier. Of course, neither the conservation of coherent energy nor the compensation of entropy is perfect, otherwise, no one would ever need to eat, nor would ever age. But such a dynamic structure of the system is the key to maximising the storage of coherent energy and the speed and efficiency with which coherent energy can be mobilised (see Ho, 1995). Thermodynamically, then, the organism is a dynamically closed system of minimally dissipative coupled cycles feeding off the one-way energy flow, so that the unavoidable dissipation is exported to the environment (Figure 3).

Figure 3

The special energy relationship in the organism, therefore, is what enables it to mobilize energy at will, whenever and wherever required and in a perfectly coordinated way. In the ideal, the organism can be conceived as a quantum superposition of coherent activities, with instantaneous (nonlocal) noiseless intercommunication throughout the system. The flow of qi in meridian theory corresponds rather well to the mobilisation of coherent energy. Coherent energy is vital energy, and it is arises because the organism is especially good at capturing energy, storing and mobilising it in a coherent form.

Let us look more closely at the mobilisation of coherent energy. Coherent energy is stored everywhere within the system over the entire range of space-times. Consequently any subtle influence arising anywhere within the system will propagate over the entire system and get amplified to global effects. In other words, the system, by virtue of being full of coherent energy everywhere, will be ultrasensitive to very weak signals. This may be the basis of all forms of subtle energy medicine.

Quantum coherence in living organisms was still firmly rejected by mainstream biologists when I proposed it in 1993 (Ho, 1993). I was in turn inspired by the idea that organisms may store energy as 'coherent excitations', which originated with solid-state physicist Herbert Fröhlich in the 1960s (see Fröhlich, 1968). Later on, quantum physicist turned biophysicist, Fritz Popp, suggested that organisms are quantum coherent photon fields (see Popp *et al*, 1981; 1992). Today, mainstream scientists including physicist Roger Penrose (1994) have begun to invoke quantum coherence to account for the macroscopic, phase-correlated electrical activities observed by neurophysiologists in widely separated parts of the brain (see Freeman, 1995; Ho, 1997).

I must emphasise that the theory of the organism just presented is firmly based on empirical experimental findings from our own laboratory as well as from established laboratories around the world. Many of the findings are published in scientific journals, but there is little or no satisfactory explanation for them within conventional mainstream biology. I won't have time to describe all the experimental results which have built up a picture of coherence in the organism (see Ho, 1998). Perhaps the most suggestive evidence is our discovery in 1992 that all organisms are liquid crystalline.

What we actually discovered was a novel noninvasive optical imaging technique based on the polarised light microscopy (Ho and Lawrence, 1993; Newton *et al*, 1995; Ross *et al*, 1997). It is a technique that earth scientists and other have used for studying mineral crystals, and more recently liquid crystals; in other words, any material with molecular order. But crystals have static order, so how can living, mobile organisms be crystals? Indeed, the imaging technique demonstrates that organisms are so dynamically coherent at the molecular level that they *appear* to be crystalline (Ho and Saunders, 1994; Ho *et al*, 1996). That is because light vibrates at 10^{14} Hz, much faster than the molecules can move coherently together, which is at most 10^{10} Hz. So long as the motions among the molecules in the cells and tissues are sufficiently coherent, they will appear to be statically ordered, or crystalline, to the light passing through. This is analogous to the ability of a very fast film to capture the image of a moving object as a sharply focussed 'still' picture. This imaging technique is telling us that the living organism is coherent beyond our wildest dreams, with dynamic order that extends from the molecular to the macroscopic.

There is a dynamic, liquid crystalline continuum of connective tissues and extracellular matrix linking directly into the equally liquid crystalline cytoplasm in the interior of every single cell in the body (see Ho, 1997; Ho, 1998; Ho and Knight, 1998, and references therein). Liquid crystallinity gives organisms their characteristic flexibility, exquisite sensitivity and responsiveness, thus optimizing the rapid, noiseless intercommunication that enables the organism to function as a coherent, coordinated whole. In addition, the liquid crystalline continuum provides subtle electrical interconnections which are sensitive to changes in pressure, pH and other physicochemical conditions; in other words, it is also able

to register ‘tissue memory’. Thus, the liquid crystalline continuum possesses all the qualities of a ‘body consciousness’ that may indeed be sensitive to all forms of subtle energy medicines including acupuncture.

The connective tissues of our body include the skin, bones, tendons, ligaments, cartilege, various membranes covering major organs and linings of internal spaces. We tend to see them as serving purely mechanical functions to keep the body in shape, or to act as packing material. Actually, connective tissues may also be largely responsible for the rapid intercommunication that enables our body to function effectively as a *coherent* whole, and are therefore central to our health and well-being.

The clue to the intercommunication function of connective tissues lies in the properties of *collagen* , which makes up 70% or more of all the proteins of the connective tissues. Connective tissues, in turn form the bulk of the body of most multicellular animals. Collagen is therefore the most abundant protein in the animal kingdom.

There are many kinds of collagens -- all sharing a general repeating sequence of the tripeptide, (X-Y-glycine), where X and Y are usually proline or hydroxyproline (reviewed in Ho and Knight, 1998; Haffegee, 1999; Zhou, 1999). They also share a molecular structure in which three polypeptide chains are wound around one another in a triple-helix (rather like an electric flex) with the compact amino acid glycine in the central axis of the helix, while the bulky amino-acids proline and hydroxyproline are near the surface. In the fibrous forms, the triple-helical molecules aggregate head to tail and side-by side into long *fibrils*, and bundles of fibrils in turn assemble into thicker fibres, and other more complex three-dimensional liquid crystalline structures. Some collagens assemble into sheets constructed from an open, liquid crystalline meshwork of molecules. All these structures are formed by *self-assembly*, in the sense that they need no specific ‘instructions’ other than certain conditions of pH, ionic strength, temperature and hydration (Zhou *et al*, 1996; Haffegee, 1999). The process is predominantly driven by hydrophilic interactions due to hydrogen-bonding between water molecules and charged amino-acid side-chains of the protein. Hydrogen bonds is a special kind of chemical bond in which a hydrogen atom is shared between atoms such as oxygen and nitrogen. It is the most important and ubiquitous chemical bond in living systems. If you don’t know anything else, you must know the hydrogen bond. A water molecule is made of one oxygen atom and two hydrogen atoms and each of the two hydrogen atoms can make a hydrogen bond with another the oxygen belonging to another water molecule or a protein molecule. And the oxygen atom of the water molecule can accept two other hydrogen atoms in hydrogen-bonds.

But collagens are not just mechanical fibres and composites. Instead, they have dielectric and electrical conductive properties that make them very sensitive to mechanical pressures, pH, and ionic composition and to electromagnetic fields (reviewed in Ho, 1998; Ho and Knight, 1998; in particular, Zhou, 1999). The electrical properties depend, to a large extent, on the bound water molecules in and around the collagen triple-helix. X-ray diffraction studies reveal a cylinder of water surrounding the triple-helix which is hydrogen-bonded to the hydroxyproline side-chains. Nuclear magnetic resonance studies and Fourier Transform InfraRed (FTIR) spectroscopy have both provided evidence of *three* populations of water molecules associated with collagen. These are *interstitial* water, very tightly bound within the triple-helix of the collagen molecule, and strongly interacting with the peptide bonds of

the polypeptide chains; *bound* water, corresponding to the more loosely structured water-cylinder on the surface of the triple helix; and so called *free* water filling the spaces between the fibrils and between fibres. Typically, there is a layer of water some 4 to 5 molecules deep separating neighbouring triple-helices. This biological water is integral to the liquid crystallinity of collagens (Zhou *et al*, 1999) and other composites such as the extracellular matrix, the cell membrane and the 'cytoplasm'.

The existence of the ordered network of water molecules, connected by hydrogen bonds, and interspersed within the protein fibrillar matrix of the collagens is especially signicant, as it is expected to support rapid jump conduction of protons, ie, hydrogen atoms without its electron, which constitute positive electric charges. This jump conduction is a kind of semi-conduction and is much faster than ordinary electrical conduction or conduction through nerve fibres. That is because it does not actually require any net movement of the charged particle itself. It is passed rapidly down a line of relatively static, hydrogen-bonded water molecules.

Jump conduction of protons in collagen has been confirmed by dielectric measurements. The conductivity of collagen increases strongly with the amount of water absorbed (from 0.1 to 0.3g/g collagen), in accordance with the power-law relation,

$s(f) = XfY$

where f is the water content, and$X$ and Y are constants. The value of Y is found to be 5.1 to 5.4, and is a function of the collagen fibrillar structure. These results suggest that continuous chains of ordered water molecules join neighbouring ion-generating sites enabling proton jumps to occur. The high value of the exponential suggests that up to 5 or 6 neighbours may be involved in the jump conduction. Based on these findings, it is estimated that conductivity along the collagen fibres is at least one-hundred time that across the fibre.

A major factor contributing to the efficiency of intercommunication is the structured, oriented nature of collagen liquid crystalline fibres. Each connective tissue has its characteristic orientation of fibrous structures which are clearly related to the mechanical stresses and strains to which the tissue is subject. This same orientation may also be crucial for intercommunication.

Aligned collagen fibres in connective tissues provide oriented channels for electrical intercommunication, and are strongly reminiscent of acupuncture meridians in traditional Chinese medicine. As collagen fibres are expected to conduct (positive) electricity preferentially *along* the fibres due to the bound water, which are predominantly oriented along the fibre axis, it follows that these conduction paths may correspond to acupuncture meridians. By contrast, acupoints typically exhibit 10 to 100-fold lower electrical resistances compared with the surrounding skin, and may therefore correspond to singularities or gaps *between* collagen fibres, or, where collagen fibres are oriented at right angles to the dermal layer. The actual conducting channels may bear a more subtle relationship to the orientation of the collagen fibres, as conductivity depends predominantly on the layer(s) of bound water on the surface of the collagen molecules rather than the collagens themselves. So-called free water may also take part in proton conduction as the result of induced polarization, particularly as water molecules naturally form hydrogen-bonded networks. This would be

consistent with the observed increase in conductivity of collagen as hydration increases to a level well beyond the bound water fraction, around 0.15g/g; and with the fact that the normal hydration level of tendon is about 65%.

The hydrogen-bonded water network of the connective tissues is actually linked to ordered hydrogen-bonded water in the ion-channels of the cell membrane that allow inorganic ions to pass in and out of the cell. There is thus a direct electrical link between distant signals and the intracellular matrix of every single cell in the body, leading to physiological changes inside the cells, including all nerve cells. This electrical channel of intercommunication is in addition to and coupled with the mechanical tensegrity interactionsbetween the connective tissues and the intracellular matrix of every single cell, a continuum that always changes as a whole. Any mechanical deformations of the protein-bound water network will automatically result in electrical disturbances and conversely, electrical disturbances will result in mechanical effects.

As mentioned earlier, proton jump-conduction is a form of semi-conduction in condensed matter and much faster than conduction of electrical signals by the nerves. Thus the 'ground substance' of the entire body may provide a much better intercommunication system than the nervous system. Indeed, it is possible that one of the functions of the nervous system is to slow down intercommunication through the ground substance. Lower animals which do not have a nervous system are nonetheless sensitive. At the other end of the evolutionary scale, note the alarming speed with which a hypersensitive response occurs in human beings, or how rapidly they can respond to an emergency. There is no doubt that a body consciousness exists prior to the 'brain' consciousness associated with the nervous system.

I have argued that a body consciousness possessing all the hallmarks of consciousness -- sentience, intercommunication and memory -- is distributed throughout the entire body. Brain consciousness associated with the nervous system is embedded in body consciousness and is coupled to it (Ho, 1997; 1998).

Under normal, healthy conditions, body and brain consciousness mutually inform and condition each other. The unity of our conscious experience and our state of health depends on the complete coherence of brain and body.

Traditional Chinese medicine based on the acupuncture meridian system places the emphasis of health on the coherence of body functions which harmonizes brain *to* body. This makes perfect sense if one recognizes the brain as part of the body. Western medicine, by contrast, has yet no concept of the whole, and is based, at the very outset, on a Cartesian divide between mind and brain, and brain and body. Because there is no concept of the organism as a whole, there is, in effect, no theory of health, only an infinite number of disease models, each based on the supposed defect of a single molecular species. There is an urgent need to develop a theory of health for proper delivery of healthcare in the next millenium.

Acknowledgment

Peter Saunders, Fritz Popp, Franco Musumeci, Kenneth Denbigh, Geoffrey Sewell, John Bolton, David Knight and Stephen Swithenby have taught me a lot of what I did not know about mathematics, physics and chemistry, and shared their insights with me, some of them over many years. Stephen Ross, Julian Haffegee, Zhou Yu-Ming and Richard Newton were my collaborators on many of the experimental projects. Without their enthusiasm, ingenuity and support, the work described in this paper would never have been done.

References

- Dold, C. (1998). Needles & Nerves. *Discover* September, 58-62.
- Freeman, W.J. (1995). *Societies of Brains. A Study in the Neuroscience of Love and Hate*, lawrence Erlbaum Associates, Hove.
- Fröhlich, H. (1968). Long range coherence and energy storage in biological systems. *Int. J. Quantum Chemistry* 2, 641-649.
- Haffegee, J. (1999). Collagen self-assembly and alignment *in vitro*. M. Sc. Thesis, Bioelectrodynamics Laboratory, Open University.
- Ho, M.W. (1993). *The Rainbow and The Worm. The Physics of Organisms*, World Scientific, Singapore.
- Ho, M.W. ed. (1995b). *Bioenergetics, S327 Living Processes*, Open University Press, Milton Keynes, especially Chapters 3, 5, 7, 8.
- Ho, M.W. (1997a). Quantum coherence and conscious experience. *Kybernetes* 26, 265-276.
- Ho, M.W. (1998). *The Rainbow and The Worm. The Physics of Organisms, 2nd. Ed.* World Scientific, Singapore.
- Ho, M.W. and Knight, D.P. (1998). The acupuncture system and the liquid crystalline collagen fibers of the connective tissues. Am. J. Chinese Medicine 26, 251-263.
- Ho, M.W. and Lawrence, M. (1993). Interference colour vital imaging: A novel noninvasive microscopic technique. *Microscopy and Analysis* September, 26.
- Ho, M.W. and Saunders, P.T. (1994). Liquid crystalline mesophase in living organisms. In *Bioelectrodynamics and Biocommunication* (M.W. Ho, F.A. Popp and U. Warnke, eds.)World Scientific, Singapore.
- Ho, M.W., Haffegee, J., Newton, R.H. Ross, S., Zhou, Y.M. and Bolton. J.P. (1996). Organisms as polyphasic liquid crystals. *Bioelectrochemistry and Bioenergetics* 41, 81-91, 1996.
- Newton, R.H., Haffegee, J. and Ho, M.W. (1995). Colour-contrast in polarized light microscopy of weakly birefringent biological specimens. J. Microscopy 180, 127-130.
- Penrose, R. (1994). *Shadows of Mind*, Oxford University Press, Oxford.
- Popp, F.A., Li, K.H. and Gu, Q. eds. (1992). *Advances in Biophotons Researc* h, World Scientific, Singapore.

- Popp, F.A., Ruth, B., Bahr, W., Bohm. J., Grass, P., Grohlig, G., Rattemeyer, M., Schmidt, H.G. and Wulle, P. (1981). Emission of visible and ultraviolet radiation by active biological systems. *Collective Phenomena* 3, 187-214.

- Ross, S., Newton, R.H., Zhou, Y.M., Haffegee, J., Ho, M.W., Bolton, J. and Knight, D. (1997). Quantitative image analysis of birefringent biological materials. *J. Microscopy* 187, 62-67.

- Zhou, Y.-M. (1999). The optical properties of living organisms, Ph.D. Thesis, Open University, Bioelectrodynamics Laboratory.

- Zhou, Y.M., Newton, R.H., Haffegee, J., Brown, J.Y., Ross, S., Bolton, J.P., Ho, M.W.: Imaging Liquid Crystalline Mesophases *in vivo* and *in vitro*: Measuring Molecular Birefringence and Order Parameter of Liquid Crystals. *Bios Journal*, 1996.

- Zhou, Y,-M., Newton, R.H., Haffegee, J.P. Meek, K. and Ho, M.W. (1999). Effects of different solvents on collagen birefringence and structure. (in preparation).

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