Anatomic characterization of acupuncture system and ultra-weak photon emission

Roeland Van Wijk[1,2,*], Kwang-Sup Soh[3], Eduard P. A. Van Wijk[1]

[1]International Institute of Biophysics, Raketenstation, Kapellener Strasse,

D-41472 Neuss, Germany

[2]Faculty of Biology, Utrecht University, Padualaan 8, 3584CH Utrecht, The Netherlands

[3]FPRD, School of Physics & Astronomy, Seoul National University, Seoul 151-747, Korea

*Corresponding author: Tel: +49 2182 825131; Fax: +49 2182 825132

E-mail: meluna.wijk@wxs.nl

Abstract

During the past 20 years, the connective tissue has been recognized as an integral component of the Chinese acupuncture meridian system. This has offered an interesting correspondence between the classical Chinese theory and a 200 year-old European theory on connective tissue as basic bioregulatory system. We review supporting evidence from biochemistry, cell biology, biophysics and biophotonics. Anatomic, cellular and molecular studies reveal the enormity and pervasiveness of such tissue from the highly structured, strong and dense fascia, via the Bonghan ducts and connections to skin and internal organs to the fine-structured extracellular matrix surrounding individual cells. Tracing coherent events from the macromolecular to the cellular level has improved the understanding the processes of intercommunication and the system's self-healing response. The liquid crystalline state of highly structured extracellular collagen as well as cellular components, e.g., DNA, are discussed in relation to biophoton emission properties of the system. It is concluded that our understanding of the biophoton emission properties will have a profound influence on the effectiveness of regeneration medicine generally.

Keywords: Biophoton; Ultra-weak photon emission; Bioelectromagnetism; Acupuncture; Bonghan system; Connective tissue

1 Introduction

According to classical Chinese theory, acupuncture meridians are "channels" with "meridian qi" flowing through them [1]. These meridians run longitudinally along the surface of the body linking acupuncture points. Charts portraying acupuncture points and meridians date as far back as 300 BC [2]. Modern acupuncture charts highlight 12 principal meridians serving as "links" between the extremities and trunk and head. In addition,

many other “accessory” meridians are described as well as deep internal “branches” which originate at specific points on the principal meridians and extend to internal organs. Although acupuncture texts and atlases generally agree on the location of the principal meridians, considerable variability exists as to the number and location of internal branches and extra points. According to the Standard Acupuncture Nomenclature proposed by the World Health Organization [3], the meridian acupuncture system contains approximately 400 acupuncture points along 20 connecting meridians. Acupuncturists use anatomical landmarks (such as bony prominences, muscles, or tendons) as well as proportional measurements (e.g., fraction of distance between elbow and wrist) to determine the location of each point [4]. The term meridian “qi” possibly alludes to dynamic processes such as communication, movement, or energy exchange [5]. Disruption of the meridian channel network is believed to be associated with disease; needling of acupuncture points is thought to be one way to influence this system [4].

Connective tissue has been recognized as an integral component of the meridian system [6]. Early Chinese medical thinkers of the Han Dynasty spoke of a “lining” of the body and the organs which they called Li; it was usually considered the opposite of biao or surface. Biao was typically used to indicate skin and body hair whereas the lining excluded the skin. This distinction reflects an understanding of the superficial fascia of the body [6, 7, 8]. Xie Lin wrote: The Yin Wei controls the Qi of the greasy membranes which travels to the lining of the body [9]. “Lining” refers to superficial fascia and probably the deeper fascial structures [7]. The implications are that Li flows through the fascia. The Luo vessels (the “branches”) also flow through the same fascia. Therefore, both exist throughout the entire body.

Modern bio-medical science is based on the concept of cell pathology generally disallowing the concept of meridian pathways and energy exchange [10]. However, if we hypothesize that the network of acupuncture points and meridians can be viewed as a representation of the network formed by interstitial connective tissue, we could develop a Western medical concept of a basic bioregulatory system (German: Das Grundsystem) [11, 12]. The concept of a basic bioregulatory system was postulated 200 years ago; it was developed parallel to the cell pathology model.

In 1767, Bordieu postulated the existence of an organ that provides nutrition to all tissues and facilitates their collaboration. He believed that the essentials of diseased processes reside in this most extensive organ of the body [13]. In 1845, Reichert recognized the vital importance of the connective tissues of the body. He emphasized that there is no direct contact between (vegetative) nerve endings, capillaries and parenchymous

cells. The interstitial tissue both separates and simultaneously functions to facilitate nerve action and nutrition trafficking [14]. In 1869, Von Rindfleisch elaborated on the cellular humoral neural components [15]. Buttersack demonstrated that the system has its own structure and physiology [16]. The physical chemistry of the system was investigated by Schadé [17]. The collagen fibers presenting as a loosely knit network are, during expansion, able to absorb large amounts of acid. Subsequently, it has been documented that homeostasis of the acid/alkaline level resides largely in the interstitial tissue [17]. The qualities and functions of the system were summarized by Standenath: "It is an intermediary for metabolite and fluid flow between the capillary system and parenchymous cells; it governs metabolism by regulating levels of H_2O, ions, and nutrition; it has storage capacities; it regulates tonus; it has (immune) defense functions [18]. In 1949, Eppinger compiled data about the behaviour of the system during illness. Under normal conditions, the system of pores and crevices that delineates the organs is hardly visible. Only after "swelling", due to some pathology, can it be easily discerned [19]. Other data suggested that all loose connective tissues "amalgamate" throughout the body and extracellular fluid flows at a slow rate [20]. The concept has matured as a result of extracellular matrix research.

The goal of this article is to present a conceptual model linking traditional Eastern acupuncture theory and Western bioregulatory concepts. This objective will be approached with biophysical, molecular cell biological, and biophotonic perspectives.

2. The acupuncture system and its relationship with the fascial planes of connective tissue

The ancient Chinese were primarily concerned with the efficient manner that acupuncture works and less interested in acquiring a logical understanding of its mechanism. Over the past 30 years, studies aimed at understanding the acupuncture point/meridian system from a "Western" perspective searched for histological features that could differentiate acupuncture points from surrounding tissue. Several authors have suggested a correspondence between acupuncture meridians and connective tissue [7, 21, 22].

The hypothesis that acupuncture points are preferentially located over fascial planes of connective tissue was investigated [23, 24]. He described the common anatomic components of an acupuncture point (AP): at the AP position there exists an accompanying composite of a blood vessel and a nerve within a sheet of loose connective mesenchym perforating the superficial fascia that separates the subcutaneous from muscle tissue (Fascia corporis

superficialis, Fcs). This is characteristic for 82% of all classical AP's [25]. The perforations are markers below the fascia for the myo-tendon kinetic chain of the muscle complex. The line connecting the AP on such a chain represents the course of the meridian. This was demonstrated for the fascia-myo-tendon chain of the lung meridian. The chain consisted of: Ligamentum collaterale mediale pollicis (LU 11), M. abductor pollicis brevis (Lu10), M extensor pollicis brevis (Lu 9) Tendo und M. abductor pollicis longus (Lu 8, 7), M. brachioradialis (Lu 6), M. brachialis (Lu 5), M. biceps brachii (Lu 4) M. deltiodeus (Lu 2), and M. pectoralis major (Lu 1). In the area without Fascia corporis superficialis (e.g., the head) the AP contains a blood vessel-nerve complex entering through the openings of the bones (e.g., Foramina supraorbitale, laterale, mediale, infraorbitale or mentale) and interdigitating with the skin of the face. This acupuncture point anatomic complex was published by Heine [26, 27] and eventually confirmed by several other researchers [28-32].

Specific structural properties of acupuncture points have also been reported as neurovascular bundles [33-35), veins perforating fascia [36], neuromuscular attachments [37-40], and various types of sensory nerve endings [41-43]. However, none of latter studies included statistical analyses comparing acupuncture points with appropriate "nonacupuncture" control points.

Another type of evidence focusing on a correspondence between acupuncture points, meridians and connective tissue was studied by Heine by locating acupuncture points and meridians in a series of gross anatomical sections [8] wherein the researchers marked acupuncture points on the heart (H3, H2, H1), pericardium (P3, P2), lung (L5, L4, L3, L2, L1), large intestine (Li11, Li12, Li13, Li14), triple heater (Sj10, Sj11, Sj12, Sj13, Sj14) and small intestine (Si8, Si9, Si10, Si11) meridians. Overall, more that 80% of acupuncture points and 50% of meridian intersections of the arm appeared to coincide with intermuscular or intramuscular connective tissue planes [8]. The probability that such a percentage of points would fall on fascial planes was $P<0.001$. Likewise, the probability of 14 of 28 meridian intersections (50%) falling on fascial planes is also $P<0,001$.

Another experimental evidence in support of this hypothesis was provided from studies on the biomechanical response to needling [8]. During needle insertion and manipulation, acupuncturists aim to elicit a characteristic reaction to acupuncture needling known as "de qi" or "obtaining qi". Needle manipulation typically consists of rapid rotation (back-and-forth or one direction) and/or pistoning (up-and-down motion) of the needle [44]. During de qi, the patient feels an aching sensation in the area surrounding the needle. Simultaneously with this

sensation, the acupuncturist feels a “tug” on the needle, described in ancient Chinese texts as “Like a fish biting on a fishing line“ [45]. This biomechanical phenomenon has been referred to as “needle grasp “ [8]. Needle grasp involves connective tissue [8, 48]. In both in vivo and in vitro experiments, it was observed that, during acupuncture needle rotation, connective tissue winds around the acupuncture needle, creating a tight mechanical coupling between needle and tissue. In human and animal studies using a computerized acupuncture-needling instrument [46, 47], this needle grasp was quantified by measuring the force necessary to pull the acupuncture needle out of the skin (pullout force). In a quantitative study of needle grasp in 60 healthy human subjects [46], the pullout force was measured at eight different acupuncture point locations, compared with corresponding control points located on the opposite side of the body, 2 cm away from each acupuncture point. Pullout force was on average 18% greater at acupuncture points than at corresponding control points.

3. Electrical conductance and the acupuncture system

Since the 1950s, it has been discovered and confirmed with refined techniques [49] that most acupuncture points correspond to high electrical conductance points on the body surface [50-54] and visa-versa [50, 55, 56]. Acupuncture points typically register as local maxima in conductance, elevated by a factor of 10 to 1000 compared with the surrounding skin. Since the 1970s, this fact has led to the development of instruments for diagnostic purposes based on electrical characteristics of acupuncture points [57, 58]. Differing electrical properties are often found to correlate with states of health and disease [59, 60].

Such instruments measure skin conductance and its change when stimulated by direct current (DC) or alternating current (AC) [57, 58]. The technology takes advantage of the knowledge that electrical properties of acupuncture points are based on charge movements and selective permeability of ions through different layers of the skin. Generally, the epidermal and dermal layers are represented as two domains in a series, each with its capacitance and resistance with very different response (relaxation) times [58, 61]. Several factors are known to affect skin conductance e.g., pressure, moisture, skin abrasion [62, 63]. To date, only a few studies have controlled for these factors such as compression and stretching were studied [61, 64, 65]. The generator of potential change increases with compressional force. The magnitude of potential changes depends on thickness of the tissue under the skin, curvature of compressing surface and if the skin perspires [66].

Van Wijk and Wiegant [67] studied the influence of pressure on changes in conductivity using fine-mechanical devices; the pressure-registering electrode could be moved vertically with the help of a micrometer screw and a rotating switch. Pressure-related conductivity changes differ at different locations on the skin. The effect of pressure can be most accurately assessed by examining particular acupuncture points, that could be positioned in such a way that in a downward movement the pressure electrode experienced resistance in exactly the opposite direction wherein the tangential pressure is at a minimum [68]. It was concluded from these results that the phenomenon of pressure tolerance is of great importance for the characterization of AP's.

Combining the morphological and conductance data presented above leads to the conclusion that an acupuncture point contains both local maximum electrical conductance and maximum electrical current density. It is also a converging point of surface current and a singular point of abrupt change in electrical flow.

The morphogenetic singularity [69-71] theory suggests that the meridian system acts as conduits for electrical current. A recent study combined ultrasound evaluation and tissue impedance measurements to examine the electrical properties of connective tissue planes associated with meridians. The working hypothesis was that electrical impedance (which is inversely proportional to electrical conductivity) is lower along those acupuncture meridians associated with loose connective tissue planes (i.e., between muscles or between muscle and bone). Gold-plated acupuncture needles (instead of surface electrodes) were inserted into the tissues. A four-electrode technique was utilized to measure tissue electrical impedance. The electrodes were placed in a straight line. A constant amplitude alternating (AC) current was passed between the two outer electrodes while voltage was measured between the two inner electrodes. Data demonstrated for individual subjects tissue impedance differences between control and meridian segments [72]. A significant difference in mean tissue impedance was documented between meridian and control segments (Repeated Measurements ANOVA, main effect $p=0.004$). When comparisons were performed within each location, difference in mean tissue impedance at the Pericardium location were highly significant ($p=0.0003$). Analyses performed within the Spleen location did not result in significant differences between the two segments ($p=0.70$).

These documented differences were explained by the different anatomic locations [72]. The Pericardium control needles were primarily inserted into the relatively wide belly of the flexor digitorum superficialis muscle width. In contrast, because of the variable width of the flevor digitorum longus and its orientation perpendicular to the

skin surface, the Spleen control segment was often close to the connective tissue plane separating this muscle from the soleus. Therefore, in some subjects, the Spleen control needle may have penetrated as much connective tissue as the Spleen meridian needles. In the ten subjects for which both medial and lateral edges of the flexor digitorum longus could be clearly delineated on the ultrasound images, greater flexor digitorium longus muscle width was positively correlated with greater tissue impedance in the Spleen control relative to the meridian segments (r=0.60).

4. Molecular Biology of Extracellular Matrix and Connective Tissues

Connective tissue and epithelial tissue represent two extremes of organization. At the interface between an epithelium and connective tissue, the matrix forms a basal lamina important in controlling cell behavior [73]. In connective tissue, the extracellular matrix is plentiful with cells sparsely distributed within. Direct attachments between one cell and another are relatively rare.

The extracellular matrix is, generally, composed of a variety of proteins and polysaccharides that are locally secreted and assembled into an organized meshwork in close association with the surface of the cell that produced them. The amounts of protein and polysaccharides found in different organs vary greatly; plentiful in cartilage and bone and minor in brain and spinal cord. The variations in the relative amounts of different macro-molecules and the way in which they are organized give rise to a diversity of forms, each adapted to the functional requirements of the particular tissue. The vertebrate extracellular matrix was once thought to serve mainly as a relatively inert scaffold to stabilize the physical structure of tissues. However, now it is clear that the matrix has a far more active and complex role in regulating the behavior of its cells by influencing their survival, development, migration, proliferation, shape, and function. Matrix has a correspondingly complex molecular composition. The matrix can become calcified to form rock-hard structures of bone or teeth [74] as well as the transparent matrix of the cornea. It can also adopt a ropelike organization that gives tendons their tensile strength [75].

In most connective tissues, macro-molecules are secreted largely by cells called fibroblasts. In certain specialized types of connective tissue, e.g., cartilage and bone they are secreted by cells of the fibroblast family that have more specific names: e.g., chondroblasts, form cartilage and osteoblasts form bone.

The two most prominent classes of extracellular macro-molecules make up the matrix: (1) fibrous proteins including collagen, elastin, fibronectin, and laminin all having both structural and adhesive functions; and (2) polysaccharide chains of the class called glycosaminoglycans (GAGs) usually found covalently linked to protein in the form of proteoglycans.

The proteoglycan molecules in connective tissue form a very hydrated, gel-like "ground substance" in which the fibrous proteins are embedded. The polysaccharide gel resists compressive forces on the matrix while simultaneously permitting rapid diffusion of nutrients, metabolites, and hormones between the blood and the tissue cells. The collagen fibers both strengthen and help organize the matrix; rubberlike elastin fibers give it resilience. Many matrix proteins help cells attach to the appropriate locations.

Glycosaminoglycans (GAGs) are unbranched polysaccharide chains composed of repeating disaccharide units [76]. They are called GAGs because one of the two sugars in the repeating disaccharide is always an amino sugar. GAGs are very negatively charged because sulfate or carboxyl groups are present on most of their sugars. They are also strongly hydrophilic. Thus, GAGs tend to adopt highly extended conformations that occupy a huge volume relative to their mass. They form gels even at very low concentrations [77]. The high density of negative charges attract many cations, most notably Na^+, that are osmotically active and attract large amounts of water into the matrix. This creates a swelling pressure, or turgor, that enables the matrix to withstand compressive forces. The four main groups of GAGs are distinguished according to their sugars, the type of linkage between the sugars, and the number and location of sulfate groups: (1) hyaluronan, (2) chondroitin sulfate and dermatan sulfate, (3) heperan sulfate, and (4) keratan sulfate.

Except for hyaluronan, all GAGs are found covalently attached to protein in the form of proteoglycans. Proteoglycans are easily distinguished from other glycoproteins by the nature of their sugar side chains. At least one of the sugar side chains of a proteoglycan must be a GAG. Whereas glycoproteins contain 1 – 60 % carbohydrate by weight in the form of numerous short, branched oliosaccharide chains, proteoglycans can contain as much as 95% carbohydrate by weight, mostly in the form of long, unbranched GAG chains [73].

In principle, the diversity of proteoglycans is almost unlimited by both their core proteins and GAG chains. Even a single type of core protein can vary greatly in the number and types of attached GAG chains. Moreover, the

underlying repeating pattern of disaccharides in each GAG can be modified by a complex pattern of sulfate groups.

Given the great abundance and structural diversity of proteoglycan molecules, it would be surprising if their function were limited to providing hydrated space around and between cells [73]. Their GAG chains, for example, can form gels of varying pore size and charge density. One additional function is to serve as selective sieves to regulate the traffic of molecules and cells according to their size, charge, or both.

Besides associating with one another, GAGs and proteoglycans associate with fibrous matrix proteins such as collagen and with protein meshworks such as the basal lamina, creating extremely complex structures [73].

Collagens are the major proteins of the extracellular matrix [78]. The collagens are a family of fibrous proteins secreted by connective tissue cells and a variety of other cell types. As a major component of skin and bone, they are the most abundant proteins in mammals constituting 25% of the total protein mass [79]. The primary feature of a typical collagen molecule is its long, stiff, triple stranded helical structure in which three collagen polypeptide chains, the α chains, are wound around one another in a ropelike superhelix. Collagens are extremely rich in proline and glycine, both of which are important in the formation of the triple-stranded helix. Proline, because of its ring structure, stabilizes the helical conformation in each α chain whereas glycine is regularly spaced at every third residue throughout the central region of the α chain. Being the smallest amino acid with only a hydrogen atom as a side chain, glycine allows the three helical α chains to pack tightly together to form the final collagen superhelix. Approximately 20 types of triple-stranded collagen molecules exist. The main types of collagen found in connective tissues are I, II, III, V, and XI. Type I is the principal collagen of skin and bone and by far the most common. These are fibril-forming collagens with ropelike structure. After being secreted into the extracellular space, these collagen molecules assemble into higher-order collagen *fibrils*. These are thin structures (10 – 300 nm in diameter in mature tissues) many hundreds of micrometers long and clearly visible in electron micrographs. Collagen fibrils often aggregate into larger, cablelike bundles several micrometers in diameter which can be seen in the light microscope as collagen *fibres.*

Collagen types IX and XII, fibril-associated collagens, decorate the surface of collagen fibrils. They are thought to link fibrils to one another and to other components in the extracellular matrix. Types IV and VII are network-

forming collagens. Type IV molecules assemble into a sheet or meshwork that constitutes a major part of mature basal laminae. Type VII molecules form dimers that assemble into specialized anchoring fibrils attaching the basal lamina of multilayered epithelia to the underlying connective tissue and are especially abundant in the skin.

In contrast to GAGs, which resist compressive forces, collagen fibrils form structures that resist tensile forces. The fibrils have various diameters and are organized in different ways in different tissues. In mammalian skin, for example, they are woven into a wickerwork and, therefore, resist tensile stress in multiple directions. In tendons, they are organized in parallel bundles aligned along the major axis of tension. In mature bone and in the cornea, they are arranged in orderly plywoodlike layers with fibrils in each layer lying parallel to one another and nearly at right angles to the fibrils in the layers on either side.

Cells interact with the extracellular matrix both mechanically as well as chemically, often with dramatic effects on the architecture of the tissue. For example, fibroblasts work on the collagen they have secreted, crawling over and tugging on it, helping to compact it into sheets and draw it out into cables. When fibroblasts are mixed with a meshwork of randomly oriented collagen fibrils that form a gel in a culture dish, they tug on the meshwork drawing in collagen from their surrounding and thereby causing the gel to contract to a small fraction of its initial volume. In similar fashion, a cluster of fibroblasts can surround itself with a capsule of densely packed and circumferentially oriented collagen fibrils. If two fibroblasts are apart on a collagen gel, the intervening collagen becomes organized into aligned fibrils that connect the two cells. The fibroblasts subsequently migrate along the aligned collagen fibrils influencing the alignment of the fibrils. Subsequently, collagen fibrils affect the distribution of the fibroblasts. Fibroblasts presumably have a similar role in generating long-range order in the extracellular matrix helping, for example, to create tendons, ligaments and the tough, dense layers of connective tissue that bind together most organs [73].

In the close interaction between fibroblasts and extracellular matrix, a major role is played by a number of non-collagen proteins that specifically bind to other matrix macromolecules and receptors on the surface of cells. These proteins therefore contribute to both organizing the matrix and helping cells attach to it. The principle component is fibronectin, a large glycoprotein. The fibronectin fibrils that form on or near the surface of fibroblasts are usually aligned with adjacent intracellular actin stress fibers. In fact, intracellular actin filaments promote the assembly of secreted fibronectin molecules into fibrils and influence fibril orientation.

The interaction between cytoskeleton and fibronectin is very interesting. The contractile actin and myosin cytoskeleton pulse on the fibronectin matrix and generate tension. As a result, the fibronectin fibrils are stretched, promoting fibronectin polymerization and matrix assembly. This interaction between the extracellular matrix and the cytoskeleton is reciprocal in that, as described earlier, intercellular actin filaments can promote the assembly and influence the orientation of fibronectin fibrils. Since the cytoskeleton can exert forces that orient the matrix macromolecules, the cell secretes and subsequenty, the matrix macromolecules can organize the cytoskeleton of the cells they contact. The extracellular matrix can then, in principle, propagate order from cell to cell, creating large-scale oriented structures.

5. The system's self-healing response: relation to connective tissue and acupuncture

In vivo, fibroblasts are normally non-dividing or slowly growing cells embedded in a three-dimensional collagen matrix in the presence of interstitial fluid. This situation drastically changes under conditions of tissue stress. In that case, a defense procedure is initiated in the extracellular matrix which can ultimately result in inflammation and the stimulation of fibroblasts to proliferate. The biological processes of fibroblast-proliferation and inflammation are intimately associated. They occur as part of the body's normal response to many events including long-term lowering of pH in over-exercise of organs, trauma, bacterial infection or exposure to physical agents as heat and cold and radiant energy. In addition, prominent, histological changes in the connective tissue occur. The process of inflammation has a strict sequence of events. The reaction starts with a (transient) vasoconstriction mediated by the sympathetic nervous system, followed by vasodilatation, increased blood flow, increased vascular permeability that results in hyperemia edema. In the next phase, polymorphonuclear leukocytes associate with endothelial cells and infiltrate into the adjacent tissue. The ongoing contraction of endothelial cells leads to the infiltration by lymphocytes and macrophages in later stages of inflammation. Finally, the normal structure is restored with destructed tissue areas filled by fibroblasts and new collagen matrix.

The extravascular collagen matrix changes during the inflammation process. It loosens in early phase and contracts in late phase of the process [80, 81]. The molecular interactions initiating the response are complicated but many steps have been identified. An important molecule for man is histamine. The mast cells – the major

source of histamine – lose their characteristic granules containing active materials as heparin and histamine at the time of injury. Histamine directly increases permeability of the microcirculation. Simultaneously, certain enzymes destroy norepinephrin which is required to maintain tonus of the microcirculation, resulting also in vasodilatation. Proteolytic enzymes can attack directly the basement membrane of the microcirculation, rendering it leaky. Some of these released proteases may also be capable of activating kallikrein which, in turn releases bradykinin from α_2-globulin substrate found normally in the circulation. These proteases may also act directly in a kallikrein-like manner to release kinins from appropriate extracellular substrate. These kinins increase markedly the permeability of the microcirculation, causing a further increase in concentration of proteins and cells within the wound space. Other principle mediators are prostaglandins E1, E2, F1a and F2a, which are terminal mediators of the acute inflammatory response.

Packing of collagen is mainly determined by the fibroblasts: the number, their capacity to synthesize collagen synthesis and collecting ability [82, 83]. Insight in this process was largely obtained by extensive studies of the relation between fibroblast activation and collagen matrix structure utilizing in vitro models. In vitro model consists of the collagen gels containing different concentrations of collagen with cells within it, either fibroblasts of phagocytic leukocytes (PMNL). Studies have demonstrated that phagocytic activaty is strongly influenced by collagen packing. Lowering collagen concentration causes an increased phagocytic response. Higher concentrations retard this activity. The contraction and packing of collagen is regulated by fibroblasts. The contracting forces by fibroblasts depend on the initial cell density and collagen concentration. A collagen matrix gels with low collagen and fibroblast concentrations represents an early stage of inflammation. Starting with this situation, the process of restructuring can be studied, including the regulation of the proliferation ability of fibroblasts vis-à-vis the contraction of collagen. When quiescent fibroblasts are placed in an open collagen matrix they resumed DNA synthesis and cell doubling [84]. The rate of initiation of the DNA synthesis and cell proliferation depends on the initial collagen concentration and cell density. From these studies it is evident that the collagen network has an effect on DNA synthesis and cell multiplication. Conditions that allow a high level of DNA synthesis also result in increased numbers of fibroblasts.

Fibroblasts in three-dimensional collagen matrices have been extensively used to study their biosynthetic capacities, including the synthesis of proteins as collagen. It appeared from those studies that contraction of the collagen gels parallels reduced protein synthesis, in particular the production of collagen [84].

The role of the fibroblasts in restructuring the collagen network is crucial and depends on the cell's capacity to collect collagen in a given matrix structure. The condensation of fibrils of the lattice occurs as the result of a "collection" process executed by cells as they extend and withdraw cytoplasmic podia that attach to collagen fibrils. It is likely to assume that in early phases of wound repair the collection process by fibroblasts is disturbed, allowing the leukocytes optimal access to the extracellular matrix. However, the more fibroblasts are present, the more the rate of collagen contraction becomes proportional to the density of fibroblasts in the collagen matrix. The contraction force exerted by fibroblasts also depends on the collagen density. The extent of the collagen gel contraction was inversely related to the collagen concentration used. The cellular activity to collect collagen becomes less when high concentrations of collagen and intermolecular cross-links are already present.

6. Bonghan system

A recent breakthrough in the identification and characterization of acupuncture points and meridians is the claim made by Bonghan Kim, a medical surgeon, who discovered anatomically distinctive corpuscle-like tissues at the acupoints, and threadlike ducts at the meridians of human skin [85, 86]. He traced the ducts and found that they formed a circulatory network throughout the body. He also reported that the ducts and corpuscles float inside blood and lymph vessels, and spread on the surfaces of internal organs.

Until recently, Bonghan Kim's discovery could not be reproduced mainly because the formula of the staining dye that was essential for identifying the Bonghan ducts (acupuncture meridians) was kept secret. His work has therefore been neglected, as one might expect, for a long time [87]. In an exception to this neglect, the Japanese anatomist Fujiwara [88] was in fact able to confirm Kim's results partially, but his work has not attracted much attention either.

Without the secret formula the existence of intravascular Bonghan ducts inside the blood vessels of rabbits and rats was recently confirmed [89], and the acridine orange fluorescence method [90] was found to distinguish clearly the threadlike Bonghan ducts from fibrins. Other step toward rediscovering the Bonghan system was the observation of threadlike structures on the internal organs of rabbits and rat by three independent groups [91-93]. Bonghan ducts inside large lymphatic vessels of rabbits and rats were also observed by using three different staining techniques, i.e. Janus Green B, fluorescent magnetic nanoparticles, and Alcian Blue [94-97]. Search for the Bonghan ducts and corpuscle in the skin, in the brain and spinal cord are at present in progress.

A series of investigations are being performed to elucidate the details of the Bonghan ducts and corpuscles: (1) the anatomy and the basic histology with conventional staining methods and confocal laser scanning microscopy [90, 94, 98], (2) the ultra-structure by using various techniques of electron microscopy such as scanning electron microscopy (SEM), transmission electron microscopy (TEM), cryo-SEM, and SEM with a focused-ion-beam (FIB/SEM) [99], and (3) the cellular nature by using immunohistochemistry [100], (4) the circulatory function by injecting nanoparticles [101], and Alcian blue [102], and (5) the neurophysiological connection by studying the hormone contents [103].

The network of Bonghan ducts

Bonghan system is a novel circulatory system that forms a network throughout animal body. A Bonghan corpuscle (BHC) and Bonghan duct (BHD) correspond to an acupoint and meridian, respectively. Bonghan ducts are linked either with one end of the BHC or with both ends.

According to BH Kim [85] the BHC in the reticular layer of the skin at the acupoint is an oval structure with a long diameter of 1.0 - 3.0 mm and a short diameter of 0.5 - 1.0 mm. The bottom part of the BHC is connected with the bundle of blood vessels and Bonghan ducts. The BHD is a semi-transparent and somewhat yellowish thread-shaped structure surrounded with connective tissues, and it contains densely distributed capillary vessels. In addition to the BHC/D corresponding to the acupoints and meridians in the skin there are several other BHC/D at various places inside a body.

The subsystems are categorized as followings:

(1) Superficial BHC/D: Those located in the skin are the anatomical substance of the classical acupoints and meridians.

(2) Intravascular BHC/D: Those running inside the large veins, arteries and lymphatic vessels exist afloat in the blood/lymph stream not adhering to the vessel wall.

(3) Extravascular BHC/D: Those running outside the blood vessels. For instance, the BHD starting from the BHC at the Zusanli (St36) runs along the ischiatic nerves and blood vessel bundles.

(4) Organ-surface BHC/D: Those spread on the surfaces of internal organs such as liver, stomach, small and large intestine and bladder. They are not fixed on the surface, and can be lifted up.

(5) Intra-organ BHC/D: Those exist inside the organs.

(6) Neural BHC/D: Those inside the brain and spinal cord and those running along at the outside of the peripheral nerves.

Among these the intravascular and organ-surface BHC/D were confirmed in the last few years, and the search for the superficial, extravascular, and neural BHC/D are in progress.

Characteristic features of the BHC are (1) the existence of chromaffine cells which produce noradrenalin and adrenalin neurotransmitters, (2) plexus of blood vessels and capillaries, and (3) nerve endings [85]. Abundance of blood vessels and nerve endings at acupoints were confirmed by others [104]. Recently we observed that there are abundant lymphatic vessels at the acupoints [105].

A distinguishing feature of the BHD is the distribution of rod-shape nuclei whose lengths are 10 - 20 μm. The nuclei are arranged in a broken-line striped fashion. The rod-shape nuclei are the common feature of all the BHDs that we observed in the blood vessels, lymphatic vessels, on the organ surface, and in the skin. Figure 1 shows typical examples of BHDs depicting the distribution of rod-shape nuclei.

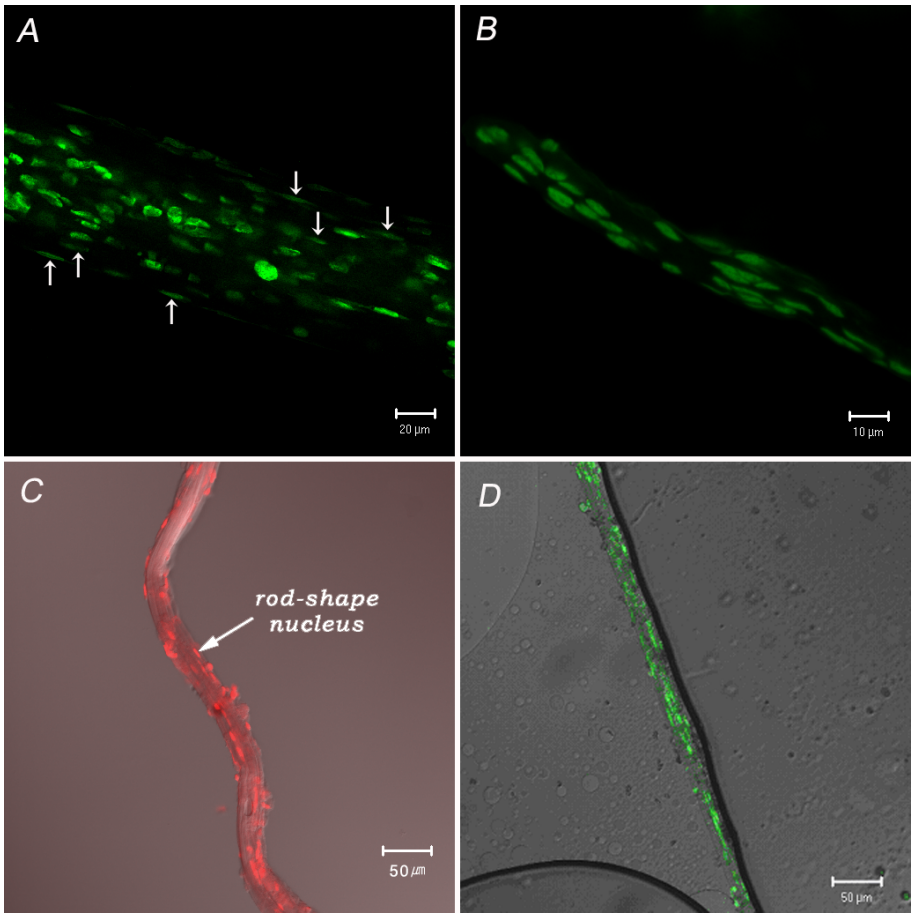

Figure 1: Distribution of rod shape nuclei in various NTS. Confocal Laser Scanning Microscopic images of the threadlike structures showing rod-shape nuclei (arrows) distributed as broken-lined striped fashion. (A) The NTS was stained by YoYo-1, DNA-specific dye after taken from an Alcian blue injected lymphatic vessel of a rabbit [97]. (B) The NTS was stained by acridine orange, another DNA staining dye after taken from a Janus Green B injected lymphatic vessel of a rabbit [94]. (C)

The NTS was stained by Feulgen reaction, a DNA-specific dye, after taken from the organ surfaces of rabbits [98]. (D) The NTS was stained by acridine orange after taken from the caudal vena cava of a rabbit [90]. The shapes, lengths, and distribution of the rod-shape nuclei are similar to each other for the four cases. This suggests that the NTS in lymph vessels, in blood vessels, and on organ surfaces belong to the same system.

Another characteristic feature of the BHD is the cribriform structure of its cross-section. The diameters of the channels in the BHD are various from about 10 μm to submicron. Figure 2 displays the cribriform images of some BHDs.

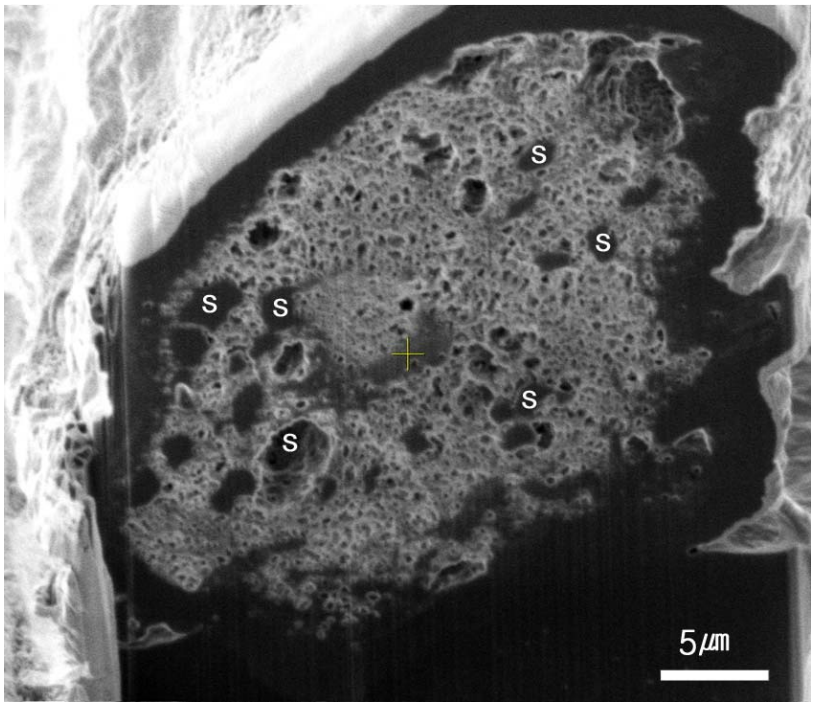

Figure 2: FIB/SEM micrograph of a novel threadlike structure taken from the surface of a rabbit's large intestine. This suggests that the morphological structures of the NTS are similar among different mammals (Yoo JS et al., Micro Res Tech, 2006) [99]. S: sinuses.

The above two features are morphological hallmarks of the BHD that distinguish the BHD from blood and lymphatic vessels and nerves.

Biochemical components in the Bonghan liquid

Biochemical analysis of the BHC, BHD, and Bonghan liquid (BHL) that flows in the BHD is in a very early stage, and only some rudimentary results have been obtained. BH Kim raised the possibility that the BHD is a

novel path for hormones such as adrenaline (A) and noradrenalin (NA) [86]. Using capillary electrophoresis method we [106] were able to confirm the Adrenalin in the organ-surface BHC/D of rabbit. This qualitative experiment was followed by more quantitative study using ELISA (Cat Combi ELISA kit) that yielded higher A-concentration (20.6 ± 8.8 ng/ml) than NA-concentration (5.8 ± 2.6 ng/ml). This result could be an interesting feature of BH-system because it suggested that BHC might be an NA/A-producing organ. Indeed, the immunohistochemical examination showed the existence of chromaffine cells that are known to be NA/A-producing cells [103]. Thus, the BHC is a novel NA/A-producing tissue in addition to the currently known postganglia of sympathetic nerves and the adrenal medulla.

Another important chemical in the BHD mentioned by BH Kim [86] was hyaluronic acid. A consistent experimental result was done by Ifrim who showed that acupoints and meridians were strongly stained by Alcian blue which is a muco-polysaccharide staining dye [107]. The Alcian blue staining technique was used to visualize the BHD in blood vessels of mice [108], and in lymphatic vessels of rabbits [97], and the technique was also utilized to measure the speed of flow in the organ-surface BHD [102]. However, precise measurement of the hyaluronic acid concentration in the BH-liquid has not yet been performed.

Probably the most important component in the BH-liquid is the BH-microcell of spherical shape (diameter 1 – 2 μm). It contains one or two chromosomes enclosed by a thin membrane [109].The origin of the BH-microcell is micro-nucleation of some cells in organs and tissues.

In the first stage, point-like small granules appear and move around within nuclei. The movement becomes faster and granules come out from the nucleus after its membrane is ruptured. The granules move more vigorously in the cytoplasm, and finally the membrane disintegrates and the BH-granules are scattered around.

According to Kim the BH-granulization process appears in normal tissue cells and can be also induced by various chemical and physical factors common to stress [109]. In Western medical science, microcells are cytoplasmic fragments that contain micronuclei composed of one or a few chromosomes surrounded by a thin rim of cytoplasm and a cell membrane. They are produced by enucleation of micronucleate cells [111] and have also been directly generated without the necessity of forming micro-nucleated cells by first placing mitotic cells directly into cytochalasin B and centrifuging in the Percoll gradient [112]. Another source of microcells is tumor tissues. The relative numbers of microcells in tumor tissue markedly increase after chemotherapy, irradiation or

immunotherapy [113]. Without speculating about the mechanism, the microcells may reflect the highly organized regulation of cell proliferation in a tissue. The number of cells in an organ is tightly regulated – not simply by controlling the rate of cell division, but also by controlling the rate of cell death. Cells are able to commit suicide by activating an intracellular death program. This process is therefore called programmed cell death, although it is more commonly called apoptosis (from a Greek word meaning "falling off"). In adult tissues, cell death exactly balances cell division. If part of the liver is removed in an adult rat, for example, liver cell proliferation increases to make up the loss. Conversely, if a rat is treated with Phenobarbital – which stimulates liver cell division (and thereby liver enlargements) – and then the Phenobarbital treatment is stopped, apoptosis in the liver greatly increases, until the liver has returned to its original size.

Cells that die as a result of acute injury typically swell and burst. They spill their contents all over their neighbors – a process called cell necrosis – causing a potentially damaging inflammatory response. By contrast, a cell that undergoes apoptosis dies neatly, without damaging its neighbors. The cell shrinks and condenses. The cytoskeleton collapses, the nuclear envelope disassembles, and the nuclear DNA breaks up into fragments. Most important, the cell surface is altered displaying properties that cause the dying cell to be rapidly phagocytosed, either by a neighboring cell or by a macrophage, before any leakage of its content occurs. This not only avoids the damaging consequences of cell necrosis but also allows the organic components of the dead cell to be recycled by the cell that ingests it.

We recently obtained BH-microcells from BH-corpuscles using a glass capillary. They were 1~2 μm spherical shapes, and stained strongly by acridine-orange revealing their DNA contents. They exhibited a jittering motion, and the motion seemed, affected by illumination of UV-A light [110].

Microcells have been widely used for cell-fusion studies, especially for microcell-mediated chromosome transfer. Approaches involving microcell-mediated chromosome transfer led to the study of cell senescence genes, which provide a tool for investigating carcinogenesis [114] and Downs's syndrome [115]. Microcell development was observed in perinuclear bodies of interphase nuclei in damaged macrocells of the Jungarian hamster fibroblastoma cell line HT-1080 after the application of the cytotoxic drug, thiophosphamidum [113]. It is one of the pending questions whether the BH-microcell that flows in the BHD is similar to or different from the microcells that are produced in vitro in Western medicine [116].

BHD, Connective tissue and extracellular matrix

The structure of the BHD and its surrounding materials were investigated on the organ surfaces of rats and rabbits to elucidate its extracellular matrix (ECM) by using immunohistochemistry and electron microscopy. Among the fibrous proteins elastin, fibronectin, laminin and collagen type I were expressed in the BHD on the surface of the small intestine of a rat by immunohistochemistry. Collagen type IV was not detected. The laminin was observed at the outermost boundary of the BHD. The transmission electron micrographs showed that the outer boundary looked like a reticular laminin, a kind of basement membrane whose major components are known to be laminin and fibronectin. Collagen fibrils and elastin of the ECM forming a meshwork were identified by electron micrography [117].

About the cells in the BHD, histological, immunohistochemical and electron microscopic studies revealed that there are endothelial cells at the inner boundary of channels in the BHD, and significant numbers of immune-function cells such as monocytes, macrophages, eosinophils and mast cells as well as fibroblasts.
The cellular and extracellular matrix structures of the BHD on the organ surfaces are consistent with connective tissue theory of acupoint [8, 118]. But the most relevant one, i.e., the BHD in skin (or acupuncture meridian) has not yet been identified or characterized. Studies on the optical properties of collagen in connection with bio-imaging techniques like Optical Coherence Tomography are intense biophotonic research area [119].

7. Acupuncture and connective tissue as an intercommunication system: molecular basis

Temporal and the spatial organization of a cell and its extracellular matrix are essentially determined by the dynamics of metabolic organization. Metabolic organization is predominantly regulated by process within cells. The goal of this section is to describe features of the structure and function of cells, trace coherent events from the macromolecular to the cellular level, and define aspects that seem possibly relevant to intercellular communication systems and the connective tissue.

A eucaryotic cell contains approximately one billion protein molecules. It is thought that there are approximately 10,000 types of protein in an individual vertebrate cell. In all cells, proteins are arranged into functional and dynamic complexes; complexes are as large as or larger than ribosomes. A further level of organization involves

the confinement of functionally related proteins within the same membrane, such as the nucleus or mitochondrion. An even higher level of organization is created and maintained by the cytoskeleton. It enables the living cell, similar to a city, to have many specialized services concentrated in different areas but extensively connected by path communication.

In order to explain this internal dynamic organization and the adaptive behavior of biological systems, one must deal with the dynamic non-equilibrium energy-driven processes and the constraints based on quantum coherent phenomena of the biological organization.

We will focus on the fundamental principle of domain dynamics that guides cellular organization by discussing the structural dynamics of cellular water. Sherrington stated in 1938. “Although it is fluid and watery, most of the cell is not a true solution. A drop of a true solution, a homogenous liquid, could not ‘live’. In the cell there are heterogeneous solutions. The great molecules of proteins and aggregated particles are suspended, not dissolved. A surface is a field for chemical and physical action. The interior of a pure solution has no surface. But the aggregate (“internal surface”) in the cells in the form of foamy colloids is enormous. Part of the secret of life is the immense internal surface of the cell” [120]. At the 1965 conference on “Forms of water in biological systems” organized by the New York Academy of Sciences, the recognition of the role of water in cellular organization was further understood [121]. At that conference, the cell was presented as a drop of polyphasic colloid opposite from the previous understanding that the cell is a membrane bag filled with dilute solution. That drop of polyphasic colloid is a mixture of different environments; some rich in particles, others not. Water serves as the dispersion medium of protein, nucleic acids, carbohydrates, lipids and ion particles. Subsequently, many scientists have studied the association of enzymes with vicinal water and other proteins that include the cytoskeletal filaments [122-135]. The data have suggested that, due to the unique properties of water, water is structurally aligned with protein molecules differently than with normal water. Water is unique as a liquid because of its ability to form three-dimensional, mutually hydrogen bonded networks of molecules.

Macro-molecular network of protoplasmic molecules and the enclosed water interact in a mutual manner such that biopolymers have an effect on the structure of water. Simultaneously, water structure is significant for protoplasmic organization. The zones of water at biological interfaces have consequences for the solubility of small molecules as well as for the macro-molecular organization. If water exists in different hydrogen-bonded states in various regions of the protoplasm, both protein conformations and the formation of macro-molecular aggregates are likely to be affected.

This has important consequences for metabolic functioning. It leads to the concept that coherence within metabolic cycles is part of the supramolecular organization of enzymes. Long-range mobile protonic states are the most essential coherent events in organized cellular processes dependent upon those interactions that are assembled in multi-enzyme metabolic domains [136-138]. Such a metabolon is possible as a result of the specific recognition of different enzyme molecules. The enzymes, constituting metabolons, are organized in such a way that the enzymes of both the direct and reverse routes are regulated reciprocally. Such cycles are observed in the metabolic reactions that involve both ATP utilization and generation. The same reciprocal regulation of enzymes is present in both the production and utilization of NADH. Although these cyclic events seem to reflect energy waste, their transition to a higher level of organization with strongly coupled reaction networks converts them into effective regulation of both direct and reverse routes. These routes are separated in time wherein energy loss is minimized. Minimal energy loss is a major way to define the coherent volume of a domain. The cost of regulation has been estimated to be very high, reaching 20% of energy available in a biosystem. However, maintenance of homeostatis is the gain [139]. Increase of number and diversity of enzymatic metabolic links within a domain results in a biosystem with lesser but larger domains of long-lived and stable networks. A new cycle is, therefore, an extension of the coherent volume of the domain.

It is widely recognized that a comparison can be made between a living state and a liquid crystal. Molecular orientation was recognized already by Peters in 1927 [140] as possibly being important for living protoplasm [141]. Liquid crystals are states or phases of matter between solid crystals and liquids; hence the term, mesophases. Unlike liquids which have little or no molecular order, liquid crystals have both orientational order and varying degrees of translational order. Unlike solid crystals, liquid crystals are flexible, malleable, and responsive [142, 143]. There are many kinds of liquid crystals, those which are most like liquids and others that most resemble solid crystals. Those that are like liquids can flow like water. Even though all molecules tend to be aligned in one direction, individual molecules can move quite freely and change places with one another while maintaining their common orientation. The ones that resemble solid crystals will have order in all three dimensions. The molecules may even be extensively and covalently cross-linked together, but they still remain flexible and responsive.

All the major constituents of living organisms may be liquid crystal forms [143]. These include lipids of cellular membranes, DNA, possibly all proteins (especially cytoskeletal proteins), muscle proteins, and proteins in the connective tissues such as collagens and proteoglycans [79, 144]. However, very few researchers have embraced the idea that organisms may be essentially liquid crystalline. Yet, Needham did, in fact, propose that very possibility. Direct evidence has, only recently, been documented. One example is nuclear magnetic resonance (nmr) studies of living human muscles [145] Another study successfully imaged live organisms using an interference color technique that amplifies weak birefringence typical of biological liquid crystals. The team further discovered that all organisms to date are polarized along the anterior-posterior or oral-adoral axis in such a way that when the axis is properly aligned, all the tissues in the body are maximally colored [140].

It is important to recognize that liquid crystals typically undergo rapid changes in orientation (phase transitions) when exposed to electric (and magnetic) fields. They also respond to changes in temperature, hydration, shear forces and pressure. Biological liquid crystals carry static electric charges and are therefore also influenced by pH, salt concentration and the dielectric constant of a solvent [79]. Thus, the entire cell is now understood to be mechanically and electrically interconnected in a "solid state" [128] or "tensegrity system" [146, 147]. Such can be referred to as liquid crystal.

With a better understanding of the significance of coherent cell domains of the "living" organism, we are beginning to achieve a more complete image of the structural and functional complexity of the whole organism. A significant parameter, therefore, to consider in relation to cellular activity is the intercellular communication flow system. The speed of flow, its control, and its directionality have long been overlooked in favor of coherence at the cell level. This factor highlights the relationship between structure and function of the extracellular matrix and connective tissue. According to the hypothesis (model) proposed in this background review, functional cooperation between cellular processes might be understood if we postulate that the liquid crystal of connective tissue is an essential part of coherent structure.

Studies have revealed that collagens are not just materials with mechanical properties. Instead, they have electrical properties that 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 [148]. Evidence for bound water in collagen also comes from Fourier

Transform Infra Red (FTIR) spectroscopy [149]. Nuclear magnetic resonance studies provided evidence of three populations of water molecules associated with collagen. These are (a) interstitial water, very tightly bound within the triple helix of the collagen molecule and interacting strongly with the peptide bonds of the polypeptide chains, (b) bound water, corresponding to the more loosely structured water-cylinder on the surface of the triple helix, and (c) free water filling the spaces between the fibrils and fibers [150].

The ordered network of water molecules connected by hydrogen bonds and interspersed within the protein fibrillar matrix of the collagens is especially significant; as it is expected to support rapid jump conduction of protons (positive electric charges). This has been confirmed by dielectric measurements [151]. The conductivity of collagen is a function of the collagen fibrillar structure. It strongly increases with the amount of water absorbed in accordance with power-law relationship. The results suggest that continuous chains of ordered water molecules join neighboring ion-generating sites enabling proton jumps to occur. It has been estimated that up to 5 or 6 neighbors may be involved in the jump conduction [22]. Based on these findings, it was also estimated that conductivity along fibers is at least one-hundred times that across the fiber [152].

The collagenous, liquid crystalline mesophases in connective tissue combined with the associated structured water constitutes a semi-conducting, highly responsive network that extends throughout the organism. This network is directly linked to the intracellular matrices of individual cells via proteins that pass through the cellular membrane. The connective tissues and intracellular matrices, together, form both a global tensegrity system [147, 155] as well as an excitable electrical continuum for rapid intercommunication throughout the body [156]. In addition, they have dielectric and electrical conductive properties that make them very sensitive to mechanical pressures, pH, ionic composition [81, 153, 154] and to electromagnetic fields. They are, therefore, highly “tunable responsive systems” and as such, ideal for intercommunication [156, 157].

Consequently, both the DC electrodynamic field and the acupuncture system have a common anatomical basis. The most promising functional correlate of the acupuncture meridian system is analogous to electrical transmission lines [158-160] throughout the highly structured connective tissue. This supports rapid semi-conduction of protons. Liquid crystal facilitates coherent excitations even more. Weak signals of mechanical pressure, heat or electricity may be readily amplified and propagated by a modulation of proton currents or coherent polarization waves [161]. This facilitates interconnection of all the cells of the body connective tissues.

Cells easily intercommunicate so that living systems can function as both a continuum and coherent whole [155, 162].

Proton jump-conduction is a form of semi-conduction in condensed matter. It is much faster than conduction of electrical signals by nerves [22]. The "ground substance" of the entire body may provide a much better intercommunication system than the nervous system. It has even been speculated that one of the functions of the nervous system is to slow down intercommunication through the ground substance [22]. Argument can be that lower animals which do not have a nervous system are nonetheless sensitive.

Regarding the effect of needling within the acupuncture system, one researcher [163] summarizes the entire procedure from a Western physiologic perspective. The insertion and twirling of a needle in an acupuncture point produces a strain which is transduced into an electric current because of the piezoelectric properties of the connective tissue. The electrons generated in this way are led throughout the body along the "channels" of dominant electrical transmission lines made up of proteins and mucopolysaccharides possessing semiconductive properties. When the stimulus arrives at the cells of a specific organ, the electric current is again transduced, owing to the inverse piezoelectric effect, into the chemical or mechanical energy necessary to restore physiologic functioning on both a molecular and cellular level.

8. Bioelectromagnetism, bioenergy and biophotons

A major factor contributing to the efficiency of intercommunication in connective tissues is the structured, oriented nature of collagen liquid crystalline mesophases. Each connective tissue has its characteristic orientation of fibrous structures. The alignment has long been recognized in the structure of bone, cartilage and "Langer lines" [164] in the skin. The predominant orientations are clearly related to mechanical stresses and strains on the tissue during development and growth [165].

It is timely to summarize some characteristics of electrical currents. It was initially demonstrated that electrical injury currents typically flow away from skin wounds and sites of amputation [160]. Injury currents themselves constitute evidence that conductive circuits link the entire body such that cuts result in current leakage. These currents are, allegedly, involved in healing and regeneration. Thus, these currents mobilize cells to migrate to the site of injury in order to initiate healing and regenerative processes. It is significant that the immediate injury

currents are all positive, as suggestive of proton currents. Only later, after the regenerating blastema is formed, do the currents reverse to negative [160].

Due to the bound water, collagen fibres are expected to preferentially conduct (positive) electricity predominantly along the fibre axis. Collagen fibre aligment in connective tissues may provide channels for electrical intercommunication and be correlated with the acupuncture system of meridians and points in traditional Chinese medicine. Keep in mind that the correlation is also related to the DC body field. By contrast, acupuncture points typically exhibit low electrical resistances compared with the surrounding skin and may, therefore, correspond to singularities, gaps between collagen fibres or where collagen fibres are oriented at right angles to the dermal layer. A number of structures mentioned earlier which are at or near acupuncture points have a common feature in that they are located in local gaps in fascia or collagen fibres. The possible conducting channels may bear a more subtle relationship to the orientation of the collagen fibres since conductivity depends predominantly on the layer(s) of bound water on the surface of collagen molecules rather than the collagens themselves [166].

The correlation between collagen alignment and the acupuncture system has been tested utilizing corroborative skin conductance measurements. In addition, alignment in skin biopsies were examined at acupuncture points and meridians compared with non-acupuncture non-meridian areas, utilizing quantitative imaging in interference color polarizing microscopy. This approach plotted molecular alignment in sections of the skin and other connective tissues [167, 168] and also confirmed that body structures are united and supported by the fascial components [75]. For example, each of the individual muscles is infused with intramuscular connective tissue and surrounded with fascia [169]. Altogether, the data suggest a continuous regulation system at both macro- and micro scale. Besides the extensive sheaths and folds around and between the organs, there is an immense quantity of tissue both encircling all living cells and every fluid which fills the joint cavities and serous spaces. An overview of fascia reveals the enormity and pervasiveness of such tissue resulting in a complete functioning unit, the myofascial system. If all other tissues were removed from the body, the remaining fascia alone would be enough to present a normal contour with a subdivision into two differing layers in the body: (a) the superficial fascia lying just underneath the skin in the form of thin, strong elastic sheets serving both as a container and as a support for the entire body [170], and (b) the deep, denser fascia consisting of a series of continuous planes and bands extending from the skin to the bone (171-173]. Where movement is necessary, around joints for example,

the tissue loosens. Where greater strength is required, the tissue becomes thicker and denser with a more parallel arrangement of the fibrous structure.

The Bonghan duct system can be considered the network connection to the skin and internal organs, ultimately resulting in the connections with the matrix that surrounds cells. The broad plasticity of fascia offers an excellent environment in which other more specialized tissues such as the organs may thrive and function [170, 172]. Connective tissue system, then, is both a part of normal everyday functioning (homeostasis) and voluntary action as originally proposed in the "basic bio-regulatory system" or "Grundsystem". Connective tissue both generates and conducts energy, highly significant for Oriental medical theory and practice [7].

Special electromagnetic properties of the connective tissue have raised the question whether there is any relationship between the above properties and the biophoton concept. Intact whole organisms as well as individual tissues spontaneously emit measurable intensities of light (i.e., photons in the visible part of the electromagnetic spectrum). The terms "electromagnetic waves", "photons" and "light" are synonymous. The different terms arose from various ways of describing "light". Usually, the visible part of the spectrum is called light; in general, the term photon applies to the whole spectrum of electromagnetic radiation. How is light generated? From classical physical principles this question is straightforward – every accelerated or moving charge in a heterogeneous electromagnetic field emits electromagnetic radiation. Additionally, certain quantum processes generate and absorb photons. The electrons in atoms and molecules can absorb photons of distinct wavelength and, as a result, are transferred into an excited level. If the delivered energy exceeds the ionization barrier, a free radical is generated.

The description of the living state from the perspective of electromagnetic bioinformation has emphasized that the organism is an open system that exchanges energy and information, primarily through electromagnetic interaction with the environment [174]. The stream of matter which is dissipated during the life cycle interacts mainly via electromagnetic fields. In a very general way, the exchange of information within the electromagnetic interaction is performed by means of charged particles and photons. In other words, the electromagnetic system within an organism is created: (a) by the material part: the flux of matter in and out of the system (electrons, atoms, molecules). These particles carry electrical charges and are part of electric currents; and (b) by photons that are the quanta of electromagnetic interaction. Any variation in the framework of electromagnetic

interactions in the coupled "environment – cell" is associated with a variation of the electromagnetic fields. From this perspective, ultra-weak photon emission (UPE) provides information about the statistical properties of the system's state and can be used as a non-destructive tool for inspection of "meridian qi" energy.

Analysis of UPE has demonstrated that it occurs in the broad spectral range of 440-850 nm [175]. Theoretically, photon emission originates mainly from: (a) reorganization of hydrogen bonds and Van der Waals complexes within vital structures, (b) radiative relaxation of metastable energy-rich structures (states) in membranes, cytosol, cytoskeleton and in superhelical structures of DNA in the nuclear chromatin; or (c) superhelical structures in the extracellular matrix [175]. Energy liberated in a single elementary step of these interactions is too low to excite electronic energy levels that correspond to the observed spectral range of UPE (400-800 nm). Therefore, molecular interactions collectively accumulate small portions of energy until the critical value is reached. These data correspond with the quantized electromagnetic field confined to membranes and cytoskeletal structures inside cells [176, 177].

It has been speculated that the extracellular, highly structured connective tissues reveal similar properties of collective photon emission dynamics, based on the molecular structures of its constituents. Evidence comes from fundamental study on the delayed luminescence characteristics of bovine Achilles' tendon [178]. The tendon is a quasi-unidimensional, hierarchically ordered system formed by aggregates of the collagen triple helix. Photo-induced delayed luminescence is dependent on the order parameters of the system. The results cannot be described in terms of excitation and de-excitation of the electronic levels of single molecules. Instead it is necessary to consider the existence of collective electronic states [179, 180]. It produces behavior analogous, under certain aspects, to those present in living systems. The results have been recently confirmed by other researchers [181] using collagen gels and collagen fibrils extirpated from rat tails. In the latter study, the optical interaction between collagen bundles and different biological materials (germinating seeds) was also studied. It was concluded that the collagen structures conduct and modify the photon pulses coming from biological sources.

Bonghan Duct: Optical channel with relay stations

In considering the possibility that cells and organisms may communicate at long range by means of electromagnetic signals, Presman [182] suggested that there may be a system of communication that sends

messages simultaneously to all organs, including those perhaps not directly connected with the nerve network. He proposed that electromagnetic signals are involved, which is consistent with the sensitivity of animals to electromagnetic fields. Biophotons could be the electromagnetic signals that Presman envisioned, as practically all organisms emit biophotons at a steady rate from a few photons per cell per day to several hundred photons per organism per second.

The biophysical model for inter- and intra-cellular communication by Nagl and Popp [184] postulated that the biophoton is trapped and emitted by a cellular physical resonance device, presumably DNA, resulting in emission with a high degree of coherence. Rattemeyer and Popp [183] suggested that the DNA molecule is an exciplex in which photons are stored and which can be a source of biophotons. Exciplex formation in DNA has been shown to predominate, even at room temperature. The non-coding DNA may act as a photon store and coherent radiator, because of its enormous polymer size and its ability to form exciplexes. The resulting long-range electromagnetic waves and fields can be seen as the basis of self-organization.

With DNA and biophotons we still need a network or channel to biologically realize the Presman-Popp postulation. Bonghan theory is just the answer. It supplies the channels with DNA granules inside. The channels are part of the connective tissue distributed all over the body, connecting the acupoints in the skin to the internal organs. As the channels form a network of one-dimensional tubes with light sources, they can be an optical channel which can produce a coherent photon state (Figure 3). Thus, we can understand the coherence of biophotons, and the regulation mechanism of the body as a whole. This picture is the scientific basis of acupuncture therapy, and could lead to a new quantum communication paradigm based upon biological function.

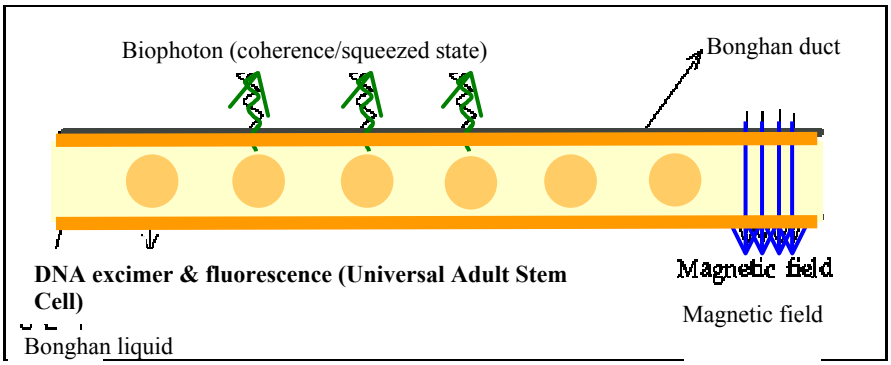

Figure 3: Optical channel model of biophotons in a Bonghan duct. DNAs are sources of coherent biophotons which propagate along the duct. (Schematic diagram).

In order to elaborate and test the optical communication channel of the Bonghan duct or acupuncture meridian we need to consider its detailed optical properties. There are, however, very little known results [185]. Some

major components that determine or regulate the optical characteristics of the ducts can be considered: (a) the cellular or extra cellular material of the BHD, and (b) the material that fills or flows in the channel of the BHD. In this respect the biochemical components we mentioned in the previous section need special attention, i.e., hyaluronic acid, adrenalin & noradrenalin, and BH-microcell.

Hyaluronic acid is present in soluble and condensed form. Depending upon the concentration and the average molecular weight of the hyaluronan, the fluid containing it behaves as an elastic body or a viscous fluid. Hyaluronans may be present in the tight intercellular spaces in a condensed, more structured form than the random coiled form, and the condensed structure of hyaluronan may have some biological functions other than those suggested by its elastoviscous properties. We suppose that the concentration and structure of hyaluronan in the BHD is a deterministic factor for the optical properties of the BH-liquid. Yet no investigation on the interaction of light and hyaluronan has been reported, therefore it remains an educated guess.

The diameter of the channels in the BHD is a geometric attribute contributing to the optical fiber properties. The diameter can be influenced by the concentration of catecholamine such as adrenalin or noradrenalin. What are the effects of catecholamine concentration on the BH-system is entirely unknown, and a possible effect like controlling the diameters of channels in the BHD remains a guess. In such a case, however, optical channel properties of the BHD may be controlled through this hormone concentration.

The BHD may not be merely an inactive optical fiber but an active one because it contains an active light source in the liquid, that is, the BH-microcell. As mentioned above the BH-microcell contains one or a few chromosome(s) whose DNA can be a source of light. Effect of light on BH-microcell proliferation was mentioned in BH Kim's early work [109], but detail is unknown. The effects of UV-A on the random motion was studied to detect that UV-A increases the average speed but more rigorous experiments are in need [110].

The measurement of the optical properties of the BHC on the organ surface of a rat was compared with those of the surrounding tissue-dermis and muscles. The transmittance and reflectance were measured in the range of 400-700 nm wavelength. The organ-surface BHC had lower absorption and scattering coefficients than its surrounding tissue-dermis and muscles, which made it appear more transparent. Thus the organ-surface BHC can transport light with high efficiency and act as an optical channel [186]. This is quite a promising outcome that encourages further investigations in this direction.

Are the structured nature and corresponding electromagnetic properties of human connective tissues reflected in ultra-weak photon emission? This is difficult to answer. We might obtain some indication by recording the

human photon emission; in particular: (a) UPE intensity over the body in relation to skin and/or connective tissue structure (or fascial system) and (b) fine structure of UPE in relation to acupuncture points.

The research in human photon emission began at least three decades ago. The early publications [187, 188] reported a statistically significant 11% increase of the signal above background noise. The researchers considered both that quantification was not reliable and simultaneously considered it as evidence for "an envelope of radiation surrounding living organisms". They ruled out that emission was caused by body temperature. Another research group obtained more reliable data on human body photon emission by utilizing a photon detection system at a constant temperature of –23^{o}C [189, 190]. Their data demonstrated for the first time anatomical variations by recording five different areas of the body. It is interesting that topologically simple structured body parts (abdomen, back, chest) emit at a lower intensity than topologically complicated parts (head, hands).

A further development came with the introduction of two-dimensional photon counting, initiated in the “Inaba Biophoton Project” in Japan, 1986. The early images demonstrated technical problems, and also suggested that photon emission of the hand was not uniform [191, 192]. In these studies, it was also demonstrated that photon emission intensity did not correlate with surface temperature.

Another important development in human photon emission research was F.A. Popp’s installment of a photo-multiplier detector hung on runners in a special dark room that could be manipulated in three dimensions. It facilitated scanning of human spontaneous photon emission while lying on a bed. During 1994 and 1995, biophoton emission was recorded from several locations of 80 healthy and diseased subjects [193]. A systematic study was not performed; however, data confirmed differences between body locations.

With these observations in mind, the question can be asked whether differences in spatial resolution of human emission by either two-dimensional photon counting or scanning with a photomultiplier tube reveals a common human pattern and whether such pattern is in a relationship to connective tissue structures as well as the acupuncture system.

9. Anatomical patterns of biophoton emission

Anatomical mapping of biophoton emission rates throughout the human body was extensively studied by the Van Wijk group at the International Institute of Biophysics (IIB) at Neuss in Germany. The measurement system was especially suitable for studying anatomical patterns of emission rates as the PMT could be moved in three dimensions over a subject lying on a bed below, and both the PMT and the subject were in a light-tight dark room [194, 195].

The low-noise PMT (9235 QB, selected type; Electron Tubes Limited, Ruislip, England; previously EMI) maintained at -25^{o}C for reduction of the dark current which was routinely measured before and after each experiment. The spectral range of effective quantum yield of the PMT was 200-650 nm, and the diameter of the quartz window was 52mm. During the experimental period the average back ground was 5.4 ± 0.3 cps (counts per second). A 7 cm long cone shaped extender was attached to the front of the PMT allowing recording of emission from a 9 cm diameter anatomic area at a fixed distance. The inner size of the dark room was 2 m x 1.5 m x 2 m, and the room was ventilated, and maintained at 20 ^{o}C.

A systematic multi-site recording wherein 29 anatomic sites were selected such that the distribution of UPE could be studied as right-left symmetry, dorsal-ventral symmetry, the ratio between the central anatomic location and extremities as well as flat versus highly structured anatomy revealed some generic features: (a) the thorax-abdomen region has the lowest emission; (b) the hand and the head region emit the highest levels [196, 197]. The data simultaneously suggested that a "common anatomic human biophoton percentage distribution emission pattern" exists corresponding to the just described levels of emission.

A subsequent study with 20 healthy subjects was performed to measure biophoton emission at the 12 anatomic spots from the frontal torso, head and hands (Figure 4). These 12 locations were selected according to the CCD data which were obtained in a concomitant experiment that will be described shortly.

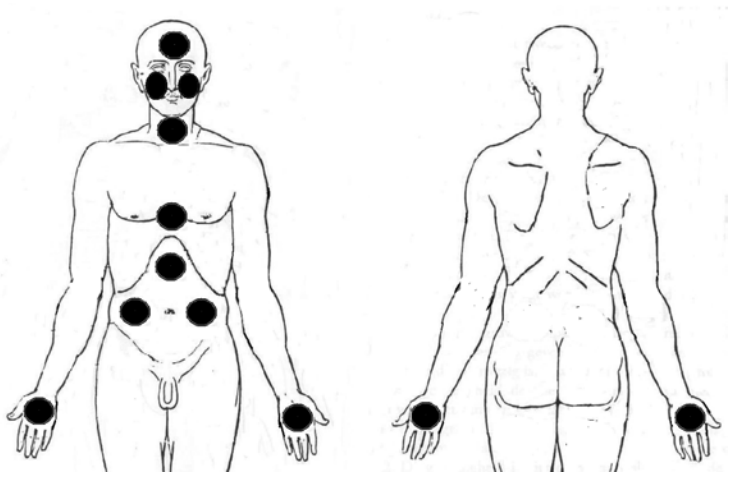

Figure 4: Anatomic locations used to register spontaneous emission of 20 male subjects.

The data from this study illustrates the existence of a "common" human male body emission pattern amongst the simultaneous existence of individual differences. As shown in the Table 1, photon emission from the abdomen was the lowest: values increased along the central axis rostally to the throat.

Anatomic location	Contribution (%)	Correlation coefficient
Abdomen-right	4.8	0.76 ($p<0.05$)
Abdomen-left	4.7	0.78 ($p<0.05$)
Stomach	5.3	0.70 ($p<0.05$)
Heart	7.0	0.90 ($p<0.05$)
Neck	9.8	0.85 ($p<0.05$)
Cheek-right	10.3	0.80 ($p<0.05$)
Cheek-left	10.1	0.78 ($p<0.05$)
Forehead	9.2	0.77 ($p<0.05$)
Hand palm-right	11.2	0.87 ($p<0.05$)
Hand palm-left	10.1	0.89 ($p<0.05$)
Hand dorsum-right	9.2	0.89 ($p<0.05$)
Hand dorsum-left	8.4	0.87 ($p<0.05$)

Table 1: Percentage contributions of photon emission from individual anatomic locations to total emission, and correlation of individual anatomic locations tot total emission.

Highest values were observed over the cheeks; emission again decreased at the forehead. About the deviations from the "common" human anatomic emission pattern, eighty five percent of the subjects demonstrated an average deviation not exceeding 30% of the values expected on the basis of the "common" pattern.

Another system to characterize anatomic distribution of spontaneous human biophoton emission is the two-dimensional imaging technology using CCD cameras.

A cryogenically cooled CCD camera system whose operating temperature was -100 ^{o}C with a dark signal (electronic noise) of 0.65e^{-}/pixel/h, and spectral range was 400 – 900 nm was used to measure biophoton emission from the upper frontal torso, head, neck and upper extremities of a single subject [198].

The emission intensity around the face and neck was highest and gradually decreased over the torso and subsequently over the abdomen.

There also existed a gradual decrease in intensity from the superior central torso to its lateral dimensions. Dorsally, the highest intensity was emitted from the neck. The image of the head demonstrated that the eyes exhibit a distinctly lower intensity. Viewed from the palm side the four fingers demonstrated increased intensity from forefinger to little finger. However, the backside of the four finger illustrated an increased intensity in the reverse order.

In addition, the dorsal side of the fingers and nails produced a high emission. The CCD data facilitated the selection of the 12 skin locations mentioned above. The anatomical pattern obtained by the PMT corresponded with photon emission images utilizing the highly sensitive technology of the modern CCD sensor [198].

It is reassuring that an independent experiment measuring biophoton emission from finger nails and palm sides of finger ends using PMT showed consistent results with those of CCD data [199]: The nails produced higher emissions than the fingerprint sides.

The etiology of the "common" pattern of emission is presently unknown. The lowest emission from eyes, and the highest emission from finger nails may provide some clues. It is interesting that highly structured anatomic locations that are more shaped and structured emit more than the unstructured parts, suggesting a connection with heterogeneity of the electrical field. Further research is required to clarify relationships between emission and anatomic areas.

10. Biophoton as bio-signal for diagnosis.

The motivation to study photon emission of acupuncture points was to implement objective and quantitative diagnostic methods for the Traditional Chinese Medicine (TCM). The reliability of Traditional Chinese Medicine (TCM) diagnoses is a serious issue because practitioners examining the same subjects showed considerable variability of diagnosis [215,216].

Inaba and coworkers [200] compared the intensity at acupuncture points with that of non-acupuncture points. The authors reported that around the forearms and hands, the photon emission intensity had a tendency to decrease gradually from the acupuncture point named the Shang-yang point to Ho-ku and then Chu-chih acupuncture points, and that their intensities differed between right and left. The authors suggested that the emission intensity of acupuncture points was in general higher than the intensity of no-acupuncture points. Recent CCD images of photon emission from the hands were obtained at the same laboratory with more advanced two dimensional imaging techniques [198]. These images made clear that acupuncture points cannot be distinguished from their surrounding emission.

It is necessary to develop other objective methods of diagnosis which can corroborate TCM concepts like the "eight principles" (yin/yang, interior/exterior, cold/heat, and deficiency/excess). Balance is one of the essential concepts in TCM, i.e., balances in the function of the body such as left/right, upper body/lower body, dorsal (yang)/ventral (yin)-balances. Evaluation or diagnosis of a patient's physical state is a dichotomic classification according to the "eight principles" based upon a practitioner's subjective inspection, listening, inquiring, and palpation. It was envisaged that biophoton emission might be an effective signal to be utilized for quantification of the "balance" concept: the emission rates from the left/right, dorsal/ventral, and upper body/lower body could be numerical comparators of the corresponding physiological or some metabolic states between the opposite pairs.

With this viewpoint in mind the simultaneous left-right biophoton measurement system was developed. Two identical head-on type PMTs (R331-05 Selected, Hamaruatsu, Japan) whose spectral range was from 300 nm to 650 nm had the effective detection area 46 mm in diameter. The dark count at 22 ^{o}C was about 15 cps, and the room temperature was kept at 22 ± 1 ^{o}C. The PMTs were placed in two separate dark chambers, and the measuring system and the subjects were in a light-tight dark room.

The hypothesis that left-right imbalance of the biophoton emission rates might be an indication of a certain disease was first hinted upon by the finding that a multiple sclerosis patient emitted more biophotons than

healthy people and the left-right symmetry was broken [201]. Jung et al studied 7 cases of hemiparesis patients, and found that the left-right differences of biophoton emission rates were very large compared with the 20 healthy subjects both for the palm and dorsum of hands [202]. For the 7 patients the average difference between the left and right hands were:

$$\Delta^{P}_{L-R} = 106.2 \pm 60.5 \text{ cps}, \quad \text{(palm)},$$

$$\Delta^{P}_{L-R} = 111.2 \pm 61.4 \text{ cps}, \quad \text{(dorsum)}.$$

On the other hand, for the 20 healthy people, the average differences were

$$\Delta^{P}_{L-R} = 17.3 \pm 15.1 \text{ cps}, \quad \text{(palm)},$$

$$\Delta^{P}_{L-R} = 8.6 \pm 8.4 \text{ cps}, \quad \text{(dorsum)}.$$

However, in later experiments with more subjects this left-right difference did not necessarily appear in other patients. Thus, it is rather inconclusive at the present time: it is not clear what specific factor causes the left-right differences. Yet, it is clearly established that a healthy person in normal condition does show the left-right balance.

About the yin/yang balance we followed the TCM viewpoints that palm and dorsum of a hand represent yin and yang, respectively. In a long-term investigation with three subjects, the biophoton emission from hands of these three healthy persons was recorded. Over a period of one year of measurements, the subjects participated in the experiment every Friday. Four areas of human hands, namely, left palm, right palm, left dorsum and right dorsum were studied. Prior to this work, only two studies of long-term biophoton measurements had been reported due to practical difficulties. Cohen and Popp [194, 195] concentrated their study upon daily recordings of the left and right hands and forehead for nine months.

The frequency count analysis shows that the distributions possess a narrow width for palms and a broad width for dorsal sides of hands with respect to all the three subjects. Besides, the average value of monthly biophoton emission displays little variation for palm and considerable variation for dorsum of hands. Furthermore, the dorsal sides show fluctuations twice as large as the palmar sides. The authors speculated that the Yang (+) side

of hands is more active according to traditional Chinese medicine; thus, this activity is reflected in the instability of biophoton emission rates. Therefore, they conjectured that the biophoton information from dorsal hands reflects the activity of the human body [203]. The authors also examined whether or not there was a discriminative feature related to a specific season or month. Results indicated that emission rates of biophotons were at a minimum in autumn, especially in September and October for all three participants. This result accords with Van Wijk's observation [204].

An attempt was made to quantify yin (palm)/yang (dorsum), and up (hand)/down (feet) balance by parametrizing the differences as the following polarizations, using the parameter X and Y. These parameters of polarization were defined as:

$$\frac{\text{emisison rates of (dorsum} - \text{palm)}}{\text{emission rates of (dorsum} + \text{palm)}},$$

$$Y = \frac{\text{emisison rates of (palm} - \text{sole)}}{\text{emission rates of (palm} + \text{sole)}},$$

The degree of polarization defined here is a concept borrowed from physics where spin polarization is similarly given. A positive X means the health state is polarized toward yang because dorsum and palm represent yang and yin, respectively. A positive Y means the subject is polarized toward up (or yang) because hand (palm) and foot (sole) represent up and down, respectively.

For an experiment with 10 volunteers there was a notable tendency for each person in the (X, Y) point distribution [205]. However, for statistically significant conclusions, further studies with more subjects are needed.

At the present time the program for the quantification and objective diagnosis of the left/right, dorsum/palm, and up/down balance is still at the initial stage, and clinical experiments are in need for a productive results.

It is interesting to consider whether left-right symmetry can be further refined utilizing photon emission data of individual finger tips. Differences between fingers could be detected in CCD images of the fingers [198]. Quantitative data come from an earlier study of Soh and coworkers [199]. They measured fingernails and fingerprints from 20 healthy living humans utilizing a PMT with a light–receiving hole with a diameter of 8mm. Biophotons from the circular area of nail or print of each finger are detected. Significantly more photons are

emitted from fingernail then from fingerprint for each finger of every subject. There is a tendency that the little finger emits less than the other fingers. Some fingers emit far stronger then others; and it depends upon each individual subject which finger emits strongest. At present it is not known why fingernails produce more biophotons. One speculation would be the optical properties of nails. However, it remains worth investigating why a certain finger emits more biophotons than other fingers. It might be closely related to the function level of the acupuncture meridian whose terminal is on the particular finger.

Effects of stimulations

The emission rate of biophoton from various parts of the human skin may reflect certain physiological or health-states of the subject either in the Western or Traditional Chinese medical viewpoints. In order to unfold this expectation one needs to investigate effects of stimulations like needling medical treatment [202, 203], meditation [206, 207], Qi-gong [208] and others. Until now mostly sporadic experimental programs were undertaken, and only a few serious clinical experiments were performed as far as the authors know. Needle-stimulation on the hemiparesis patients by an acupuncturist showed dramatic reduction in the Left-Right asymmetry of the biophoton emission [202]. For some other cases with different type of disorders, however, preliminary experiments did not find such effects. Thus, more investigations in the acupuncture needling are necessary to draw any definitive conclusion. Effects of magnetic treatment on the acupuncture points according to the "Han-Seo" treatment program was significant for some patients' biophoton emission from hands [209]. The most remarkable change observed was the exponential decay of the emission rate after the magnets were removed from the body. The patterns of change depend upon each individual and his/her health states. An enigmatic feature was also that the changes occurred only on the dorsa of hands, not on the palms [210]. No explanation on the magnetic effect is available at the present time. Experiments with "meridian-massage" showed similar patterns as the magnetic treatment except that the exponential changes occurred either at the palm or dorsal side of hands depending upon individual [209, 210]. No simultaneous measurements of other biosignals were done, and thus further analysis of such changes was not done. Nevertheless, these stimulation experiments illustrated that there are potentials of the biophoton measurement program to be utilized for medical diagnosis or evaluation of therapeutic effects. Taking herbal medicine like ginseng showed only occasionally some noticeable changes that did not reveal any regularity.

Research on photon emission and meditation has been focused on long-term and short-term aspects. Early studies demonstrated that not all Qigong masters or Zen-meditators were able to change their biophoton emission rates from hands [208]. Long-term effects of meditation were studied by comparing the spatial pattern of photon emission from experienced practitioners of Transcendental Meditation and control subjects. The average photon emission in the TM group was 35 percent lower than the control group. The anatomical pattern was almost identical for TM practitioners and control subjects [211]. The short-term effect of meditation was also studied by measuring fractal properties of photon emission within one and the same anatomic location [212]. Data led to the conclusion that before meditation, human UPE had fractal properties. Meditation results in less photon clustering [212]. These experimental data favour the opinion that (a) non-functional, conditioned responses disconnect energy cycles resulting in photon emission with photon cluster characteristics, and (b) meditation lowers photon clustering indicating a decreased associative strength with respect to conditioned responses that are non-funtional in adaptation [213].

A recent study on "the effects of a color filter used in auriculomedicine on ultraweak photon emission of the human body" is an encouraging positive result that demonstrated a subject's response in the total absence of light with a temporary increase in photon emission from the anatomic locations that had been exposed for 200s at a distance of 3 cm to a dark-adapted red filter. The stimulated emission by the exposure to the red gelatin color filters increased immediately after the beginning of the exposure, and decreased slowly after exposure to the filter [213, 214]. This is an exemplary experiment showing how the investigation on the biophoton emission and stimulation should proceed, and might eventually lead to an elucidation of the mechanism.

11. Concluding remarks

In conclusion, we note that basic research in the 200 year-old basic bioregulatory system (in German: Grundsystem) includes nowadays the anatomy, cell biology and molecular biology of the fine-structure of (a) connective tissue in fascia, (b) recently discovered Bonghan ducts, and (c) the extracellular matrix around organ cells. This system can be considered anatomically as well as physiologica1ly as an entire system. The anatomy of the system corresponds in many respects with the acupuncture system. Structural and electrical properties of acupuncture points and meridians can be more easily understood utilizing the presented system. Although the

model that is presented provides a framework for understanding intercommunication in the connective tissue and acupuncture system, several important aspects of this complex process remain to be determined.

One aspect is that the system promotes self-healing. In acupuncture, needling triggers the system influencing organ functions. To understand this action, the connective system must be systematically studied at all levels from the newly formed loose extracellular network to the highly organized macromolecular network as introduced by fibroblasts and cells derived from fibroblasts by differentiation. Although the interaction between cellular and extracellular components has been discussed, this review could not focus on the developmental biology of the system. These aspects are the key part of the structure for regulating the direct environment of organ cells, leading to maintenance of normal metabolic processes, and capacities to recover from physiological stress and repair.

Another is the fine-tuning of metabolic processes, highlighting the role of special molecular configurations, cellular water and coherent oscillations. This is one of the most fascinating growing research areas. Although many examples of coherent processes have been described in molecular and cellular biology literature, it is still not generally implemented in these research fields. It can be speculated that this knowledge is either too specialized to incorporate in modern textbooks, or simply not belonging to molecular and cell biology. Indeed, the view that is presented goes far beyond the classical boundaries of molecular and cell biology. It emphasizes also a role of biophotons in regulating metabolic processes. The regulatory role of biophotons is discussed in relation to the newly discovered Bonghan ducts and the micro-cells in these structures. The micro-cell chromosome structure has been emphasized as relay station in intercommunication. The common view is that such micro-cell structures are part of an enucleation process in the control of cell proliferation and cell death. The continuous presence of these micro-cells in the system adds at least some memory component about stress processes in the past.

Finally, this research is effective in supporting demystification of the acupuncture treatment.
The analysis of the mechanisms that regulate the intercommunication events will be important for understanding the biology of normal healing, as well as for the development and the implementation of biophoton techniques in diagnostic strategies.

References

1. Kaptchuk TJ, *The web that has no weaver. Understanding Chinese medicine.* (Contemporary Publishing Group, Inc., Chicago), 2000.
2. Veith I, *The yellow emperor's classic of internal medicine.* (University of California Press, Berkeley), 1949.
3. World Health Organization, *A proposed standard international acupuncture nomenclature: report of a WHO scientific group.* (World Health Organization, Geneva), 1991.
4. Cheng X, *Chinese acupuncture and moxibustion.* (Foreign Language Press, Beijing), 1987.
5. O'Connor J, Bensky D, *Acupuncture, a comprehensive text (Shanghai College of Traditional Medicine).* (Eastland Press, Seattle), 1981.
6. Larson D, *American J Acupuncture*, 18(1990) 251.
7. Matsumoto K, Birch S, *Hara Diagnosis: Reflections on the Sea.* (Paradigm Publications, Brookline), 1988.
8. Langevin HM, Yandow JA, *Anat Rec Part B, New Anatomist,* 269(2002a) 257b.
9. Lin X, Nan *Jing Zheng Yi. Verified meaning of the canon of perplexities (1895).* (Science and Technology Publishing Company, Shanghai), 1981, p 50.
10. NIH, *Consensus Statement. 1997. Acupuncture.* (NIH, Bethesda, MD), 15:1-34.
11. Pischinger A, *Das System der Grundregulation*. (Haug Verlag, Heidelberg), 1975.
12. Van Wijk et al, *Electrodermaal en matrixonderzoek.* (Stichting Albert Vogelprijs, Elburg), 1990.
13. Bordieu L, *Recherches sur les tissu muqueux ou l'organ cellulair.* (Paris), 1767, I, II.
14. Reichert CB, *Vergleichende Beobachtungen über das Bindegewebe und die verwandter Gebilde.* (Dorpat), 1845, S. 168.
15. von Rindfleisch E, *Elemente der Pathologie.* (Leipzig), 1869.
16. Buttersack F, *Latente Erkrankungen des Grundgewebes; insbesondere der seröse Häute.* (Stuttgart), 1912.
17. Schadé H, *Die physikalische Chemie der Inneren Medizin.* (Steinkopff), 1921
18. Standenath F, *Ergeb D Allg Pathol Anatomie d Menschen ud Tiere* 22(1928) Abtgl II 70.
19. Eppinger H, Die *Permeabilitätspathologie als die Lehre vom Krankheitsbeginn.* (Springer Verlag, Wien), 1949.
20. Molenaar H, Roller O, *Z Klin Med*, 136(1939) 1.
21. Oschman JL, *A biophysical basis for acupuncture.* Proceedings of the First Symposium of the Committee for Acupuncture Research, 1993.
22. Ho MW, Knight DP, *Am J Chin Med*, 26(1998) 251.
23. Heine H, *Dtsch Zschr Akup*, 36(1993) 99.
24. Heine H, *Dtsch Zschr Akup*, 39(1996) 75.
25. Heine H, *Dtsch Zschr Akup*, 33(1990) 94.
26. Heine H, *Dtsch Zschr Akup,* 30(1987) 75.

27. Heine H, *Acta Anat*, 152(1995) 293.
28. Zerlauth B, *Dtsch Zschr Akup*, 35(1992) 34.
29. Egerbacher M, *Dtsch Zschr Akup*, 36(1993) 75.
30. Draempehl D, Ottensmeier A, Kleinpeter A, Kiupel M, *Dtsch Ztschr Akup*, 36(1993) 104.
31. Zhang BZh, *Dtsch Zschr Akup*, 39 (1996) 29.
32. Stecco L, *La Manipalazione Neuroconnettivale*. (Editore marrapese, Roma), 1996.
33. Rabischong P, Niboyet JEH, Terral C, Senelar R, Casez R, *Nouv Presse Med*, 4(1975) 2021.
34. Senelar R, *Les characteristiques morphologiques des points chinois,* in: Nouveau traite d'acupuncture, Niboyet JEH.(ed), (Maisonneuve, Paris), 1979.
35. Bossy J*, Acupuncture Electrother Res*, 9(1984) 79.
36. Plummer JP, *Am J Clin Med*, 8, 170.
37. Liu KY, Varela M, Oswald R, *Am J Chin Med*, 3(1975) 347.
38. Gunn CC, Ditchburn FG, King HM, Renwick GJ, *Am J Chin Med,* 4(1976) 183.
39. Dung HC, *Am J Acupunct*, 12(1984) 139.
40. Pan C, Zhao A, *Moxibustion and Acupuncture Anesthesia*, in: Research on Acupuncture, Shang X. (Ed), (Springer-Verlag, New York), 1988.
41. Shanghai Medical University, Human Anatomy Department, *A relationship between points of meridians and peripheral nerves: Acupuncture anaesthetic theory study.* (People's Republic Publishing House, Shanghai), 1973.
42. Ciczek LSW, Szopinski J, Skrzypulec V, *J Trad Chin Med,* 5(1985) 289.
43. Wang K, Liu J, *Am J Chin Med*, 17(1989) 145.
44. O'Connor J, Bensky D, *Acupuncture, a comprehensive text (Shanghai College of Traditional Medicine).* (Eastland Press, Seattle), 1981.
45. Yang J, *The golden needle and other odes of tranditional acupuncture, 1601*. Translated by R. Bertschinger. (Churchill Livingstone, Edinburgh).
46. Langevin HM, Churchill DL, Fox JR, Badger GJ, Garra BS, Krag MH, *J Appl Physiol*, 91(2001b) 2471.
47. Langevin HM, Churchill DL, Wu J, Badger GJ, Yandow JA, Fox JR, Krag MH, *FASEB J*, 16(2002b) 872.
48. Langevin HM, Churchill DL, Cipolla MJ, *FASEB J*, 15(2001a) 2275.
49. Pomeranz B, *Scientific basis of acupuncture*, in: Basics of Acupuncture, Stux G (Ed), (Springer-Verlag, New York), 1997, p 30.
50. Comunetti A, Laage S, Schiessl N, Kistler A, *Experientia*, 51(1995) 328.
51. Bergsman O, Wooley-Hart A, *Am J Acupunct*, 1(1973) 27.
52. Wensel LO, *Acupuncture in medical practice*. (Reston Publishing, Reston), 1980, p 128.
53. Nakatani Y, Yamashita K, *Ryodoraku acupuncture*. (Ryodaraku Research Institute, Osaka), 1977.

54. Reichmanis M, *Electroacupuncture,* in: Modern Bioelectricity, Marino AA (Ed), (Dekker, New York), 1988, p 762.
55. Eory A., *Acupunct Electro-Ther Res*, 9(1984) 217.
56. Reishmanis M, Marino AA, Becker RO, *IEEE Trans Biomed Eng*, 22(1975) 533.
57. Tiller WA, *Journal of Holistic Medicine*, 4(1982) 105.
58. Tiller WA, *American Journal of Acupuncture*, 15(1987) 18.
59. Becker R, Reichmanis M, Marino A, *Psychoenergetic Systems*, 1(1976) 105.
60. Kobayashi T, *American Journal of Acupuncture*, 13(1985) 63.
61. Edelberg R, *Electical activity of the skin: its measurement and uses in psychophysiology*, in: Handbook of psychophysiology. Greenfield H, Sternbach R. (Eds). (Reinhart & Winston), 1972, p 367.
62. Noordgraaf A, Silage D, *IEEE Trans Biomed Eng*, 20(1973)364.
63. McCarroll GD, Rowley BA, *IEEE Trans Biomed Eng*, 26(1979)177.
64. Zipp P, Schad E, *Biomed Tech*, 24(1979) 76.
65. Ödman S, Öberg PÅ, *Med & Biol Eng & Comput*, 20(1982) 159
66. Edelberg R, *J Appl Physiol*, 34(1973) 330.
67. Van Wijk R, Wiegant FAC, *Physiological effects of homeopathic medicines in closed phials; a critical evaluation*, in: Ultra high dilution (physiology and physics), Endler PC, Schulte J. (Eds), (Kluwer Academic Publishers, Dordrecht, Boston, London) 1994, p 81.
68. Van Wijk R, *Homeopathic medicines in closed phials tested by changes in the conductivity of the skin: a critical evaluation (Blind testing and partial elucidation of the mechanisms).* (VSM Geneesmiddelen bv, Alkmaar, The Netherlands), 1992.
69. Winfree AT, *The geometry of biological time*. (Springer-Verlag, New York), 1980 p 71.
70. Cohen D, Palti Y, Cuffin BN, Schmidt SJ, *Proc Natl Acad Sci USA*, 77(1980) 1447.
71. Vinogradev IM et al, *Encyclopaedia of mathematics*. (Kluwer Academic, Norwell, MA), 8(1992) 276.
72. Ahn AC, Wu J, Badger GJ, Hammerschlag R, Langevin HM, *BMC Complementary and Alternative Medicine,* 5(2005) 1.
73. Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P (eds), *Molecular biology of the cell*. Fourth edition. (Garland Science, New York), 2002.
74. Anthony CP, Kolthoff NJ, *Textbook of Anatomy and Physiology*. (C.V. Mosby Company, Saint Louis), 1975, p 41.
75. Asimov I, *The Human Body*. (Houghton Mifflin Co, Boston), 1963, p 73.
76. Lindahl U, Höök M, *Annu Rev Biochem*, 47(1978) 385
77. Rodén L, *Structure and metabolism of connective tissue proteoglycans*, in: The biochemistry of glycoproteins and proteoglycans, Lennertz WJ, (Ed.), (Plenum Press, New York), 1980, p 267.

78. Fleischmajer R, Olsen BR, Kühn K (eds), *Biology, chemistry, and pathology of collagen*, vol.460. (The New York Academy of Sciences), 1985.

79. Knight D, Feng D, *Collagens as liquid crystals,* in: British association for the advencement of science, chemistry session, Molecular Self-Assembly in Science and Life, Keele, 1993.

80. Van Wijk R, Souren JEM, Zoutewelle G, *Immune-modulation by the extracellular matrix: the effect of Echinacea extract*, in: Matrixforschung in der Praeventivmedicin, Heine H. (Ed), (Gustav Fischer Verlag, Stuttgart-New York), 1989, p 41.

81. Van Wijk R, Souren JEM, Ovelgonne H, *The extracellular matrix, fibroblast activity and effect of Echinacea purpurea*, in: Normal Matrix and Pathological Conditions, Heine H, Anastasiadis G. (Eds), (Fisher Verlag, Stuttgart), 1992, p

82. Zoutewelle G, Van Wijk, R, *Phytotherapy Research*, 4(1990) 77

83. Souren JEM, Ponec, M, van Wijk R, *In Vitro Cellular & Developmental Biology*, 25(1989) 1039.

84. Souren JEM, Van Wijk R, *Cell Proliferation*, 26(1993), 13.

85. Kim BH, *J Acad Med Sci DPR Korea*, 90(1963) 1.

86. Kim BH, *J Acad Med Sci DPR Korea*, 168(1965) 5.

87. Chan SHH, *Neurosci Biobehav Rev*, 8(1984) 25.

88. Fujiwara S, Yu SB, *Igaku no Ayumi*, 60(1967) 567.

89. Jiang X, Kim HK, Shin HS, Lee BC, Choi C, Soh KS, *Kor J Orient Prevent Med Soc*, 6(2002) 162.

90. Lee BC, Baik KY, Johng HM, Nam TJ, Lee J, Sung B, Choi C, Park WH, Park ES, Park DH, Yoon YS, Soh KS, *Anat Rec Part B, New Anatomist,* 278(2004) 27.

91. Cho SJ, Kim BS, Park YS, *J Intl Soc Life Info Sci,* 22(2004) 609.

92. Johng HM, Shin HS, Yoo JS, Lee BC, Baik KY, Soh KS, *J Intl Soc Life Info Sci,* 22(2004) 469.

93. Lee KJ, Kim S, Jung TE, Jin D, Kim DH, Kim HW, *J Intl Soc Life Info Sci,* 22(2004) 460.

94. Lee BC, Yoo JS, Baik KY, Kim KW, Soh KS, *Anat Rec Part B, New Anatomist*, 286(2005) 1.

95. Johng HM, Yoo JS, Yoon TJ, Shin HS, Lee BC, Lee CH, Choi C, Sohn YK, Lee JK, Soh KS, *Evid Based Complement Alternat Med*, 2006, published online.

96. Yoo JS, Johng HM, Yoon TJ, Shin HS, Lee BC, Lee CH, Ahn BS, Kang DI, Lee JK, Soh KS, C*urr Appl Phys,* 2006, in press.

97. Lee CH, Seol SK, Lee BC, Hong YK, Je JH, Soh KS, *Lymp Res Biol*, 2006, accepted.

98. Shin HS, Johng HM, Lee BC, Cho SI, Soh KS, Baik KY, Yoo JS, Soh KS, *Anat Rec Part B, New Anatomist,* 284(2005) 35.

99. Lee BC, Yoo JS, Ogay V, Kim KW, Dobberstein H, Soh KS, Chang BS, *Microsc Res Tech,* 2006, DOI 101002/jemt.

100. Soh KS, Hong S, Hong JY, Lee BC, Yoo JS, *Microcirculation*, 13(2006) 166.

101. Lee CH, Yoo JS, Kim HH, Kwon J, Soh KS, *Proc 23th Symp Kor Soc Jungshin Sci*, 23(2005)129.

102. Sung B, Kim MS, Lee BC, Yoo JS, Lee SH, Kim YJ, Kim KW, Soh KS, (Speed Measurement of Flowing in the Channels of the Novel Threadlike Structures on the Surfaces of Mammalian Organs), 2007, submitted.

103. Kim JD, Ogay V, Lee BC, Kim MS, Lim I, Woo HJ, Park HJ, Kehr J, Soh KS, Bonghan corpuscle as a novel endocrine organ: Immunochemical and histological study, 2007, submitted.

104. Li AH, Zhang JM, Xie YK, *Brain Res*, 1012(2004) 154.

105. Ogay S, Kim MS, Soh KS, 2007, in preparation.

106. Yoo JS, Choi K, Baik KY, Chung DS, Soh KS, *J Intl Soc Life Info Sci,* 23(2005)292.

107. Ifrim-Chen F, Ifrim M, *Ital J Anat Embryol*, 110(2005) 51.

108. Yoo JS, Kim MS, Ogay V et al, *IFMBE Proc World Congress on Med Phys Biomed Eng*, 7(2006) 3492.

109. Kim BH, *J Acad Med Sci DPR Korea*, 168(1965) 32.

110. Sung B, Ogay V, Yoo JS, Yu HR, Lee BC, Chung C, Jung G., Soh KS, *J Intl Soc Life Info Sci,* 23(2005) 297.

111. Prescott DM, Kirkpatrick JB, *Methods cell physiol*. (Academic Press, New York), 1972, p 189.

112. Stubblefield, E., Pershouse, M, *Somat Cell Mol Genet,* 18(1992) 485.

113. Buikis I, Harju L, Freivalds T, *Anal Cell Pathol,* 18(1999) 73.

114. Rar Q, Pereira-Smith OM, *Exp Gerontol*, 35(2000) 7.

115. Kabota M, Shirayoshi Y, Oshimura M, *Biochem Biophys Res Commun*, 299(2002) 599.

116. Ogay V, Baik KY, Lee BC, Soh KS, *Acupunct Electrother Res,* 31(2006) 13.

117. Hong S, Yoo JS, Hong JY, Lee BC, Soh KS, Lee SH, Kim YJ, Kang DI, Ahn BS, Woo HJ, (Immunohistochemical and electron microscopic study of the meridian-like system on the internal organs of rats), 2007, submitted.

118. Heine H, *J Tradit Chin Med*, 8(1988) 207.

119. Kim JD, Choi CH, Soh KS, Ho DS, Kim BH, *J Kor Phys Soc*, 47(2005) 375.

120. Sherrington CS, (1940) *Man on his nature*. Gifford Lectures 1937/8, Penguin Books, Harmondsworth, Middelsex, 69 – 98.

121. Whipple HE (ed), *Forms of water in biological systems*. Annals of the New York Academy of Sciences, vol 125, 1965.

122. Ling GN, *A physical theory of the living state: The association-Induction Hypothesis.* (Blaisdell, New York), 1962.

123. Ling GN, *Int Rev Cytol*, 26(1969) 1.

124. Drost-Hansen W, *Annals of New York Acad of Sciences*, 125(1965) 471.

125. Drost-Hansen W, *Structure and properties of water at biological interfaces*, in: Chemistry of the Cell Interface, B, Brown HD (ed). (Academic Press, New York), 1971, p 1.

126. Clegg JS, *Intracellular water, metabolism and cell architecture*, in: Coherent Excitations in Biological Systems, Fröhlich H, Kremr F (eds). (Springer Verlag, Berlin), 1983, p 162.

127. Clegg JS, *Am J Physiol*, 246(1984) 133.

128. Clegg JS, Drost-Hansen W, *On the biochemistry and cell physiology of water*, in: Biochemistry and Molecular Biology of Fishes, vol.1, Hochachka PW (Ed), (Elsevier, Amsterdam), 1991, p 1.

129. Wiggins PM*, Annals of the New York Academy of Sciences*, 125(1990) 1965.

130. Wiggins PM, *Cell Biochem Function*, 13(1995) 165.

131. Ide M, Maeda Y, Kinato H, *J Phys Chem B*, 101(1997) 7022.

132. Laaksoonen A, Kusalik PG, Svishchev IM, *J Phys Chem, A*, 101(1997) 5910.

133. Nadig G, Van Zant LC, Dixon SL, Merz KM, *J Am Chem Soc*, 120(1998) 5593.

134. Sharp KA, Madan B, *J Phys Chem B*, 101(1997) 434.

135. Svergun DI, Richard S, Koch MHJ, Sayers Z, Kuprin S, Zaccai G, *Proc Natl Acad Sci USA,* 95(1998) 2267.

136. Igamberdiev AU, *Biosystems*, 31(1993) 65.

137. Igamberdiev AU, *Biosystems*, 46(1998) 95.

138. Igamberdiev AU, *Biosystems,* 50(1999) 1.

139. Kohsland DE, *Trends Biochem Sci*, 12(1987) 225.

140. Ho, MW, Saunders PT, *Liquid crystalline mesophases in living organisms*, in: Bioelectrodynamics and Biocommunication, Ho, MW, Popp FA and Warnke U. (Eds). (World Scientific, Singapore), 1994.

141. Needham J, *Order and life*. (Yale University Press, New Haven), 1935.

142. De Gennes PG, *The physics of liquid crystals*. (Clarendon Press, Oxford), 1974.

143. Collings PJ, *Liquid crystals, nature's delicate phase of matter*. (Princeton University Press, Princeton), 1990.

144. Giraud-Guille MM, *Journal of Molecular Biology*, 224(1992) 861.

145. Kreis R, Boesch C, *Journal of Magnetic Resonance B*, 104(1994) 189.

146. Ingber DE, *Cell*, 75(1993) 1249.

147. Ingber DE, *Scientific American*, January (1998) 48.

148. Bella J, Eaton M, Brodsky B, Berman HM, *Science*, 266(1994) 75.

149. Renugopalakrishnan V, Chandrakasan G, Moore S, Hutson TB, Berney CV, Bhatnagar RS, *Macromolecules*, 22(1989) 4121.

150. Peto S, Gillis P, *Magnetic Resonance Imaging*, 8(1990) 703.

151. Sasaki N, *Biopolymers*, 23(1984) 1725.

152. Pethig R, *Crit Rev Biotechnol,* 16(1996) 921.

153. Jaroszyk F, Marze E, *Ber Bunsenges Phys Chem*, 97(1993) 868.

154. Leikin S, Rau DC, Parsegain VA, *Structural Biology*, 2(1995) 205.

155. Oschman JL, *American Zoologist*, 24(1984) 199.

156. Ho MW, *Kybernetes*, 26(1997a) 265.

157. Ho MW, Haffegee J, Newton R, Zhou YM, Bolton JS, Ross S, *Bioelectrochemistry and Bioenergetics*, 41(1996) 81.

158. Tiller WA, *Some energy field observations of man and nature*, in: Galaxies of Life, Krippner S, Rubin D (eds). (Interface, New York), 1973.

159. Reichmannis M, Marion AA, Becker RO, *American Journal of Chinese Medicine,* 4(1976) 69.

160. Becker RO, *Cross currents. The promise of electromedicine, the perils of electropollution.* (Jeremy P. Tarcher, Inc., Los Angeles), 1990.

161. Mikhailov AS, Ertl G, *Science*, 272(1996) 1596.

162. Oschman JL, *The nuclear, cytoskeletal and extracellular matrices: a continuous communication network,* in: The cytoskeleton: mechanical, physical and biological interactions', a workshop sponsored by the Center for Advances Studies in the Space Life Science at the Marine Biological Laboratory, (Woods Hole, Massachusetts), 1996.

163. Lipinski B, *Med. Hypotheses*, 3(1977) 9.

164. Langer K, *British Journal of Plastic Surgery*, 31(1978) 3.

165. Reishner R, Balogh B, Menzel EJ, *Med Eng Phys*, 17(1995) 304.

166. Luzar A, Chandler D, *Nature*, 379(1996) 55.

167. Knight DP, Hu SW, Gathercole LJ, Rusaöuen-Innocent M, Ho MW, Newton R, *Philos Trans R Soc London*, 351 (1996) 1205-1232.

168. Ross S, Newton R, Zhou YM, Jaffegee H, Ho MW, Bolton JP, Knight D, *Journal of Microscopy*, 187(1997) 62.

169. Little KE, *J Amer Osteop Assoc*, 68 (1969) 675.

170. Rolf IP, *Rolfing: The integration of human structures*. (Harper and Row, New York), 1977.

171. Siemers CE, *Adult basic connective tissue*. (Ida P. Rolf Foundation, Boulder), 1973, p iii.

172. Snyder GE, *Fascia: applied anatomy and physiology*, in: Academy of Applied Osteopathy Yearbook, 1956, p. 65.

173. Page KE, The *role of the fascia in the maintenance of structural integrity*. Academy of Applied Osteopathy Yearbook, 1952, p.70.

174. Schwabl H, Klima, H, *Research in Complementary Medicine*, 12(2005) 84.

175. Slawinski S, *Research in Complementary Medicine*, 12(2005) 90.

176. Watterson JG, *Biochem J*, 248(1987) 615.

177. Jibu M, Hagan S, Hameroff SR, Pribram KH, Yasue K, *Biosystems*, 32(1994) 95.

178. Ho MW, Musumeci F, Scordino A, Triglia A, Privitera G, *J Photochem Photobiol B,* 66(2002)165.

179. Brizhik L, Musumeci F, Scordino A, Triglia A, *Europhys. Lett*, 52(2000) 238.

180. Brizhik L, Scordino A, Triglia A, Musumeci F, *Phys. Rev. E,* 64(2001) 031902-1/9.

181. Troshina TG, Loochinskaia NN, Van Wijk E, Van Wijk R, Beloussov LV, *Absorption and emission of photons by collagen samples,* in Biophotonics and Coherent Systems in Biology, Beloussov LV, Voeikov VL, Martynyuk VS. (Eds), (Springer, New York), 2006.

182. Presman AS, *Electromagnetic Fields and Life.* (Plenum Press, New York), 1970.

183. Rattemeyer M, Popp FA, Nagl W, *Naturwissenschaften*, 68(1981) 572.

184. Nagl W, Popp FA, *Cytobios*, 37(1983) 45.

185. Soh KS, *J Kor Phys Soc*, 45(2004) 1196.

186. Han YH, Yang JM, Yoo JS, Ogay V, Kim JD, Kim MS, Baik KY, Park SH, and Soh KS, Measurement of the Optical properties of In-vitro Organ-surface Bonghan Corpuscles of rats, *J Kor Phys Soc*, 2007, in press.

187. Dobrin R, Kirsch C, Kirsch S, Pierrakos J, Schwartz E, Wolff T, Zeira Y. *Experimental measurements of the human energy field*, in Psychoenergetic Systems: The Interface of Consciousness, Energy and Matter, Krippner S (Ed) (Gordon and Breach, New York) 1979.

188. Dobrin R, Kirsch C, Kirsch S, Pierrakos J, Schwartz E, Wolff T, Zeira Y. *Experimental measurements of the human energy field*, in The Energies of Consciousness, Krippner S, Rudin D. (Eds) (Gordon and Breach, New York) 1975.

189. Edwards R, Ibison MC, Jessel-Kenyon J, Taylor RB, *Complement Med Res*, 3(1989) 16

190. Edwards R, Ibison MC, Jessel-Kenyon J, Taylor RB, *Acupuncture & ElectroTherapeutocs Res Int J*, 15(1990) 85

191. Usa M, Kobayashi M, Suzuki S, Ito H, Inaba H, *ITEJ Technical Report*, 15 (1991) 1

192. Usa M, Inaba H, *Med Imaging Technol*, 13(1995) 47.

193. Cohen S, Popp FA, *Whole-body counting of biophotons and its relation to biological rhythms*, in Biophotons, Chang JJ, Fisch J, Popp FA (Eds), (Kluwer Academic, Dordrecht), 1998.

194. Cohen S, Popp FA, Knight D, Feng D, *Collagens as liquid crystals* 40(1997) 187.

195. Cohen S, Popp FA, *Skin Res Tech*, 3(1997) 177.

196. Van Wijk R, Van Wijk EPA, *Recent Res Devel Photochem Photobiol,* 7(2004) 139.

197. Van Wijk EPA, Van Wijk R, *Research in Complementary Medicine*, 12(2005) 96.

198. Van Wijk R, Kobayashi M, Van Wijk EPA, *J Photochem Photobiol B*, 83(2006) 69.

199. Kim TJ et al., *Acupun Electro Therapeutics Res Int J*, 27(2002) 85.

200. Inaba H, *Opt Electroopt Eng Contact*, 37(1999) 251.

201. Cohen S, Popp FA, *Whole-body counting of biophotons and its relation to biological rhythms.* (Kluwer Academic Publishers, Dordrecht), 1998, p186.

202. Jung HH, Woo WM, Yang JM, Choi C, Lee J, Yoon G, Yang JS, Soh KS, *Indian Journal of Experimental Biology*, 41(2003) 446.

203. Jung HH, Woo WM, Yang JM, Choi C, Lee J, Yoon G, Yang JS, Lee S, Soh KS, *Indian Journal of Experimental Biology*, 41(2003) 452.

204. Van Wijk R, *Biophoton emission from human skin,* in: International Conference on Biophotons and Biophotonics, Beijing, 2003.

205. Yang JM, Choi CH, Yu JH, Choi SM, Ryu YH, Soh KS, *J Alt Compl Med*, 12(2006) 603.

206. Wallace E, *Acute alteration of biophoton emission by intention*, PhD thesis (Cal Inst Human Sci, Encinitas), 1999

207. Chevalley C, Vekaria M, *Biophoton emission by intention*, PhD thesis (Cal Inst Human Sci, Encinitas), 2003

208. Nakamura H, Kokubo H, Parkhomtchouk DV, Chen W, Tanaka M, Zhang T, Kokado T, Yamamoto M, Fukuda N, *J Int Soc Life Inf Sci*, 18(2000) 418.

209. Park SH, Koo TH, Kim DH, et al., *J Intl Soc Life Info Sci*, 22(2004) 385.

210. Park SH, Lee SS, Soh KS, *J Kor Soc Jungshin Sci*, 8(2004) 41.

211. Van Wijk EPA, Koch H, Bosman S, Van Wijk R, *J Alt Compl Med*, 12(2006) 31.

212. Van Wijk EPA, Ackerman JM, Van Wijk R, *Research in Complementary Medicine*, 12(2005) 107.

213. Van Wijk R, Godaert G, Van Wijk EPA, *Human ultra weak photon emission in consciousness research*, in New Research on Consciousness, Locks JT (Ed) (Nova Science Publishers Inc, Hauppauge NY), 2007.

214. Van Wijk R, Ackerman JM, Van Wijk EPA, *Explore (NY)*, 1 (2005) 102. Erratum in: *Explore (NY),* 1(2005) 241.

215. Van Wijk R, Ackerman JM, Van Wijk EPA, *J Alt Compl Med*, (2006) in press.