Biophysical Communication

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# Types of Biophysical Communication

1. Nerves
	1. Motor
	2. Sensory
	3. Sympathetic / Parasympathetic nevers
		1. Vagus
		2. Other Cranial nerves
	4. Entreic
2. Fascia/ collegen
	1. What is collagen
	2. Electric conduction, Movement of Hydrogen Ions
	3. EMF
	4. Bio-mechanical Action
		1. Movement
		2. Vibraction
		3. Chanting
		4. Acupuncture needling
		5. Moxibustion
		6. Cupping
	5. Quantum Forces still being discovered
		1. Electro-Weak forces
		2. Water structures
	6. Practitioners
		1. Spiritual healers
		2. Chi gong
		3. Nadi Yoga
		4. Kriya
3. Infra-sound
	1. Chi-Gong
		1. 6-16 HZ upto 70db
4. Bio-magnetite.
	1. Bacteria creating Magnetite crystals
	2. 6-20 HZ
5. Biophoton, Brain microtubules
	1. KHz – 1 GHZ

# Appendix

## The Science of Bioenergetic and Bioelectric Technologies: Cellular Mechanisms

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**Abstract:**

Cells and cell components are designed to both transmit and receive electromagnetic energies through both biological electronic circuits and wireless communication mechanisms. This paper addresses the concept of resonant frequencies, resonant energy transfer, the electronic properties of cells and tissues and signal induction through resonant energy transfer. Frequency modulation of the body’s oscillating electromagnetic field provides the capability of using the body’s own energy field as a carrier wave for information; much like a radio station frequency modulates a radio signal with voice information. Selection of the proper frequency code can be utilized to activate cellular processes such as providing pain control, improving wound healing, increasing antioxidant production, increasing energy production through acceleration of fat metabolism or stimulating the production of hormones.

Key words: bioelectric, resonance, frequency-modulation, molecular antennas, electromagnetic, biomagnetic

**Introduction**

 Sound and electromagnetic waves are all forms of vibration. The use of vibration to alter the physiology of the human body has been both recognized through all of recorded history. Any comprehensive review of the application of vibrational energies will show that the biological liquid crystal molecules that compose the human body can be affected by vibrational energy in every portion of the frequency spectrum. Some of these energies, such as certain specific weak electromagnetic fields, may be beneficial and others such as exposure to high doses of X-ray or gamma radiation are harmful. A key concept that helps to separate useful from harmful vibration is the recognition that biological processes optimally function with certain specific frequency windows. This concept directly ties into the phenomenon of resonance.

 In order to understand how weak electromagnetic fields (EMFs) can have biological effects it is important to understand certain concepts. Many scientists still believe that weak EMFs have little to no biological effects. Like all beliefs this belief is open to question and is built on certain scientific assumptions. These assumptions are based on the thermal paradigm and the ionizing paradigm. These paradigms are based on the scientific beliefs that the effects of EMFs effect on biological tissue are primarily thermal or ionizing.

Thermally strong field

Thermally weak field

 However electric fields need to be measured not just as strong or weak, but also as low carriers or high carriers of information. Because electric fields conventionally defined as strong thermally may be low in biological information content and electric fields conventionally considered as thermally weak or non-ionizing may be high in biological information content if the proper receiving equipment exists in biological tissues.

 Weak electromagnetic fields that are bioenergetic, bioinformational, non-ionizing and non- thermal may exert measurable biological effects. Weak electromagnetic fields that have effects on biological organisms, tissues and cells are highly frequency specific and the dose response curve is non linear. Because the effects of weak electromagnetic fields are non-linear, fields in the proper frequency and amplitude windows may produce large effects, which may be either beneficial or harmful (Adey, 1988, 1993A, 1993B).

**Section 1: Electronic biology of cells**

***Electronic properties of biological molecules***

 Living organisms and cells are composed of organic polymer molecules that have liquid crystal properties. Liquid crystals are intermediate forms or phases of matter that exhibit properties of both liquids and solids (Collings, 1990).

 Because biological molecules like membrane lipids and protein polymers are flexible and responsive liquid crystals they can flow like liquids when temperature, hydration, pH, mineral concentrations, and pressure are within certain parameters while still maintaining molecular order like crystals (Papahadjopouos and Okhi, 1970; Ho, 1998).

 The molecules of liquid crystals whether inorganic or organic are electric dipoles. Electric dipoles will become oriented or aligned when they are exposed to electric or magnetic fields creating *phase transitions*. The dipole movement is a function of polarization processes and the strength of the electric field. When biological tissue is exposed to an electric field in the right frequency and amplitude windows a preferential alignment of dipoles becomes established.

 Because most biomolecules are 'electrical dipoles' they will also behave like microphone transducers capable of turning acoustic waves into electrical waves, and like loud-speakers turning electrical waves into acoustic waves (Beal, 1996a, 1996b).

 The natural properties of biomolecular structures enables cell components and whole cells to oscillate and interact resonantly with other cells (Smith and Best, 1989). According to Smith and Best, the cells of the body and cellular components possess the ability *to function as electrical resonators* (Smith and Best, 1989). This property enables whole cells to act as oscillating interacting entities (Beal, 1996a).

 Because cell membranes are composed of dielectric materials a cell will behave as dielectric resonator and will produce an evanescent electromagnetic field in the space around itself (Smith and Best, 1989).

*“This field does not radiate energy but is capable of interacting with similar systems. Here is the mechanism for the electromagnetic control of biological function* (Smith and Best, 1989).”

 This means that the applications of certain frequencies by frequency generating devices can enhance or interfere with cellular resonance and cellular metabolic and electrical functions. Since the cell membrane contains many dipole molecules, an electric field will cause preferential alignment of the dipoles. This may be one mechanism that electrical and magnetic fields alter membrane permeability, membrane functions and enzyme activities.

***Electronic properties of cells***

 *Cells are electromagnetic in nature,* they generate their own electromagnetic fields and they are also capable of harnessing external electromagnetic energy of the right wavelength and strength to communicate, control and drive metabolic reactions (Adey, 1988, 1993a, 1993b; Becker, 1990).

 Normal cells possess the ability to communicate information inside themselves and between other cells. The coordination of information by the cells of the body is involved in the regulation and integration of cellular functions and cell growth. When tissues of the body are injured the cells in and around the injured area are sent extracellular signals that turn on repair processes. The stimulus for repair has conventionally been considered to be by chemical agents such as cytokines and growth factors; however over the last five decades through the work of Robert O. Becker and others it has become apparent that mechanical, electric and magnetic signals also have a regulatory influence (Becker, 1960, 1961, 1967, 1970, 1972, 1974, 1990).

 Among the electrical properties that cells manifest are the ability to conduct electricity, create electrical fields and function as electrical generators and batteries. In electrical equipment the electrical charge carriers are electrons. In the body electricity is carried by a number of mobile charge carriers as well as electrons. Although many authorities would argue that electricity in the body is only carried by charged ions, Robert O. Becker and others have shown that electron semiconduction also takes place in biological polymers located in the connective tissues of the body (Becker and Selden, 1985; Becker, 1990). Connective tissue is a strong composite tissue composed on collagen fibers embedded in a gel-like ground substance (Oschman, 1984).

## *“The connective tissue is a continuous fabric extending throughout the animal body, even into the innermost parts of each cell* (Oschman, 2000).”

 The ECM also contains nerve fibers connected through the autonomic nervous system back to the brain, which then regulates hormone homeostasis by feedback control through the hypothalamic pituitary axis. Thus the ECM has a central role as a switching center for neural signals, chemical and hormonal signals and electrical signals.

##  *Connective is piezoelectric* generating electrical fields when stretched or compressed (Becker and Marino, 1982). Albert Szent-Gyorgyi first proposed the semiconductor nature of proteins in 1941. It is now known that virtually all molecules in the body are semiconductors (Szent-Gyorgyi, 1941, 1960, 1968, 1978). Being semiconducting, connective tissues transmit the electrical fields playing the role of an integrated circuit that allows the body to communicate with all parts of itself down to a molecular level. In this role, it transmits energy and information electrically (Ho, 1999).

 The cells of an organism are embedded in an extracellular matrix composed of organized water and biological polymers. Most of the body’s cells are hardwired into a liquid crystal polymer continuum that connects the cytoskeletal elements of the inside of the cell through cell membrane structures with the semiconductive liquid crystal polymers of the connective tissues (Haltiwanger, 1998; Oschman, 2000).

 Liquid crystal protein polymers and carbohydrates will form dendritic structures and undergo phase transitions under the influence of temperature oscillations, pressure oscillations, and electromagnetic oscillations, which will influence the mechanical, chemical, thermal, electrical properties of these molecules (Tóth-Katona et al., 2000). The liquid crystal dendritic structures within the ECM are biological electrical semiconductors that facilitate the flow of bioelectricity and information through out the body and even into the interior of the cell (Oschman, 2000).

***The electric nature of the body***

 The body’s cells and tissues possess an intrinsic electric nature that permits the transmission of signals for information and control of biological processes (Malmivuo and Plonsey, 1995). Thecurrency of information flowin the body iselectron and ionic flow*.*

 Vision, hearing, and touch are all examples of the conduction of electrical information. The eye, ear and the skin have sensory transducers that convert light waves, sound waves and mechanical waves into bioelectrical signals that are conducted to the brain (Berne et al., 1993). The mode of transmission of information in the nervous system is by frequency modulation (FM).

 The brain in turn processes the information present in the bioelectrical signals (called action potentials) sent from the sensory organs and responds by sending out other bioelectrical signals through the nerves to control the voluntary contraction of muscles, the activity of the body’s organs, hormone release, and so on (Nicholls et al., 2001).

 It is well accepted that information can be conveyed to the body in the form of electromagnetic waves. No one doubts that the eyes can detect visible light, that the ears can detect sound from pressure waves carried by the atmosphere and that the sensory information collected from both the eyes and the ears is invaluable for survival. However both visible light and sound are just different portions of the electromagnetic spectrum. It is logical to conclude and it has been proven scientifically that other portions of the electromagnetic spectrum also have beneficial biological effects.

***Biological materials possess the property of resonance***

 Intracellular and extracellular biological liquid crystal molecules inherently possess the property of resonance according to the laws of physics. Biological molecules, atoms and even electrons have special resonant frequencies that will only be excited by energies of very precise vibratory characteristics. When two oscillators are tuned to the same identical frequency the emission of one will cause the other to respond to the signal and begin to vibrate. Resonance occurs in biological molecules or even whole cells when acoustical or electric vibrations emitted from a generating source match the absorption frequency of the receiving structure producing an energy transference, which amplifies the natural vibrational frequency of the cell or the cell component (Beal, 1996a, 1996b).

 All metabolic reactions of a cell are controlled by a complex interaction of regulatory processes. These regulatory processes are usually defined in biochemistry by their chemical properties, however according to Brugemann, the internal chemical regulatory forces are in turn controlled by electromagnetic oscillations, which are biophysically specific (Brugemann, 1993). This physical principle makes it possible to obtain very specific metabolic responses when very weak electrical fields are applied or created in the body, which exactly match the frequency codes of the chemicals involved in the metabolic process you want to affect.

 When an electromagnetic field that possesses the resonant frequency of a biological molecule is generated in the body, conducting molecules of that particular type will absorb energy from the field and undergo induced electron flow.

 A fact that is not widely understood is that the cells of the body are exquisitely responsive to electrical frequencies of exactly the right frequency and amplitude (Adey, 1993a, 1993b). Researchers such as Ross Adey and others have discovered that the cells of the body have built in electromagnetic filters so they only respond to electromagnetic fields of particular frequencies and amplitudes (Adey, 1993a, 1993b).

***The body is controlled by codes***

 Science is based on the natural laws. One of the accepted laws of biology is that all biological life consists of cells and it is *the genetic code* contained in the DNA of cells that controls development of the cell and the production of proteins in the cell (Capra, 2002). Some proteins serve to provide structure to the cells while other proteins such as enzymes enable cells to function by acting as catalysts of chemical processes (Nelson and Cox, 2000). It is the interaction of enzymes with the food components (metabolites) that produce the energy supply and the building blocks needed by cells to maintain their own self-generating organization. According to Fritjof Capra, all cells use the same universal set of a few hundred small organic molecules as food for their metabolism.

*“Although animals ingest many large and complex molecules, they are always broken down into the same set of smaller components before they enter into the metabolic processes of the cells.* (Capra, 2002).*”*

 Since all cells only use the same set or alphabet of small molecules one could say that all cells utilize the same *chemical code*. The mechanisms that controls chemical reactions in cells are the electromagnetic oscillations or frequencies of the atoms of the substances involved (Brugemann, 1993). In a sense one could say that all biological processes are controlled by a chemical code that is in turn controlled by a *frequency code*.

 Because the body only uses a specific group of organic molecules such as DNA, RNA, enzymes, certain amino acids etc. in its biological processes, a frequency code is built into the system, where only electrical frequencies, which exactly match the resonant frequency of these molecules, are absorbed.

 This frequency code also includes more complex structures such as cell components that are assembled in cooperative arrays as well as different cell types. All human bodies contain numerous types of cells. Some cells are specialized like heart or kidney cells. Each cell type also has its own characteristic resonant frequency.

 According to the laws of physics everything in the universe is in a state of vibration. The *resonant frequency of a material* is defined as the natural vibratory rate or frequency of each substance be it an element or a molecule (Jones and Childers, 1990). Energy transfer can occur between materials when their resonant frequencies (oscillations) are matched. In addition when biological molecules in a cell are exposed to an externally applied or internally created electric field that matches their resonant frequency the field can be said to be coupled to the molecules and the molecules will subsequently absorb energy from the electric field. The cell membrane is the primary site of interaction between electric fields and the cell (Adey, 1993a).

 The *principle of electromagnetic coupling* allows the capability of eliciting specific biological responses when the proper frequency code has been deciphered. Application of the proper frequency code could make it possible to signal the body to perform a biological function such as the transport of fatty acids into mitochondria so that the fatty acids can be burned to produce energy.

***Absorption of electromagnetic energy by biological molecules***

 Biological molecules can absorb energy at specific discrete frequencies in the form of energy packets or quanta. This is based on the physics principle of resonance where each quantum transfers energy to the molecules in proportion to the specific frequency of that quantum (Heynick, 1987). High-energy electromagnetic fields can cause heating, ionization and destruction of biological tissue, but lower energy fields have other more subtle biological effects. At low energy levels when resonance energy transfer occurs the transfer of charge is the main effect not heating.

 Quantum energy absorption is essentially a microscopic phenomenon where the *chemical composition and molecular configuration* of the molecules in a cell determine the specific frequencies or characteristic spectra where such absorption can occur (Heynick, 1987).

 According to Louis Heynick, low energy frequencies can change the orientations and configurations of molecules without altering or destroying the basic identities of the molecules (Heynick, 1987).

*“Indeed, cooperative interactions occur among subunits of molecules within biological cells, in membranes and other cellular structures, and in extracellular fluids; in such interactions, the energy absorbed at one specific site in a structure (in a membrane or in a biological macromolecule, for example) may not be sufficient to disrupt a bond but could alter a process at the site or elsewhere in the structure, or trigger a function of the structure as a whole by release of the energy stored in the structure, thereby producing biological amplification of the incident quantum of energy*(Heynick, 1987).”

 In order to resonantly activate specific biological molecules that are involved in certain metabolic reactions in biological tissues, the selection of electromagnetic frequencies must be matched to and specific for the absorption spectra of the molecules involved in the chemical reaction that you want to effect.

***The role of chemical signals in cellular communication and regulation***

 Numerous examples now exist in biology of chemical reactions being triggered in cells by extremely small amounts of certain specific signaling molecules such as prostaglandins and hormones. What is important is not just the amount of the substance involved, but that the required substance is available in exactly the right location at the right time (Nelson and Cox, 2000). Some of the same effects can also be achieved with the application of electrical fields that have the same resonant frequencies of the signaling molecules (Xie et al., 1997).

*Chemical communication* is mediated by chemical soluble signals that travel through the bloodstream and then through the extracellular matrix (ECM) from distant locations or chemicals that are locally produced in the ECM (Nelson and Cox, 2000). These soluble signaling molecules may be produced in distant sites by endocrine cells or are secreted by cells embedded within the ECM or cells that migrate into the ECM such as macrophages, T-cells and B-cells. When these soluble signaling molecules are presented to the organ cells they can either activate or inhibit cellular metabolic reactions by activating cell membrane or cytoplasmic glycoprotein receptors (Reichart, 1999).

 *Chemical signal activation of cell receptors* will cause the receptor’s molecular structure to shift to from an inactive to an activated conformational state. This is a phase transition. When a receptor is activated it will bind to and activate other membrane bound proteins or intracellular proteins/enzymes. The outcome of receptor activation may: increase the transport of certain molecules or mineral ions from one side of the cell membrane to the other side; increase or inhibit the activity of enzymes involved in metabolic synthesis or degradation; activate genes to produce certain proteins; turn off gene production of other proteins or cause cytoskeletal proteins to change the shape or motility of the cell. When the receptor protein switches back to its inactive conformation it will detach from the effector proteins/enzymes and the signal will cease (Van Winkle, 1995).

***The role of electrical forces in cellular communication and regulation***

 *The ground substance of the ECM*, which most of the body’s cells are embedded within, contains natural fluctuating electrical fields. The electric fields of the ECM will fluctuate in response to the composition of the negative charge of the sialic acid residues of biological polymers and the ion/mineral content of the ECM. The fluctuations/oscillations of the electric field of the ECM when strong enough can lead to local depolarization of portions of adjacent cell membrane creating changes in membrane permeability (Adey, 1988, 1993a, 1993b).

 *The electrical field fluctuations* that occur in the ECM have been found to be involved in cell signaling mechanisms. A number of researchers such as Becker and Adey believe that natural weak endogenous electric fields actually control the chemical process of cell membrane signaling. This means that measures that enhance or disturb the production of these natural electric fields can impact cell-signaling processes.In the future electrical medicine will advance to the point where you can dial up and administer frequencies that will act like biochemical or pharmacological agents. When this occurs the phrase ‘beam me up Scottie’ may take on a whole new meaning.

 *Cell receptors* can be activated by chemical signals as well as by local electric fields (vibrational resonance) that have particular frequencies and amplitudes through a process known as electroconformational coupling (Tsong, 1989). Electrical oscillations of the right frequency and amplitude can alter the electrical charge distribution in cell receptors causing the cell receptors to undergo conformational changes just as if the receptor was activated by a chemical signal. The receptors can switch back and forth between conformations, which will lead to turning on the activity of membrane embedded enzymes and opening and closing ion channels.

 Ross Adey has extensively described in his publications that the application of weak electromagnetic fields of certain windows of frequency and intensity act as first messengers by activating glycoprotein receptors in the cell membrane (Adey, 1993a). This electrical property of cell receptor- membrane complexes would allow cells to scan incoming frequencies and tune their circuitry to allow them to resonate at particular frequencies (Charman, 1996).

 Adey and other researchers have reported that one effect of the application of weak electromagnetic fields is the release of calcium ions inside of the cell (Adey, 1993a). Adey has also documented that cells respond constructively to a wide range of frequencies including frequencies in the extremely low frequency (ELF) range of 1-10 Hz a range of frequencies known as the Schumann resonance frequencies that are naturally produced in the atmosphere (Adey, 1993a, 193b).

 *The natural oscillating electrical potential of the ECM* can be adversely affected or constructively supported by exposure to external electromagnetic fields. Adverse electromagnetic field exposure can be initiated by exposure to high power tension lines, transformers and electronic equipment. Constructive support includes use of *certain nutrients* and devices like infrared emitters, phototherapy equipment, and microcurrent equipment that emit electromagnetic fields and electrical currents in physiological ranges.

*Acoustical (sound) waves* of the right frequency can also affect cell-signaling and cellular metabolic processes (Beal, 1996a).

 Some of the key conceptual problems that must be addressed in order to use electromagnetic and acoustic frequencies to activate biological processes are: a) identifying the molecules/proteins/ enzymes/reactants that are involved in the metabolic reactions you want to influence, [this can be accomplished by studying biochemistry texts that describe biochemical reactions]; b) identifying the specific electromagnetic frequencies that can produce resonance in these molecules so that activation of the biochemical process is enhanced, [this can be accomplished by studying physics textbooks that describe the absorption spectra of different molecules]; c) developing an effective delivery system to efficiently transfer these frequencies into the body, [this requires research and experimentation].

***How are bioelectrical signals transmitted into the body?***

 One method is by frequency modulation similar to that used in radios and television broadcasting. Radio and television waves are electromagnetic waves that are generated by the production of oscillating electrical charges (Jones and Childers, 1990).

 All radio and television stations in the United States are assigned a specific broadcast frequency by the Federal Communications Commission (FCC). The frequency that radio and television stations always broadcast on is known as *the carrier wave* and is the frequency that a person tunes into on their radio or TV (Jones and Childers, 1990).

 It has been known for over a hundred years that a carrier wave can be used to piggyback other waves, which are known as the signal waves. The *signal waves*carry the information that is being transmitted such as sound or pictures (Carr, 2001).

 The superimposition of a signal wave on a carrier wave is known as *modulation*. Modulation can be accomplished in a number of ways. Two of the most widely used methods are amplitude modulation (AM) and frequency modulation (FM). In (AM) modulation the amplitude of the carrier wave is modulated by the information signal. In frequency modulation (FM) the frequency of the carrier wave is modulated by the information signal (Jones and Childers, 1990).

 Proper operation of such a system requires a transmitter that sends out the combined carrier and signal waves and a receiver that contains a tuning circuit that can be set to resonate at the correct frequency. The reception of the broadcast signal induces a small voltage in the receiving antenna. When the signal that is transmitted matches the tuner frequency it then passes through the tuning circuit to be amplified.

 From the point of view of the electronic biology of the human body, the cells of the body contain liquid crystal components (proteins, membranes, membrane receptors, DNA, and RNA) that possess the electronic capability of resonating to certain specific frequencies like antennas (Beal, 1996a, 1996b). In a sense the body is constructed of liquid crystal oscillators. The biological liquid crystal molecules of the cell are organized in complex structures that exhibit cooperative behavior (Ho, 1998). When the correct specific bioelectrical frequencies are supplied to the cells of the body these liquid crystal molecules will resonantly absorb energy and information (Adey, 1988, 1993a; Beal, 1996a, 1996b).

 The cellular components of the body behave as electrical circuits (since they have capacitive, inductive and resistive elements, biopotential voltage sources and ionic and electron current flows). This allows electricity and information that is carried by the frequencies of bioelectrical signals to pass into and out of the cells. Cells also have components composed of membranes, membrane receptors and cytoskeletal protein complexes that behave as tuning circuits. These cellular tuning circuits allow detection, resonant absorption and amplification of very specific bioelectrical signals that are in certain frequency and amplitude windows (Adey, 1981, 1988, 1993a; Garnett, 1998, 2002; Ho, 1998).

*Frequency modulation* of cell membrane receptors that function as electrical antennas/transducers results in voltage fluctuations across cell membranes at the frequency of the stimulus (Dallos, 1986; Russell et al., 1986). Frequency modulation will activate the receptors of cell membranes that respond to voltage changes and these receptors are in turn coupled to other membrane proteins that regulate the electrical, contractile and metabolic activity of cells.

 *Voltage changes in cell membranes* are believed to drive protein-based motors located in the lateral cell wall of outer hair cells in the cochlea of the ear (Santos-Sacchi and Dilger, 1988; Holley and Ashmore, 1990; Hallworth et al., 1993). Protein based motors are also located in muscle fibers, mitochondrial membranes and other locations in the body (Rayment et al., 1993, Spudich, 1994; Neupert and Brunner, 2002).

 Numerous writers such as Fritjof Capra have noted that nature conserves mechanisms that work (Capra, 2002). In the author’s opinion bioelectrical forces such as voltage changes in cell membranes and inward current flows may in fact drive all of the protein/enzyme-based motors in the body. This opinion is based on the fact that an inward current is known to exist between the cell membrane and other cell structures such as the mitochondria and DNA (Garnett, 1998). In addition, electrical currents can enter the cell through ion channels in the cell membrane that act as electrical rectifiers resulting in the entry of minerals such as potassium or calcium ions, which produces a signal amplifying effect (Nicholls et al., 2001). Some of the electrical charges that compose these inward electrical currents travel through an intracellular oscillating biological electrical circuit composed of liquid crystal semiconducting proteins of the cells cytoskeleton (Oschmann, 2000).

 The interior of every cell is composed of an integrative structure composed of cytoskeletal proteins that have been shown to form hardwired connections between the cell membrane and the DNA and the mitochondria. The fact that these liquid crystal cytoskeletal proteins also possess semiconducting properties allows them to transfer charges (current) and establish a circuit between the cell membrane and internal structures like DNA and the mitochondria. The cytoskeleton of cells in a sense hardwires all of the components of the cell into a solid-state biological computer.

*Data supporting the concept that cell components can respond to external frequencies with metabolic changes*

 In order for an electromagnetic field to activate a metabolic process in the body a field induced molecular change must occur.

*“It is at the atomic level that physical processes, rather than chemical reactions in the fabric of molecules, appear to shape the transfer of energy and the flow of signals in living systems* (Adey, 1993a)*.”*

 Proteins are sophisticated molecules that play critical structural and functional roles in the cells. Proteins help provide cell structure, strength and flexibility. Proteins also have functional roles as signaling molecules in the processes of cell communication and as enzymes in the chemical reactions of cells. The functional properties of proteins in turn are dependent upon their three-dimensional structure (Grattarola et al., 1998).

 Proteins that catalyze chemical reactions are called enzymes (Holyzclaw et al., 1991). The body’s enzymes are natural catalytic molecules that promote chemical reactions without themselves being used up. Enzymes are specific for certain chemical substances because they recognize specific chemical structures both by their three-dimensional shape as well as by their chemical properties (Jespersen, 1997).

 Proteins embedded in cell membranes that act as signal devices are called receptors. Receptors respond to chemical signals from the blood stream to initiate chemical pathways within the cells and to assist in the transport of materials into and out of cells (Nelson and Cox, 2000). The scientific data also shows that receptors also respond to electric fields (Adey, 1993a).

 Enzymes and membrane receptors, like all proteins, are folded into 3-dimensional structures. The three-dimensional structure of a protein arises because each protein is composed of a unique ordered sequence of amino acids. The proteins of human cells are all made of chiral molecules called L-amino acids (Nelson and Cox, 2000).

 The location and sequence of amino acids, the location and sequence of negative and positive charges, and the interaction of the protein with water and other biological molecules determines the three-dimensional structure of a protein at body pH (Grattarola et al., 1998; Nelson and Cox, 2000).

 Linus Pauling was the first scientist to discover that specific sequences of amino acids in a protein can cause itto coil or wind itself and then take on a helical shape called an alpha-helix (Pauling, 1988). This structure is particularly prominent in proteins that are embedded in cell membranes (Nelson and Cox, 2000). In electrical terms coils and helices are inductors, transducers and antennas.

 The coil-to-helix transition is a nonlinear phenomenon (Grattarola et al., 1998), which means that it can be triggered by absolutely miniscule amounts of energy. The coil-to-helix transition is a cooperative phenomenon called a two-state function, which is characteristic of any type of electronic or biological device appropriate for information processing (Grattarola et al., 1998).

 Enzymes and receptors are types of proteins that possess the ability to fluctuate back and forth between active and inactive states much like **electrical switches** that can either be set to an on or off positions. This cyclical movement between the active position and the rest position of these types of proteins involves a reversible shift in the distribution of electrical charges, which subsequently alters the 3-dimensional folding and chemical binding sites of these proteins. This alteration in protein folding, called a configurational or conformational change is accompanied by changes in both the chemical reactivity and the electrical properties of these proteins (Wuddel and Apell, 1995).

 For many years biologists have recognized that the triggering mechanism that turns on enzymes and receptors causing them to transition between their active and rest states involves chemical interactions where chemical compounds transfer electrical charges between one another. However, new research has now proven that the transfer of electric charges does not always require a chemical carrier. In fact enzymes and receptors can also be activated by electric charges directly transferred from resonantly coupled electric fields (Derényi and Astumian, 1998). This is because the intramolecular charge transfer that occurs in enzymes and receptors undergoing conformational transitions within their cycle conveys to these molecules the ability to transduce energy directly from oscillating electric fields **(**Astumian et al., 1989).

 A number of researchers, especially Ross Adey, have shown that weak electromagnetic fields may resonantly interact with the glycoproteins of the cell membrane acting like first messenger signals that activate intracellular enzymes (Adey, 1993b). These electromagnetic signals can create conformational changes in cell membrane proteins when these membrane proteins transductively couple with electromagnetic frequencies provided the frequencies are within certain amplitude and frequency windows (Adey, 1993b). This means the cell membrane proteins can act like electrical transducers that behave as on off electrical switches that activate chemical processes inside of the cell (Adey, 1980, 1981, 1988, 1993b; Adey et al., 1982).

*The essential molecular functions appear in fact to be determined by electromagnetic mechanisms. A possible role of molecular structures would be the carrying of electric charges, which generate, in the aqueous environment, a field specific to each molecule. Those exhibiting such coresonating or opposed fields ("electroconformational coupling") could thus communicate, even at a distance* (Benveniste, 1993).*”*

 For example, it is well recognized by biologists that cell enzymes such as Na, K-ATPases require energy to pump ions such as sodium and potassium across cell membranes. However, new data shows that these enzymes can either be activated by chemical energy derived from ATP or by energy directly absorbed from electric fields (Xie et al., 1997). In this case energy from the electric field substitutes for the energy normally provided chemically by ATP (Derényi and Astumian, 1998). Any electromagnetic effect on a chemically based biological reaction in the body is dependent upon the electric or magnetic frequency sensitivity of the rate constant of the enzyme involved in the chemical reaction (Weaver et al., 2000). Membrane receptor proteins can also be activated by resonantly coupling to electric fields (Astumian and Robertson, 1989).

 *"If fields can affect enzymes and cells, [one should expect] to be able to tailor a waveform as a therapeutic agent in much the same way as one now modulates chemical structures to obtain pharmacological selectivity and perhaps withhold many of the side-effects common to pharmaceutical substances* (Davey and Kell, 1990).*”*

 The key step necessary for this mechanism to work is to produce an electric field in the body, which exactly matches the resonant frequency of the enzymatic process or membrane receptor that you wish to stimulate so that the enzyme or receptor is able to resonantly couple to the field.

***Biological Antennas***

 Their shapes can classify antennas, and their shape determines their radiation pattern. Antennas emit power that is different at different angles (Carr, 2001).

 The cells of the body communicate with each other by chemical signal molecules that are either carried by the bloodstream to cells in distant locations or are released directly on the cell surfaces from nerve fibers and local tissue cells (Nicholls et al., 2001).

 The binding of a signaling chemical to a cell membrane receptor triggers an amplified biological response such as the opening of a cell membrane ion channel, which allows the entry of minerals like calcium into the cell. Other amplified responses include the activation of enzymes and secondary messenger signals (Mehrvar et al., 2000).

 It is not widely known, but cell membrane receptors and even DNA can also act like electrical antennas and transducers responding to signals of electrical fields of the right frequency and amplitude (Adey, 1993a, 1993b).

 *Cell membrane receptors* composed of proteins that have coil and helical configurations can act as receiving antennas for electrical fields as well as electrical transducers and electrical inductors. These components are organized into complex cooperative arrays that facilitate communication (signaling and information transfer) between cells in the body as well as between cells and the external environment (Gilman, 1987). The transducing element in cell membrane biosensor complexes couples a chemical or electrical signal to a biological response that might include the movement of minerals into the cell or a cascade of enzyme reactions (Mehrvar et al., 2000).

 *Helical antennas* produce directed beams when their diameter and coil spacing are large fractions of the wavelength. They provide moderately wide bandwidth and circular polarized beams (Carr, 2001). When helical antennas are used the receiving helical antenna has to be wound in the same direction as the sender's. Helical antennas, like DNA, can be stacked, which allows a way for this type of cell antenna to obtain high gain with only a few turns on each helix.

 In summary, it is the author’s opinion that the structures of cells have components that have electronic features allowing cells to detect and respond to electrical frequencies that act as information signals triggering biological responses through the process of *signal amplification.*

***The mechanism of resonant electrical frequency interactions with cells***

 The mechanism of resonant electrical frequency interactions with cells includes the reception of the electrical signal/charge transfer by receptor antenna/transducers that are coupled to membrane bound G-proteins that are also coupled to intracellular enzymes like adenylate cyclase.

 Membrane bound G-proteins and the intracellular enzymes that they are linked to form a complex of proteins that operate as an amplifier for the signal they receive. For example, certain G-proteins are coupled to and activate specific intracellular enzymes that in turn increase the cell concentrations of second messenger systems like cAMP. Increasing cell levels of cAMP in turn activates an enzyme called protein kinase A, which in turn activates other enzymes such as hormone sensitive lipase (Nelson and Cox, 2000; Nicholls et al., 2001).

 Different electrical frequencies will activate different receptors, different G-proteins, different intracellular enzymes and different second messenger systems thus producing different biological reactions and cascades.

 Certain steps must be taken in order for an individual to be able to electrically modulate the biological reactions he or she wants to influence. He or she must first identify, choose, and apply energies that provide the correct electrical frequencies that activate the signaling mechanism involved in activating or inhibiting a biological process. In addition an individual who makes an effort to improve the health of their cell membranes by proper modification of the diet with food and or supplements may receive even greater benefits from this type of technology.

**Section 2: Electric currents and magnetic fields naturally exist in the body**

***The production of electrical currents and magnetic fields in the body***

 It is now well recognized in medicine that electrical currents and magnetic fields are continually being produced in the body at all times. For example, cardiologists measure the electrical currents produced by the beating heart and neurologists measure the electrical activity of the brain.

*Electricity in the body* comes from the food that we eat and the air that we breathe (Brown, 1999). Cells derive their energy from enzyme catalyzed chemical reactions, which involves the oxidation of fats, proteins and carbohydrates. Cells can produce energy by oxygen-dependent aerobic enzyme pathways and by less efficient fermentation pathways.

 The specialized proteins and enzymes involved in oxidative phosphorylation are located on the inner mitochondrial membrane and form a molecular respiratory chain or wire. This molecular wire (electron transport chain) conducts electrons donated by several important electron donors through a series of intermediate compounds to molecular oxygen, which becomes reduced to water. In the process ADP is converted into ATP.

 The biological activities of cells, tissues and the bloodstream thus generate electrical currents in the body and electrical fields that can be detected on the skin surface; however the laws of physics require that the generation of an electrical current always results in the production of a corresponding magnetic field in the surrounding space. A current flowing through a volume conductor always gives rise to a magnetic field (Jackson, 1975).

 Through the use of a piece of equipment called a SQUID (Superconducting Quantum Interference Device) magnetometer scientists have now objectively proven that there is a weak magnetic energy field around the human body. This biomagnetic field arises because of physiologic activities within the human body, which in electrical terms is a volume conductor.

*Biomagnetic signals* are thought to arise from intra-cellular currents that are produced by muscular contraction or neural excitation of tissue cells (Rottier, 2000). The current produced in the cells flows out of the cells through cell membrane protein connections and cell ion channels into the extracellular matrix creating bioelectric current flows in the body. When this natural electrical current flows in the body a weak magnetic field is also produced outside of the body (Rottier, 2000). According to the physics principle of induction, the creation of an electric current in a material will always induce a corresponding magnetic field and the movement of conductive material in a magnetic field or the exposure of a conductive material to a fluctuating magnetic field will induce an electric current in the material. Thus the application to the body of an appropriate fluctuating magnetic field will produce electrical activity in the tissues and cells of the body.

 Even though scientists and practitioners for centuries have used electronic equipment to measure bioelectrical fields that are present on the skin. [Field potentials that appear at the surface of the body are the basis of clinical electrocardiography (ECG), electromyography (EMG), electroencephalography (EEG), etc.] The detection of the magnetic component had to wait until 1963 when researchers at Syracuse University first measured the magnetic field produced by the heart, which is one-millionth the strength of the earth's magnetic field (Baule et al., 1963).

 In 1971, equipment sensitive enough to measure the brain’s weak biomagnetic field, which is even 100 times weaker than the heart’s magnetic field, was developed (Cohen, 1972).

***The bioelectrical control system***

 Endogenous weak electric fields are naturally present within all living organisms and are apparently involved in pattern formation and regeneration (Nuccitelli, 1984).

 The body uses electricity (biocurrents) as part of the body’s mechanism for controlling growth and repair (Borgens et al., 1989). Some of these biocurrents travel through hydrated liquid crystal semiconducting protein-proteoglycan (collagen-hyaluronic acid) complexes of the ECM. Key elements that support this physiologic function include proper hydration, and normal protein configurations, which allow for the water to be structured in concentric nanometer thick layers (Ling, 2001). The production of normal ECM components and proper mineral ion concentrations are also important.

 Healthy production of collagen and hyaluronic acid in the ECM is in turn dependent upon the interactions of: internal cellular machinery that produces proteins and sugars, especially proper reading of the genetic code; availability of construction material like amino acids such as lysine and proline that are needed for collagen production; intracellular availability of cofactors of protein and sugar producing enzymes such as zinc, magnesium, trace minerals, vitamin C, bioflavinoids and B-complex vitamins; and the availability of endogenously produced and ingested precursor molecules such as glucosamine, mannose, galactose etc.

 Biocurrents in the ECM pass through the cell membrane into the cell and electrons produced in the cell also pass out through the cell membrane.

 Dr. Merrill Garnett has spent four decades studying the role of charge transfer and electrical current flow in the cell (Garnett, 1998). Dr. Garnett believes that biological liquid crystal molecules and structures such as hyaluronic acid, prothrombin, DNA, cytoskeletal proteins and cell membranes are involved in maintaining both an inward and outward current. The inward current flows from the cell membrane to cell structures like mitochondria and DNA and the outward current flows back along liquid crystal semiconducting cytoskeletal proteins back through the cell membrane to the ECM.

## *Electrical properties of the ECM*

 The protein polymers that compose the ground substance of the ECM are negatively charged. The number and type of sialic acid residues that cap the glycoproteins of the cell surface also determine the degree of negative charge of the cell surface. The negative charges of the ECM-glycocalyx interface helps determine water balance, ion balance and osmotic balance both in the ground substance of the ECM and inside of the cells.

 Tissues of the body that are injured have a higher electrical resistance than the surrounding tissue (Wing, 1989). The cell membranes of these tissues become less permeable to the flow of ions and more electrically insulated. This results in the endogenous bioelectric currents avoiding these areas of high resistance (Wing, 1989). The reduction in electrical flow through an injured area is one factor that interferes with healing.

 Increasing the electrical resistance of a tissue will impede the flow of healing biocurrents (Becker, 1985). Decreasing the electrical flow through an injured area also results in a decrease of the membrane capacitance of the cells in that area.

 Conversely improving the electrical conductance of the ECM will improve healing and improve cell membrane charge. Correction of tissue inflammation and ECM toxicity can improve the electrical functions of the ECM. Therefore the composition and degree of toxicity of the ECM-glycocalyx interface will affect the electrical field and the flow of biocurrents in the ECM. The electrical field and biocurrent conduction in the ECM in turn will affect: cell membrane capacitance, permeability of the cell membrane, signaling mechanisms of the cell membrane, intracellular mineral concentrations, nutrient flow into the cell and waste disposal (Wing, 1989; Oschman, 2000).

*The ECM can be cleared of toxins* by a variety of measures. Detoxification strategies used by medical clinicians include the use of chelating agents, antioxidants and the support of antioxidant pathways, oral enzymes, microcurrent devices, acoustical devices and phototherapy devices (lasers and LEDS).

 The body’s biocurrents and the electrical field of the ECM controls cell differentiation and the metabolic activity of mature cells. Mesenchymal cells will differentiate under the influence of electrical fields: fibroblasts to fibrocytes, myoblasts to myocytes, chondroblasts to chondrocytes and osteoblasts to osteocytes (Becker, 1985).

 Both internally generated and externally applied electromagnetic fields can affect cell functions. The primary external electromagnetic force is the sun, which produces a spectrum of electromagnetic energies. Life evolved utilizing processes that harness the energy of light to produce chemical energy, so in a sense light is the first nutrient.

 *Regeneration is a healing process* where the body can replace damaged tissues. Some of the most important biophysical factors implicated in tissue repair and regeneration involve the natural electrical properties of the body’s tissues and cells (Brighton et al., 1979), such as cell membrane potential and protein semiconduction of electricity. The body utilizes these fundamental bioelectronic features to naturally produce electrical currents that are involved in repair and regeneration (Becker, 1961, 1967, 1970, 1972, 1974, 1990). RobertO.Becker has shown in his research that the flow of endogenous electrical currents in the body is not a secondary process, but in fact is an initiator and control system used by the body to regulate healing in bone and other tissues (Becker, 1970, 1990; Becker and Selden, 1985).

 For example, in bone the proper production and conduction of endogenous electrical currents is required to stimulate primitive precursor cells to differentiate into osteoblasts and chondroblasts (Becker and Selden, 1985; Becker, 1990). Once the bone forming osteoblasts are created, they *must maintain a healthy cell membrane electrical potentia*l and have available certain critical nutrients in order to form the polysaccharide and collagen components of osteoid. Endogenous bone electrical currents created through piezoelectricity (Fukada, 1957, 1984) are also required for deposition of calcium crystals (Becker et al., 1964). When the biophysical electrical properties of the tissues are considered, it makes sense to develop therapeutic strategies that support the body’s biophysical electrical processes to potentiate the healing of injured or diseased tissues.

***Electrical properties of cell membranes***

 The cell membrane is a dividing structure that maintains biochemically distinct compartments between the inside (intracellular) and outside (extracellular) spaces (Marieb 1998).

 In order to maintain balance in intracellular fluid and electrolytes, water, sodium and potassium are in constant motion between the intracellular and extracellular compartments (Edwards 1998). The passage of electrically charged ions through a membrane will create a flow of electric currents through the membrane. These ions in turn will affect the metabolism of the cell and the potential of the cell membrane.

 Extracellular fluids and intracellular fluids contain different concentrations of minerals. These minerals carry positive charges and are called cations. In order to maintain electric neutrality negatively charged molecules called anions must match these cations in concentration. Sodium is the main cation of ECF whereas potassium is the major cation of ICF. Chloride and bicarbonate are the main anions of ECF, while proteins and organic phosphates are the main anions of ICF. Uncharged molecules such as glucose or urea are also present in both compartments (Edwards, 1998).

 The lipid structure of a cell membrane makes it relatively impermeable to the passage of charged molecules. Therefore charged molecules must cross through ion channels. Ion channels are transmembrane protein molecules that contain aqueous pores connecting the inside of the cell to the extracellular space. These channels can open and shut in response to a variety of signals. The passage of charged molecules through ion channels in the cell membrane endows the membrane with an electrical conductive property allowing for inward and outward current flows(Aidley and Stanfield, 1996). This is one factor that establishes electric circuits in biological tissues.

 So it would be expected that all living cells of thebody would naturally have a weak, electric current flowing through them. In fact there are bioelectrical circuits continually circulating throughout the body (Stanish, 1985).

 The buildup of different concentrations of mineral ions on either side of the membrane also helps create a membrane potential and endows cell membranes with the electrical property of capacitance. *Capacitors* are well known electronic components that are composed of two conducting sheets or metal plates separated by a thin layer of insulating material. Cells contain several forms of biological capacitors, which consist of an insulating material (the membrane) covered on both sides by collections of charged dissolved minerals, which serve the same function as a conducting metal plate. Because the exterior cell membrane and the membranes of cell organelles like the mitochondria in animals and the chloroplasts in plants are biological capacitors they have the capacity to accumulate and store charge and hence energy to be given up when needed.

 Energy is taken from a circuit to supply and store charge on the plates. Energy is returned to the circuit when the charge is removed. The area of the plates, the amount of plate separation and the type of dielectric material used all affect the capacitance. The dielectric characteristics of a material include both conductive and capacitive properties (Reilly, 1998). In cells the cell membrane is a leaky dielectric. This means that any condition, illness or change in dietary intake that affects the composition of the cell membranes and their associated minerals can affect and alter cellular capacitance.

 A cell or body is coupled to an electric field in proportion to its capacitance such that the greater the frequency of the electrical field the greater the current flow in the cell or body. For soft tissues low frequency natural or applied electrical fields create currents that are conducted primarily along the surface of cells in the ECM-cell membrane interface (Adey 1993a). Conduction of electrical currents in the ECM is the dominant effect when very low frequency electrical fields are created in or applied to biological tissues.

 When high frequency fields are applied with external signal generators this results in charging of the cell membranes causing an increase in cell membrane capacitance and increased conduction of current through the cell membranes.

 Because cell membranes naturally have capacitance this makes the cell membrane frequency-dependent conductors. At high frequencies a greater percentage of current will flow into and out the cell as a circuit loop. Higher frequency fields can strongly affect cell membrane permeability, which in turn can affect nutrient entry into the cells and toxin release from the cells and the ECM.

 In summary an increase in cellular membrane capacitance may: change membrane permeability, increase cellular nutrient and mineral entry in to the cell and facilitate release of impregnated toxins from the membrane and cell interior.

***Mineral and electrical abnormalities in injured tissues***

 F.W. Cope in his writings has described a characteristic pattern of electrolyte and fluid abnormalities that occur in any tissue that is damaged. He calls this pattern the ‘tissue damage syndrome’. When cells are injured from any cause cells will lose potassium, and accumulate sodium and water (Cope, 1978).

 According to Cope, the proteins of a healthy cell exist in normal electronic configurational state where a significant proportion of cell water is structured or bound in concentric rings around the protein molecules. In addition *when the proteins are in their healthy configuration* the negatively charged sites on the protein matrix will have a greater preference for association with potassium rather than with sodium (Cope, 1978). If Cope is correct this may be one of the factors that accounts for the finding that healthy cells have high cell potassium and low cell sodium concentrations.

 A number of proteins are present within the cell and in the ECM. Other proteins lie on the inner and outer surface of cell membranes and some are embedded within the cell membrane. These proteins consist of linear chains of amino acid residues with attached carbohydrate and or lipid molecules. The electro attractive and repulsive forces between these components and the external or internal salt-water environment cause these proteins to fold into three-dimensional shapes called conformational states. Protein function is dependent on these conformational states. The cell membrane and its associated membrane proteins are dynamically active with the associated proteins undergoing continuous changes in state. In proteins that are enzymes the conformational state determines whether or not the enzyme will expose its ligand binding sites.

 But if the membrane protein is an ion channel the conformational structure will determine whether the channel is open or closed. When the channel is open it is able to pass ions such as potassium, sodium, chloride, and calcium, across the cell membrane (Hille, 1992). The cell membrane is relatively impermeable to ions unless its protein based ion channels are open. When functioning normally the cell membrane will establish different concentrations of charged ions on either side of the membrane. This cell membrane property creates an electrical potential across the membrane.

 The ability of the cell proteins to stay in their normal configurational state is dependent on the cell being free from chemical, physical or hypoxic damage. When physical, chemical or hypoxic damage occurs to a cell many cell proteins will change to an abnormal damaged configurational state. In that state *“the cell proteins lose their preference for association with potassium rather than sodium, and lose much of their ability to structure water”* (Cope, 1978). When these protein changes occur potassium leaves the cell and is replaced by sodium. In addition the water content and the percentage of unbound water within the cell increases (the cell swells) (Ling and Ochsenfeld, 1976).

 Proteins can also be induced to resume their normal configuration by measures that increase the intracellular concentration of potassium, magnesium, and ATP. This will result in cell water becoming more structured and will cause the cell to release unstructured cell water and sodium (Cope, 1978).

 The structuring of water around intracellular proteins will also affect the configurational state, liquid crystal, and electrical properties of these proteins. Structured or bound water has less freedom of movement than unbound water. Nuclear magnetic resonance (NMR) can be used to measure the amount of water that is structured in normal and cancerous cells. Hazelwood and his colleagues showed in a 1974 NMR study that malignant tissues have significantly increased amounts of unbound water compared to normal tissues (Hazelwood, 1984).

 The changes in the degree that water is structured in a cell or in the ECM will affect the configurations and liquid crystal properties of proteins, cell membranes, organelle membranes and DNA.

 The use of electrical and phototherapy devices such as lasers and LEDS will change the electric field of the ECM and create current flow both in the ECM and through the cell membrane depending on the frequency applied. These changing electrical fields will modify the electrical potential of cell membranes, intracellular mineral concentrations and cellular energy production by affecting the activity of ionic membrane pumps (Liu et al., 1990; Blank, 1992).

 Modification of the electrical potential of cell membranes can be used to increase the abnormally low transmembrane potential of injured tissues**.** Effects that are seen when membrane potential is increased include: enhanced cellular energy (ATP) production, increased oxygen uptake, changes in entry of calcium, movement of sodium out of the cell, movement of potassium into the cell, changes in enzyme and biochemical activity, and changes in cellular pH.

 It appears that modulation of the electric field of the ECM and changing current flows in biologically closed electric circuits can increase low transmembrane potential, increase the entry of potassium and calcium, increase sodium and water movement out of the cells, reduce intracellular acidity, improve oxygen entry into hypoxic cells, increase mitochondrial production of ATP through aerobic metabolism.

## *Polychromatic states and health: a unifying theory?*

 Prigonine’s 1967 description of dissipative structures gave a model and an understanding of how open systems like biological organisms that have an uninterrupted flow of energy can self-organize. Biological systems are designed to take in and utilize energy from chemical sources (food), but they can also utilize energy and information from resonant interactions with electromagnetic fields and acoustical waves to maintain their dynamic organization.

*“Energy flow is of no consequence unless the energy is trapped and stored within the system where it circulates before being dissipated* (Ho, 1996).”

 This means that cellular structures that tranduce, store, conduct and couple energy are critical features of any living organism. Living systems are characterized by a complex spectrum of coordinated action and rapid intercommunication between all parts (Ho, 1996). The ideal complex activity spectrum of a healthy state is polychromatic where **all frequencies** of stored energy in the spectral range are equally represented and utilized (Ho, 1996). In an unhealthy state some frequencies may be present in excess and other frequencies may be missing. For example it has been reported that a healthy forest emits a polychromatic spectrum of acoustical frequencies and an unhealthy forest will have holes in its frequency spectrum. Yet when the forest regains its health it again emits a polychromatic spectrum of frequencies. The frequency holes got filed in!

 When an area of the body is not properly communicating it will fall back on its own mode of frequency production, which according to Mae-Wan Ho leads to an **impoverishment of its frequency spectrum** (Ho, 1998). In looking at the example of cardiac frequency analyzers it has been discovered that sick individuals have less heart rate variability than healthy individuals.

 The concept of polychromatism makes sense when phenomena such as the healing effects of: sunlight, full spectrum lights, LED phototherapy, music, and acoustic therapy are considered. Something or things (frequency or frequencies) that may have been missing are provided by these treatments.

 From the consideration of applied frequency technologies it can be theorized that one aspect of why these consonant technologies work is because they supply frequencies that are missing in the electromagnetic and acoustical spectral emissions of living organisms. When missing frequencies are supplied they in a sense fill gaps in the frequency spectrum of a living organism. Dissonant technologies would identify frequency excesses and pathogenic frequencies and would provide frequency neutralization by phase reversal.

 If we consider polychromatism to be the model of the healthy state then it makes sense that technologies that provide missing frequencies can play beneficial roles in health care. Research has shown that both cells and tissues respond to a variety of electromagnetic signals in ways that suggest a degree of specificity for both the tissue affected and the signal itself.

**Section 3 Use of magnetic fields and acoustics in humans**

***The concept of electromagnetic windows in cell biology***

 The application of a varying magnetic flux to an area of the body will induce an electric field, along the perimeter of the area according to the basic laws of electromagnetism. In 1831 Michael Faraday, one of the first electrical pioneers, was the first person to describe the phenomenon of electromagnetic induction. He discovered that he could produce a measurable electrical current in a wire conductor simply by moving a magnet near the wire. This discovery became the basis for Faraday’s Law of Induction, which is a basic law of electromagnetism (Jones and Childers, 1990).

 When varying magnetic fields are applied to human tissues that contain free (or mobile) charge carriers, these charge carriers will be accelerated by the electric field thereby generating eddy currents in the tissues. The induced electric field or the generated current depends upon the rate of change, dB/dt, of the magnetic field, with the electric field or current increasing with increasing rate of change.

“When living cells are exposed to sinusoidal or otherwise time-varying magnetic fields it is likely that electric fields and thus currents will be induced within them (Edmonds, 2001).”

 The activation of biological processes in the human body takes place within a large range of electric fields. If the magnetic device induces too high an electrical field it will elicitate the action potentials of excitable cells in the region. The elicitation of cellular action potentials is undesirable since it may lead to disturbing symptoms in the patient or give rise to undesirable physiological reactions. For example, the effects of large induced electrical fields can cause flexing of muscles due to activation of muscle cells or elicitation of nerve impulses due to activation of neural cells.

*“Time-varying magnetic fields that induce current densities above 1A/m2 in tissue lead to neural excitation and are capable of producing irreversible biological effects such as cardiac fibrillation* (Tenforde, 1990).”

 Since sudden death is a side effect that needs to be avoided, the area of interest is in the use of magnetic fields that will induce current densities in the physiological range.

 Bone contains proteins that have piezoelectric properties so mechanical stress will create endogenous electrical currents. Endogenous electrical current densities under physiologic conditions approximate 1 Hz and 0.1 - 1.0 microA/cm2 (MacGinitie et al., 1994).

 The endogenous current density in many organs and tissues lie in the range of 0.1-10 mA/m2 (Bernhardt, 1979). Current densities less than this in general are thought to produce few biological effects; however the work of Jerry Jacobson has shown that even weak picotesla magnetic fields do produce noticeable biological effects.

 Time-varying magnetic fields that induce current densities greater than approximately 1-10 mA/m2 have been reported by many researchers to produce various alterations including cell growth acceleration, enzyme activation, and changes in the metabolism of carbohydrates, fats, proteins and nucleic acids (Tenforde, 1990).

 The main goal in treating biological tissues i.e. bone healing, wound healing, nerve growth, and angiogenesis with a time- varying magnetic field is to induce tissue currents. These currents must have enough intensity and duration to be capable of activating cellular signaling processes and extracellular signals, thus initiating enzyme reactions, membrane transport, cell proliferation and differentiation and other biological processes without being so strong that they create undesirable physiological reactions.

**Uses of EMFs in medicine**

 Both magnets as well as electromagnetic therapy devices have been reported to relieve physical symptoms such as pain and edema and facilitate the healing of broken bones (Barker, 1984). Electromagnetic devices are now widely used by orthopedists in the treatment of fractures. Although the underlying physiological mechanisms are still not completely understood, several medical studies have shown that pulsating electromagnetic fields can stimulate bone formation and bone graft incorporation (Cruess et al., 1983; Rubin et al., 1989). The United States Food and Drug Administration has already approved this form of therapy for the treatment of delayed and non-union fractures.

 The use of pulsating electromagnetic fields has also been reported to be useful in promoting healing of bedsores (Ieran et al., 1990) and in neuronal regeneration Kort et al., 1980).

**Gauss strengths of magnetic fields**

 The approximate magnetic field strength of the earth is ½ Gauss (Becker, 1990). The typical strength ranges for biomagnets is from 300 - 4,000 Gauss.

“The primary physical interaction of time-varying magnetic fields with living systems is the induction of electric fields and currents in tissues (Tenforde, 1990).”

 The physical characteristics of time-varying magnetic fields that are important in creating biological effects include the fundamental field frequency, the presence of harmonic frequencies, maximum and average flux densities, the waveform of the signal (sinusoidal, square or pulsed), the rise and decay time of the magnetic-field waveform and the polarity of the signal (Tenforde, 1990).

**Some representative examples of magnetic field strengths used in treatment studies**

 Use of a static magnetic field of 500 Gauss for 1 hour has been found to be useful for treatment of myofascial shoulder pain. Static magnetic fields may decrease the intensity of myofascial shoulder pain in persons with spinal cord injuries (Panagos et al., 2004).

 The effect of a static magnetic field on synovitis in rats was studied. One group of rats was held in a cage with a magnet of 3,800 Gauss on the bottom of the cage (treated), while another group was held in a cage without a magnet (control). The data showed that synovitis and the inflammatory process are significantly suppressed by a magnetic field of 3,800 Gauss (Weinberger et al., 1996).

 Research has shown that pulsed electromagnetic fields (PEMF) safely induce extremely low frequency (ELF) currents that can depolarize, repolarize, and hyperpolarize neurons. In a study performed by Weintraube and Cole PEMF therapy was used in individuals with neuropathic pain unresponsive to medications. They used a noninvasive pulsed signal with strength of about 20 Gauss and a frequency of about 30 Hz which was directed into the soles of the feet for 9 consecutive 1-h treatments (excluding weekends). This study demonstrated that directing a PEMF to refractory feet can provide unexpected short term analgesic effects in more than 50% of individuals who are treated (Weintraube and Cole, 2004).

*“The analgesic-therapeutic efficacy and tolerability of a low-frequency electromagnetic field (ELF),* ***modulated at a frequency of 100 Hz*** *with a sinusoidal waveform and mean* ***induction of a few gauss****, has been demonstrated by the authors in numerous previous studies of various hyperalgic pathologies, particularly of the locomotor apparatus. In the present study, the authors tested a new type of all-inclusive field, denoted TAMMEF, whose parameters (frequency, intensity, waveform) are modified in time, randomly varying within the respective ranges, so that all the possible codes can occur during a single application. For the comparison, 150 subjects (118 women and 32 men, between 37 and 66 years of age) were enrolled. They were affected by cervical spondylosis (101 cases) or shoulder periarthritis (49 cases). Unbeknownst to them, they were randomly divided into three groups of 50 subjects. One group was exposed to the new TAMMEF, another group to the usual ELF, and the third group to simulated treatment. The results show that the effects of the new TAMMEF therapy are equivalent to those obtained with the ELF* (Rigato et al., 2002).”

 A study reported by Valbona et al has showed that chronic pain in postpolio patients can be relieved by application of magnetic fields applied directly over an identified pain trigger point. This placebo controlled study was done with fifty patients with diagnosed postpolio syndrome who reported muscular or arthritic-like pain where **300 to 500 gauss** magnetic devices were applied to the affected area for 45 minutes.

*“Patients who received the active device experienced an average pain score decrease of 4.4 +/- 3.1 (p < .0001) on a 10-point scale. Those with the placebo devices experienced a decrease of 1.1 +/- 1.6 points (p < .005). The proportion of patients in the active-device group who reported a pain score decrease greater than the average placebo effect was 76%, compared with 19% in the placebo-device group (p < .0001). CONCLUSIONS: The application of a device delivering static magnetic fields of 300 to 500 Gauss over a pain trigger point results in significant and prompt relief of pain in postpolio subjects* (Valbona et al., 1997).”

 A study has been reported that examined the effects of electromagnetic fields on wound healing in rats.

*“Thirty six male Wistar rats were used; a rectangular lesion was made in the back of each animal (4.2 cm x 2.3 cm). They were divided into 3 groups: group C (control) with sham treatment; group C50, treated with continuous electromagnetic fields of 5 mT (50 Gauss) and group P200, treated with pulsed electromagnetic fields of 20 mT (200 Gauss). The treatments were of 30 minutes a day during 21 days. The results showed a facilitating effect of electromagnetic fields on wound healing in rats. Pulsed electromagnetic fields seem to have a precocious and larger healing effect than continuous electromagnetic fields* (Patino et al., 1996).”

 Dr. Jerry Jacobson and colleagues have done clinical studies on neurological disorders with an externally applied pico Tesla (10R Tesla, or 10(-8) gauss) magnetic fields. *The field strength of their magnetic treatments is significantly lower than used by other researchers* (Jacobson et al., 1995).

 In a study reported in 1993 the treatment of 86 patients with trophic ulcers of the lower extremities showed the use of magnetotherapy in combination with galvanization and intratissue electrophoresis was effective. The researchers created an electric field with a density of current equal to 0.05-0.1 mA/cm2. Simultaneously, applying low-frequency magnetotherapy with induction of 30 mT and area of exposure of 20 cm2 was applied to a trophic ulcer site (Alekseenko et al., 1993).

*“A process for treating an arthritic body organ including the step of subjecting the arthritic body organ to an electromagnetic field of under* ***20 Gauss*** *and generated by an annular coil into which the arthritic body organ is placed, the coil being driven by a pulsed DC voltage having a rectangular wave form consisting of an abruptly rising and abruptly deteriorating current pulsing at the rate of 1-30 pulse bursts per second. Under the present invention the target organ is subjected to an electromagnetic field driven by a pure DC voltage having an abruptly rising and abruptly deteriorating wave form at the* ***rate of 1-30 cycles per second****. The field at the target organ is of low intensity, preferably under 20 Gauss, and the field lines are oriented, where the target organ is on an appendage, such that the flux lines travel toward the distal end of the appendage.* (U.S. Patent 5,842,966).”

**Acoustics**

*“The basic physical characteristics of sound are its frequency, intensity, and spectrum. Frequency, measured in hertz (Hz) or cycles per second (cps) is the number of positive or negative pressure fluctuations of a sound wave each second. The gross frequency range of human hearing for young, healthy, and undiseased ears is from below 20 to over 20,000 hertz* (US Navy, 1991).”

 Below 20 hertz sound is basically felt not heard this is called the infrasonic range. Over 20,000 hertz is considered to be the ultrasonic range sounds in this range cannot be heard. A review of the literature finds that sound vibration has physiological effects on the body throughout the entire spectral range.

***Vibroacoustics***

 Both vibroacoustic and vibrotactile devices that transmit sound as vibration to the body have been found to promote healing and produce physiological states of relaxation. Individuals treated with this technology will experience a reduction in muscle tone, blood pressure and heart rate.

 In conventional Vibroacoustic (VA) therapy a combination of relaxing music and pulsed, sinusoidal low frequency tones between 20Hz and 70Hz are played through a bed or chair containing large speakers or transducers (Wingram, 1997). The direct contact of a transducer with the surface of the skin will allow the penetration of microvibrations into the tissues. These microvibrations have been reported to have a selective effect upon various biological structures that include improved lymphatic and venous drainage, reduction in edema, and improved pain control (Patrick, 1999; Coope, 2003).

 An example of a vibroacoustic device is the Vitafon, which delivers a continuous sweep of acoustic energy through a pair of transducers. A continuous frequency sweep between 4 Hz to 1.5 kHz and is used for maximization of the hydrodynamic pump effect in veins. A continuous frequency sweep between 400 Hz to 12-18 kHz and is used to decrease vascular resistance in capillaries.

 A research group headed by Dr. Clinton Rubin has discovered that the exposure to mechanical frequencies between 20-50 Hz produce an anabolic response in bone. This research correlated the facts that muscles of the extremities naturally produce vibrations in this range and that this frequency domain is critical to the regulation of the musculoskeletal system. In addition as these muscles deteriorate in aging, disease, extended bed rest and space flight the anabolic effect is diminished (Rubin et al., 2002).

 Not all vibroacoustic energy is produced by machines in fact a significant number of animals produce sound waves in both the infrasonic and low end of the hearing range of humans. Within the last few years scientists have discovered that these sounds serve both to communicate and to promote healing of injuries.

 A 2001 study done by Dr. Elizabeth von Muggenthaler of the Fauna Communications Research Institute recorded the purr of feline animals. In this study Forty-four felids were recorded including cheetahs, ocelots, pumas, domestic cats, and servals.

*“Every felid in the study generated strong frequencies between 25 and 150 Hz. Purr frequencies correspond to vibrational/electrical frequencies used in treatment for bone growth/fractures, pain, edema, muscle growth/strain, joint flexibility, dyspnea, and wounds. Domestic cats, servals, ocelots, and pumas produce fundamental, dominant, or strong frequencies at exactly 25 Hz and 50 Hz, the two low frequencies that best promote bone growth/fracture healing [Chen et al., Zhong. Wai Ke Za Zhi. 32, 217--219 (1994)]. These four species have a strong harmonic exactly at, or within 2 Hz of 100 Hz, a frequency used therapeutically for pain, edema, wounds, and dyspnea. An internal healing mechanism would be advantageous, increasing recovery time and keeping muscles and bone strong when sedentary* (von Muggenthaler, 2001).”

***Cymatics***

 Cymatics is the study of wave phenomena that was pioneered by a Swiss medical doctor and natural scientist, Hans Jenny (1904-1972). Dr. Jenny performed numerous experiments in his career where he exposed powders and liquids to sound waves. He discovered that by use of different sound frequencies that he could cause inert materials to form patterns, which mirrored patterns found throughout nature, art and architecture. His discoveries were developed by Sir Peter Guy Manners into a form of sound therapy.

 According to Sir Peter Guy Manners of Worcestershire, England, **cymatic therapy** uses a computerized instrument to produce sound waves within the audible range that are applied directly through the skin to stimulate the body’s regulatory control systems (Manners).

 According to Manners, "Every object, whether inanimate or alive, possesses a unique electromagnetic field that exhibits antagonistic, complimentary (resonant), or neutral reactions when it interacts with other electromagnetic fields. Resonant equilibrium represents the healthy state (resonance may be defined as the frequency at which an object most naturally vibrates); illnesses is represented by resonant disequilibrium (Manners).”

***Summary***

 This paper has reviewed the interaction of electricity, magnetism and acoustics with biological tissues. It can be shown that electromagnetic and acoustic devices can have measurable impacts on human beings.

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## Type‐I Collagen Modeled as a Liquid Crystal

By Alexander Thomas

Separate Document

## Water bridges of Water in Collagen Fibers



## The Acupuncture System and The Liquid Crystalline Collagen Fibres of the Connective Tissues

## Liquid Crystalline Meridians

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### Abstract:

We propose that the acupuncture system and the DC body field detected by Western scientists both inhere in the continuum of liquid crystalline collagen fibres that make up the bulk of the connective tissues. Bound water layers on the collagen fibres provide proton conduction pathways for rapid intercommunication throughout the body, enabling the organism to function as a coherent whole. This liquid crystalline continuum mediates hyperreactivity to allergens and the body's responsiveness to different forms of subtle energy medicine. It constitutes a "body consciousness" working in tandem with the "brain consciousness" of the nervous system. We review supporting evidence from biochemistry, cell biology, biophysics and neurophysiology, and suggest experiments to test our hypothesis.

### Meridians and fields

The meridian theory is a prominent component of traditional Chinese medicine. It was formulated in ancient China with the practice of acupuncture, moxibustion, massage and *qigong* - an integrated mind-body exercise for controlling and mobilizaing *qi* (energy) for physical fitness and well-being. The meridians are a complicated system of pathways in which "qi and blood" are said to circulate in the body, thus interconnecting the viscera and limbs, the deeper and superficial layers of the body in a fine meshwork (Yin, 1992). The meridians have effectively guided diagnosis and treatment of diseases by drugs, acupuncture, moxibustion, and massage for thousands of years. Acupuncture is also widely used for pain relief, anaesthesia, and in some cases, for treating psychiatric disturbances (Esser et al, 1976).

Yet, the meridians and their acunpuncture points have no known, straightforward anatomical correlates recognized in western medicine, such as the circulatory system or the nervous system. Attempts continue to be made to establish anatomical and functional connections between acupuncture points and a variety of structures. These include receptors supplied by sensory nerves (Wang and Liu, 1989), tendon organs, encapsulated nerve-endings, extensive neural terminals, vascular network or superficial blood vessels (Gunn, 1976; Pan et al, 1988), veins perforating fascia (Plummer, 1980), and mast cells (Zhai, 1988).

Since the 1970s, there has been growing interest in the electrical characteristics of acupuncture points and in developing instruments for diagnostic and therapeutic purposes, as reviewed by Tiller (1982). Such instruments all measure skin conductances and how they change on being stimulated by direct current (DC) or alternating current (AC). Measurements of DC skin conductances have provided evidence that acupuncture points and meridians have distinctive electrical properties compared with the surrounding skin. Acupuncture points typically represent local maxima in conductance, elevated by a factor of 10 to 100, compared with the surrounding skin, while acupuncture meridians have the chracteristics of electrical transmission lines (Tiller, 1973; Reichmannis et al, 1976; Becker, 1990).Tiller (1982, 1987)has presented several models to account for the electrical properties of acupuncture points based on charge movements and selective permeability of ions through different layers of the skin.

In the kind of measurement offered by Motoyama (1980), multiple fixed electrodes are positioned over 28 acupuncture points on the hands and feet, while the large reference electrode is attached to the wrist. A direct current is passed through the circuit by a 3V battery. The conductance typically shows a fast decay in microseconds, overlying a slow baseline conductance with a relaxation time of some tens of seconds. Motoyama attributes the fast component to semi-conduction in the dermis, while the slow component is attributed to ion movements and storage across the basal membrane separating the dermis from the epidermis. Tiller (1987) represents the epidermal and dermal layers as two domains in series, each with its capacitance and resistance with very different response (relaxation) times. The fast component is associated with the dermis, the low frequency component, the epidermis. Tiller has further suggested that the fast conductance might be due to H+, as the DC voltage supplied (3V) was sufficient to ionize water. This model identifies the differing electrical properties of the dermis and epidermis, which could account for some, though not all, of the responses of the acupuncture system to electrical stimulation. These responses are often found to correlate with states of disease and health (Becker et al, 1976; Kobayashi, 1985).

According to traditional theory, the acupuncture system is an *active* circulatory system for mobilizing energy and for intercommunication throughout the body. So, it is unlikely to be completely understood in terms of the *passiv*eresponses of skin conductances to electrodermal stimulation. The most promising functional correlate of the acupuncture system, as Becker (1990) suggests, is the direct current (DC) electrodynamical field that he and others have detected in the body of all organisms. This DC body field is involved in morphogenesis during development, in wound-healing and regeneration subsequent to injury. The direct currents making up the body field are not due to charged ions but instead depend on a mode of semi-conduction characteristic of solid state systems (Becker, 1961). The acupuncture points, moreover, may act as "booster amplifiers" of the very weak currents that typically flow along the meridians.

According to Becker (1990), the DC body field is not located in the nervous sytem itself, but in "perineural" tissues such as the glial cells in the brain and spinal cord, and the schwann cells encasing the peripheral nerves. This hypothesis would seem to conflict with the suggestion that the DC body field is correlated with the acupuncture system. The acupuncture system is clearly not directly associated with the perineural tissues, although it may have functional interconnections with the central and peripheral nervous system (Gunn, 1976; Wang and Liu, 1989; Pan et al, 1988). Also, an electrodynamical field can be detected in all early embryos and in plants and animals which do not have neural or perineural tissues (Burr and Northrup, 1935). It is likely that the DC field is functionally interconnected with the nervous system, and yet exists, to a large degree, outside the nervous system. In fact, it is widely recognized that under a variety of conditions, the speed of communication in our body is much faster than can be accounted for by the known speed of nerve conduction (see Ho, 1997a), and nerves simply do not reach all parts of our body.

We propose that both the DC electrodynamical field and the acupuncture system have a common anatomical basis. *It is the aligned, collagen liquid crystalline continuum in the connective tissues of the body with its layers of structured water molecules supporting rapid semi-conduction of protons*. This enables all parts of the body to intercommunicate readily, so the organism can function as a coherent whole. This liquid crystalline continuum may mediate hyperreactivity to allergens and the body's responsiveness to different forms of subtle energy medicine. Furthermore, it constitutes a "body consciousness" that is functionally interconnected with the "brain consciousness" of the nervous system (Ho, 1997a). We review supporting evidence from biochemistry, cell biology, biophysics and neurophysiology, and suggest experiments to test our hypothesis.

### The organism is a liquid crystalline continuum

One requirement for an intercommunication system is a continuum which can carry the signals for intercommunication. For example, a continuum of air, liquid or solid, can all serve as medium for sound and mechanical waves. If the medium is electrically polarizable, it will also transmit polarization waves. Electromagnetic waves are thought to be an exception, as they can travel through empty space. But to this day, physicists are still debating the nature of the vacuum, which carries not only electromagnetic waves but also gravity waves (see Laszlo, 1995). The living organism is a continuum. Not only is the entire cell now known to be mechanically and electrically interconnected in a "solid state" (Clegg and Drost-Hansen, 1991) or "tensegrity system" (Ingber, 1993, 1998); *all* the cells in the body are in turn interconnected to one another via the connective tissues (Oschman, 1984, 1996).More accurately, perhaps, we recently discovered that the living continuum is liquid crystalline, with all the properties that make liquid crystals ideal for intercommunication (Ho et al, 1996; Ho, 1997a).

Liquid crystals are states or phases of matter in between solid crystals and liquids, hence the term, *meso*phases. Unlike liquids which have little or no molecular order, liquid crystals have orientational order, and varying degrees of translational order. But unlike solid crystals, liquid crystals are flexible, malleable, and responsive (De Gennes, 1974; Collings, 1990). There are many kinds of liquid crystals, from those which are most like liquids, to ones that most resemble solid crystals. Those that are like liquids can flow in the way water does, and 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, and molecules may even be extensively covalently cross-linked together, but they will remain flexible and responsive.

Liquid crystals typically undergo rapid changes in orientation or phase transitions when exposed to electric (and magnetic) fields - which is why they are widely used in display screens. 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 dielectric constant of the solvent (Collings, 1990; Knight and Feng, 1993).George Gray (1993), who has studied liquid crystals for many years, refers to liquid crystals as "tunable responsive systems", and as such, ideal for making organisms.

It is already widely recognized that all the major constituents of living organisms may be liquid crystalline (Collings, 1990) - lipids of cellular membranes, DNA, possibly all proteins, especially cytoskeletal proteins, muscle proteins, and proteins in the connective tissues such as collagens and proteoglycans (Bouligand, 1972; Giraud-Guille, 1992; Knight and Feng, 1993). Recent nuclear magnetic resonance (nmr) studies of muscles in living human subjects provide evidence of their "liquid-crystalline-like" structure (Kreis and Boesch, 1994). However, very few workers have yet come to grips with the idea that *organisms* may be essentially liquid crystalline.

The importance of liquid crystals for living organization was actually recognized a long time ago, as pointed out by Joseph Needham (1935).Hardy suggested in 1927 that molecular orientation may be important for living protoplasm, and Peters, two years later, made the explicit link between molecular orientation and liquid crystals. Needham, indeed, proposed that organisms actually *are* liquid crystalline. But direct evidence for that has only recently been provided by Ho and coworkers ( Ho and Lawrence, 1993; Ho and Saunders, 1994; Ho et al, 1996). who successfully imaged live organisms using an interference colour technique that amplifies weak birefringences typical of biological liquid crystals. They further discover that all organisms so far examined are polarized along the anterior-posterior or oral-adoral axis, so that when that axis is properly aligned, all the tissues in the body are maximally coloured; the colours changing in concert as the organism is rotated from that position. Not only live organisms, but also fresh-frozen or well-fixed sections of the skin, cartilage and tendons, all exhibit the same brilliant interference colours typical of living organisms.

The connective tissues are still regarded by most workers in purely mechanical terms - their functions are to keep the body in shape, to act as packing between the major organs and tissues, to strengthen the wall of arteries, veins, intestines and air passages, and to provide the rigid elements (bony skeleton) for the attachment of muscles. A more enlightened view is that of a global tensegrity system, in which compression elements (bones) are interconnected with tension elements (muscles, tendons and ligaments), and local stimuli invariably lead to global reorganization of the whole (Ingber, 1998).

Actually, connective tissues may also be largely responsible for the rapid intercommunication that enables our body to function effectively as a *coherent* whole, and are therefore central to our health and well-being.

### Collagens and Intercommunication

The clue to the intercommunication function of connective tissues lies in the properties of *collagen*, which makes up 70% or more of all the protein of the connective tissues. Connective tissues, in turn form the bulk of the body of most multicellular animals. Collagen is therefore the most abundant protein in the animal kingdom (Knight and Feng, 1993).

There are many kinds of collagens, all sharing a general repeating sequence of the tripeptide, (gly-X-Y) - where X and Y are usually proline or hydroxyproline. They also share a molecular structure in which three polypeptide chains are wound around one another in a triple-helix, with the compact amino acid glycine in the central axis of the helix, while the bulky amino-acids proline and hydroxyproline are near the surface (Van der Rest and Garrone, 1991).In the fibrous forms, the triple-helical molecules aggregate head to tail and side-by side into long *fibrils*, and bundles of fibrils in turn assemble into thicker fibres, and other more complex three-dimensional liquid crystalline structures. Some collagens assemble into sheets constructed from an open, liquid crystalline meshwork of molecules. All these structures are formed by *self-assembly*, in the sense that they need no specific "instructions" other than certain conditions of pH, ionic strength, temperature and hydration. The process seems to be predominantly driven by hydrophilic interactions due to hydrogen-bonding between water molecules and charged amino-acid side-chains (Leikin et al, 1995).However, the precise mesophase structures resulting from different conditions of self-assembly show endless variations (Zhou et al, 1996; Haffegee et al, 1998). The different kinds of collagen assemblies in different connective tissues are generally well-suited to the mechanical tasks performed by the connective tissue concerned, because they were shaped by the prevailing conditions and the relevant mechanical forces.

Recent studies reveal that collagens are not just materials with mechanical properties. Instead, they have dielectric and electrical conductive properties that make them very sensitive to mechanical pressures, pH, and ionic composition (Leikin et al, 1993, 1995),and to electromagnetic fields. The electrical properties depend, to a large extent, on the bound water molecules in and around the collagen triple-helix. X-ray diffraction studies reveal a cylinder of water surrounding the triple-helix which is hydrogen-bonded to the hydroxyproline side-chains (Bella et al, 1994). Nuclear magnetic resonance studies have provided evidence of *three* populations of water molecules associated with collagen. These are *interstitial* water, very tightly bound within the triple helix of the collagen molecule, and strongly interacting with the peptide bonds of the polypeptide chains; *bound* water, corresponding to the more loosely structured water-cylinder on the surface of the triple helix; and *free* water filling the spaces between the fibrils and between fibres (Peto and Gillis, 1990).Evidence for bound water in collagen also comes from studies using another popular physical measurement technique, Fourier Transform Infra Red (FTIR) spectroscopy (Renugopalakrishnan et al, 1989).

Bound water, or vicinal water is a very general phenomenon involving the structuring of water on solid surfaces. It is already known that up to 50 or 60% of the cell water is structured in the enormous "microtrabecular lattice" that fills the entire cell (Clegg and Drost-Hansen, 1991), which gives the cell its "solid-state" like characteristic (see above).

The existence of the ordered network of water molecules, connected by hydrogen bonds, and interspersed within the protein fibrillar matrix of the collagens is especially signicant, as it is expected to support rapid jump conduction of protons - positive electric charges - and this has been confirmed by dielectric measurements (Sasaki, 1984). The conductivity of collagen increases strongly with the amount of water absorbed (from 0.1 to 0.3g/g of dry collagen), in accordance with the power-law relation,

*() = XY*

where ** is the water content, and*X*and *Y* are constants. The value of *Y* is found to be 5.1 to 5.4, and is a function of the collagen fibrillar structure. These results suggest that continuous chains of ordered water molecules join neighbouring ion-generating sites enabling proton jumps to occur. The high value of the exponential suggests that up to 5 or 6 neighbours may be involved in the jump conduction. Based on these findings, it is estimated that conductivity along the collagen fibres is at least one-hundred time that across the fibre (Pethig, 1996). Measurements have yet to be made to reveal the true extent of anisotropy in conductivity. The increase in conductivity is most marked around 310 K (Jaroszyk and Marzec, 1993), which interestingly, is close to the normal temperature of our body . It is to be noted that the triple-helix of collagens in dilute solutions "melt" at around the same temperature - 40oC (Leikin et al, 1995). Melting may enable the collagen fibres to better realign, and hence increase conductivity. Collagen melting and realignment may be one of contributing factors to the now well-documented health-promoting effects of physical exercise (see Bortz, 1996).

The collagenous liquid crystalline mesophases in the connective tissues, with their associated structured water, therefore, 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 go through the cell membrane. The connective tissues and intracellular matrices, together, form a global tensegrity system (Oschman, 1984; Ingber, 1998), as well as an excitable electrical continuum for rapid intercommunication throughout the body (Ho, 1997a).

### Collagen fibre orientation and the acupuncture system

A major factor contributing to the efficiency of intercommunication is the structured, oriented nature of collagen liquid crystalline mesophases in all connective tissues. Each connective tissue has its characteristic orientation of fibrous structures which are clearly related to the mechanical stresses and strains to which the tissue is subject. This same orientation may also be crucial for intercommunication. Collagen alignment has long been recognized to be important in the structure of bone and cartilage. Less well known are the "Langer lines" (Langer, 1978) in the skin, corresponding to predominant orientations of collagen fibres, which are determined, at least in part, by stresses during development and growth (Reihsner et al, 1995).

Collagen fibre alignments in connective tissues providing channels for electrical intercommunication may thus be correlated with the acupuncture system of meridians and points in traditional Chinese medicine, which, as mentioned above, is also related to the DC body field identified by scientists in the West.

As collagen fibres are expected to conduct (positive) electricity preferentially *along* the fibres due to the bound water, which are predominantly oriented along the fibre axis; it follows that these conduction paths may correspond to acupuncture meridians. By contrast, acupuncture points typically exibit low electrical resistances compared with the surrounding skin, and may therefore correspond to singularities or gaps *between* collagen fibres, or, where collagen fibres are oriented at right angles to the dermal layer. 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 the fascia or collagen fibres (see Meridians and Fields). Actual conducting channels may bear a more subtle relationship to the orientation of the collagen fibres, as conductivity depends predominantly on the layer(s) of bound water on the surface of the collagen molecules rather than the collagens themselves. So-called free water may also take part in proton conduction as the result of induced polarization, particularly as water molecules naturally form hydrogen-bonded networks (Luzar and Chandler, 1996). This would be consistent with the observed increase in conductivity of collagen as hydration increases to a level well beyond the bound water fraction, around 0.15g/g dry weight; and also with the fact that the normal hydration level of tendon is about 65%.

That conductive pathways actually link the entire body is demonstrated by Han Wan and Robert Balaban of the Canadian National Heart, Lung and Blood Institute (see Ehrenstein, 1997), who are taking advantage of the variation in conductivity of different layers of tissues in the body to develop a new, non-destructive imaging technique to aid clinical diagnosis.

The correlation between collagen alignment and the acupuncture system could be tested by examining the alignment in skin biopsies at acupuncture points and meridians - with corroborative skin conductance measurements - compared with non-acupuncture, non-merdian areas. In this connection, we have developed a quantitative imaging package based on our interference colour polarizing microscopy that readily plots molecular alignment in sections of the skin and other connective tissues (Knight et al, 1996; Ross et al, 1997).

### Collagen alignment in health and injury

If our hypothesis is correct, and patterns of collagen fibre alignment are indeed important for intercommunication, then they would be expected to affect the health of the individuals concerned, and also to be involved in the processes of healing and regeneration.

Electrical injury currents typically flow from skin wounds and sites of amputation, which are found to be involved in healing and regeneration (Becker, 1990). Injury currents themselves constitute evidence that conductive circuits link the entire body, so that cuts result in leakage currents. The leakage currents mobilize cells to migrate to the site of injury to initiate the healing and regenerative processes. It is significant that the immediate injury currents are all positive, as suggestive of proton currents. Only later on, after the regenerating blastema is formed, do the currents reverse to negative (see Becker, 1990).

Since these observations were made, electromagnetic interventions have been widely used for stimulating regeneration or healing, with conflicting results. Part of the problem may have been that the strengths of electromagnetic fields used were far stronger than the endogenous fields. Another important factor which has received little attention may be the orientation of the applied electromagnetic field with respect to the alignment of collagen fibres at the site of injury. If the field orientation is inappropriate, then application of the external field is likely to be ineffective, and may even delay recovery (Watkins et al, 1985).On the basis of the estimated 100-fold difference in electrical conductivity along the fibre compared to that across the fibre, it would be expected that collagens fibres will align in the direction of the applied electric field. Again these experiments should be done to ascertain the optimum conditions for collagen alignments, which may have important implications for healing and regeneration.

### Oriented Collagens and Body consciousness

Proteins in liquid crystals have coherent motions, in the first place, because the molecules are aligned, so that not all the degrees of freedom of movement that individual molecules have will be available in the liquid crystal mesophase (Searle and Williams, 1992). Protein motions involve vibrational deformations of peptide bonds, which will generate polarization waves along the proteins, accompanied by proton conduction in the structured water shell. Fröhlich (1980) has predicted that coherent vibrations (or excitations) will result from metabolic pumping in dielectric systems such as organisms, where electromagnetic and electromechanical forces are expected to interact. Liquid crystallinity will make coherent excitations even more likely to happen. Weak signals of mechanical pressure, heat or electricity, may therefore be readily amplified and propagated by a modulation of the proton currents or coherent polarization waves (Mikhailov and Ert, 1996)

The hydrogen-bonded water network of the connective tissues is actually linked to ordered water dipoles in the ion-channels of the cell membrane that allow inorganic ions to pass in and out of the cell (Williams, 1993). There is thus a direct electrical link between distant signals and the intracellular matrix, leading to physiological changes inside the cells, including neurons and glial cells. This electrical channel of intercommunication is in addition to, and coupled with, the mechanical tensegrity interactions of the connective tissue-intracellular matrix continuum mentioned above. Any mechanical deformations of the protein-bound water network will automatically result in electrical disturbances and conversely, electrical disturbances will result in mechanical effects. The new imaging technique that Han and Balaban are developing (see above) depends specifically on detecting ultrasound emissions from mechanoelastic vibrations caused by electrical pulses applied to the tissues.

Proton jump-conduction is a form of semi-conduction in condensed matter, and is much faster than conduction of electrical signals by the nerves. Thus the 'ground substance' of the entire body may provide a much better intercom-munication system than the nervous system. Indeed, it is possible that one of the functions of the nervous system is to slow down intercommunication through the ground substance. Lower animals which do not have a nervous system are nonetheless sensitive. At the other end of the evolutionary scale, note the alarming speed with which a hypersensitive response occurs in human beings. There is no doubt that a body consciousness exists prior to the "brain" consciousness associated with the nervous system. This body consciousness also has a memory, as argued in the Section following.

### Crystal Memory

Many studies on the conformation (three-dimensional shape) of the collagen triple-helix have shown that subtle changes are correlated with specific biological activities (Fields, 1995). Cells are guided in their growth and movement by contact with collagens, and specific sites are recognized by a host of cell membrane proteins. Mutations altering collagen amino-acid sequences give subtle changes in the conformation (Bella et al, 1994) which are associated with hereditary diseases, such as osteogenesis imperfecta, chondrodysplasias and Ehler-Danlos syndrome. Changes in collagen conformation should alter the bound water. Conformations of proteins are by no means static. All proteins undergo a hierarchy of conformational changes on a range of timescales, and collagens are unlikely to be exceptions. The conformations are clustered in groups of nearly identical energy content, with very low energy barriers between individual members of the group, but separated from other groups by higher energy barriers (see Welch, 1985). Collective changes in conformation (or phase transitions) can readily be triggered, in turn altering the liquid crystalline structure and the bound water network, as dielectric studies on synthetic liquid crystals have documented (Leikin et al, 1993; Wrobel et al, 1988).

As the collagens and bound water form a global network, there will be a certain degree of stability, or resistance to change. This constitutes a memory, which may be further stabilized by cross-linking and other chemical modifications of the collagens. The network will retain tissue memory of previous experiences, but it will also have the capacity to register new experiences, as all connective tissues, including bones, are not only constantly intercommunicating and responsive, but also undergo metabolic turnover like the rest of our body. Memory is thus dynamically distributed in the structured network and the associated, self-reinforcing circuits of proton currents, the sum total of which will be expected to make up the DC body field itself.

### Coupled Body and Brain Consciousness

We have argued that a body consciousness possessing *all* the hallmarks of consciousness - sentience, intercommunication and memory - is distributed throughout the entire body. Brain consciousness associated with the nervous system is embedded in body consciousness and is coupled to it (see also Ho, 1997a,b; 1998). That bound water plays a crucial role in conscious experience is supported by recent evidence that anaesthetics act by replacing and releasing bound water from proteins and membrane interfaces, thus destroying the hydrogen-bonded network that can support proton jump-conduction (Tsukamoto and Oglie, 1995).Significantly, Becker (1990) found that general anaesthesia also leads to the complete attenuation of the DC body field. It would be of interest to study the conductivities of collagen equilibrated with different solvents and anaesthetics. We would predict that collagens equilibrated with anaethetics will show a decrease in conductivity compared to an equivalently hydrated sample.

Although brain and body consciousness are normally coupled to each other, they may decouple under certain circumstances. Surgical patients under general anaesthesia have been known to regain (brain) consciousness of pain, but not the ability to move or to express their distress. In contrast, acupuncture has been successfully used to anaesthesize patients who are fully awake. Further evidence that brain and body consciousness are to some extent independent is Becker's (1990) observation that during a perceptive event, local changes in the DC field can be measured half a second before sensory signals arrive in the brain. Similarly, Libet et al (1979) produced evidence suggesting that a "readiness potential" precedes the decision of a subject to move an arm or a leg. It appears that the activities in the brain may be preconditioned by the local DC field.

If it is true that brain and body consciousness can decouple from one another, it would be important to develop monitoring systems specific to either of them. For example, acupuncture points may show changes independently of the EEG, and hence, surgical patients whose EEG, or better yet, whose magnetoencephalogram (MEG) measured with the ultrasenstive SQUID magnetometer show wakefulness may yet have acupuncture point(s) electrodermal readings typical of the anaesthetized state. Similarly, patients anaethetized by acupunture should have the appropriate "anaethetized" electrodermal readings even though their EEG or MEG is fully "awake".

### Conclusion

We have proposed that the acupuncture (meridian) system and the DC body field detected by Western scientists both inhere in the continuum of liquid crystalline collagen fibres and the associated layers of bound water that make up the bulk of the connective tissues of the body. Acupunture merdians may be associated with the bound water layers *along* oriented collagen fibres, which provide proton conduction pathways for rapid intercommunication throughout the body; while acupuncture points may correspond to gaps in the fibres or fibres oriented at right angles to the surface of the skin. The sum total of the electrical and electromechanical activities of the liquid crystalline continuum constitutes a "body consciousness" that works in tandem with the "brain consciousness" of the nervous system. We have reviewed supporting evidence from biochemistry, cell biology, biophysics and neurophysiology, and have suggested the following experiments to test our hypothesis.

1. Dielectric measurements on oriented samples of collagen fibres, to ascertain the anisotropy of conductivity along and across the fibres (see p. 8).

2. Dielectric measurements on the conductivities of oriented samples of collagen fibres equilibrated with different anaesthetics, to ascertain the decrease in conductivity compared with samples equilibrated with water (see p. 13).

3. Examination of collagen fibre alignments in skin biopsies at acupuncture points and meridians - with corroborative skin conductance measurements - compared with non-acupuncture, non-meridian areas. This is to ascertain the association of meridians with oriented fibres and acupoints with gaps or with fibres oriented at right angles to the surface of the skin ( pp. 9-10).

4. Alignment of collagen fibres in the direction of an applied electric field, predicted from the anisotropy in electrical conductivity along and across the fibre (p. 10).

5. Simultaneous measurements of EEG/MEG and skin conductances of acupuncture points of patients under chemical anaesthesia to detect correlated and uncorrelated activities between brain and body consciousness (p. 13).

6. Simultaneous measurements of EEG/MEG and skin conductances of acupuncture points of patients under acupuncture anaesthesia to detect possible uncorrelated activities between brain and body consciousness (p.13).

It is reasonable to conclude that under normal, healthy conditions, body and brain consciousness mutually inform and condition each other, and that the unity of our conscious experience and our state of health depends on the complete coherence of brain and body. Traditional Chinese medicine based on the acupuncture meridian system places the emphasis of health on the coherence of body functions which harmonizes brain *to* body, which makes perfect sense if one recognizes the brain as part of the body. Western medicine, by contrast, has yet no concept of the whole, and is based, at the very outset, on a Cartesian divide between mind and brain, and brain and body.

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### New analysis explains collagen’s force

Experiments and simulations show that adding or removing water makes the material push and pull.

**David L. Chandler | MIT News Office
January 22, 2015**

[Press Inquiries](http://news.mit.edu/2015/collagen-mechanics-water-0122#press-inquiry-section)

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### COMMENT

Research combining experimental work and detailed molecular simulations has revealed, for the first time, the complex role that water plays in collagen — a protein that is a component of tendons, bone, skin and other structural tissues in the body.

The new analysis reveals an important mechanism that had never been observed before: Adding even small amounts of water to, or removing water from, collagen in tendons can generate surprisingly strong forces, as much as 300 times stronger than the forces generated by muscles. The findings are reported this week in the journal Nature Communications by researchers at MIT and the Max Planck Institute for Colloids and Interfaces in Germany.

“We don’t really know the physiological role of water” in the human body’s collagen-based tissues, explains Professor Markus Buehler, head of MIT’s Department of Civil and Environmental Engineering and a co-author of the paper. “Here we show that it can develop significant forces, especially in tendons, which are thought of as a passive material.”

One of the challenges in previous studies has been that natural biological samples are all different, Buehler says — so trying to determine the underlying causes of variability is tricky. In the new work, the team was able to study the same samples under a variety of conditions, enabling them to probe the causes of variations.

Then, these same materials were analyzed using an atom-by-atom computer model that can simulate the structure down to the level of individual molecules, providing a detailed view of the underlying mechanisms. The molecular simulations, carried out at MIT by Buehler and postdoc Shu-Wei Chang, matched and complemented the experimental results observed by the team members in Germany, led by Professor Peter Fratzl.

**The real and the virtual**

“We can look at the same scale, the same phenomena, in both experiments and simulations,” Buehler says. “We’re very excited by the results,” he adds, because the simulations make it possible to view “mechanisms that you cannot easily measure” in physical experiments.

Chang explains that based solely on the experimental data, there are two possible explanations for the behavior of the tendon material — but the simulations reveal that one of these explanations is infeasible. The researchers showed that within the complex structure of the protein chains that make up tendon collagen, the addition of water causes some parts of the molecule extend, and others to shrink.

The balance between the two mechanisms determines whether there is an overall shrinkage or extension of collagen molecules, Chang says — but overall, when water is removed from the molecular structure, it shrinks.

**Powerful forces**

The pull of that contraction is startlingly large: The force the drying process exerts “is almost three orders of magnitude greater than the forces generated by muscles,” Chang says. It remains to be understood what, if any, role those forces play in normal biological functioning.

Whatever the function of this process in the body, it could potentially be harnessed through tissue engineering and used for other purposes, Buehler says: “We could use water as a driver, as one of the variables to control the material.” Previously, he adds, “We would not worry about the amount of water in the material.” But now it’s possible to envision, for example, “a self-assembling system where water is regulating the process.”

Scientists might also be able to get the contrary characteristics of different biological materials to work in concert. For example, combining a material like spider silk — which actually shrinks with the addition of moisture — with a material like tendon collagen could yield a hybrid structure that doesn’t expand or shrink as humidity varies, Buehler suggests, providing a very stable structure.

In addition, the methods used in this analysis, combining detailed molecular modeling with direct experimental observation, could also be applied to many other biological materials, Chang says.

Sandra Shefelbine, an associate professor of mechanical and industrial engineering at Northeastern University who was not connected with this research, says the MIT team’s analysis “is an excellent example of how computational molecular models can be used in coordination with experiments to discover mechanisms at the atomic level.” David Mooney, a professor of bioengineering at Harvard University, adds that “this is a very striking finding, as it reveals new aspects of the structure and function of collagen, and is likely to lead to many new studies.”

The work was supported by the Alexander von Humboldt Foundation, the Max Planck Society, the German Research Foundation, the U.S. Office of Naval Research, and the National Institutes of Health.

### Relationship of acupuncture points and meridians to connective tissue planes

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Feature Article

### Relationship of acupuncture points and meridians to connective tissue planes

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See additional note

### Jason A. Yandow

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#### Abstract

Acupuncture meridians traditionally are believed to constitute channels connecting the surface of the body to internal organs. We hypothesize that the network of acupuncture points and meridians can be viewed as a representation of the network formed by interstitial connective tissue. This hypothesis is supported by ultrasound images showing connective tissue cleavage planes at acupuncture points in normal human subjects. To test this hypothesis, we mapped acupuncture points in serial gross anatomical sections through the human arm. We found an 80% correspondence between the sites of acupuncture points and the location of intermuscular or intramuscular connective tissue planes in postmortem tissue sections. We propose that the anatomical relationship of acupuncture points and meridians to connective tissue planes is relevant to acupuncture's mechanism of action and suggests a potentially important integrative role for interstitial connective tissue. Anat Rec (New Anat) 269:257–265, 2002. © 2002 Wiley-Liss, Inc.

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## INTRODUCTION

During acupuncture treatments, fine needles traditionally are inserted at specific locations of the body known as acupuncture points. According to classic Chinese theory, acupuncture points are linked together in a network of “meridians” running longitudinally along the surface of the body (Figure [1](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig1)). Despite considerable efforts to understand the anatomy and physiology of acupuncture points and meridians, the definition and characterization of these structures remains elusive (NIH Consensus Statement, [1997](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib24)).

Despite considerable efforts to understand the anatomy and physiology of acupuncture points and meridians, the definition and characterization of these structures remains elusive.

The goal of this article is to present evidence supporting a conceptual model linking traditional Chinese acupuncture theory with conventional anatomy. We hypothesize that the network of acupuncture points and meridians can be viewed as a representation of the network formed by interstitial connective tissue and that this relationship is relevant to acupuncture's therapeutic mechanism.

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#### Figure 1.

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Acupuncture meridians of the arm. Acupuncture points were located by palpation in a living subject, according to anatomical guidelines provided in a major reference acupuncture textbook (Cheng, [1987](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib5)). Connective tissue planes associated with Yin meridians are more inward and deep, compared with the generally outward and superficial planes associated with Yang meridians.

#### TRADITIONAL CONCEPTS

Acupuncture meridians are traditionally thought to represent “channels” through which flows “meridian qi” (Kaptchuk, [2000](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib15)). Although the concept of meridian qi has no known physiological equivalent, terms used in acupuncture texts to describe the more general term “qi” evoke dynamic processes such as communication, movement, or energy exchange (O'Connor and Bensky, [1981](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib25)). Disruption of the meridian channel network is believed to be associated with disease, and needling of acupuncture points is thought to be a way to access and influence this system (Cheng, [1987](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib5)).

Charts representing acupuncture points and meridians date as far back as 300 B.C. (Veith, [1949](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib34)). Modern acupuncture charts indicate 12 principal meridians “connecting” the limbs to the trunk and head. In addition, many other “accessory” meridians are also described, as well as deep “internal branches” starting at specific points on the principal meridians and reaching internal organs. The names of the principal meridians (e.g., lung, heart) represent physiological functions thought to be specifically related to each meridian, rather than the actual lung or heart organ itself. One meridian named Triple Heater is thought to be related to temperature balance between different parts of the body. Acupuncture points are mostly located along the meridians, although “extra” points outside the meridian system are also believed to exist. 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.

The Chinese character signifying acupuncture point also means “hole” (O'Connor and Bensky, [1981](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib25)), conveying the impression that acupuncture points are locations where the needle can gain access to some deeper tissue components. Modern acupuncture textbooks contain visual charts as well as written guidelines for locating each acupuncture point. These guidelines refer to anatomical landmarks (such as bony prominences, muscles, or tendons) as well as proportional measurements (e.g., fraction of distance between elbow and wrist) (Cheng, [1987](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib5)). During acupuncture treatments, acupuncturists use these landmarks and measurements to determine the location of each point within approximately 5 mm. Precise point location within this range is achieved by palpation, during which the acupuncturist searches for a slight depression or yielding of the tissues to light pressure.

#### ARE ACUPUNCTURE POINTS DIFFERENT FROM SURROUNDING TISSUE?

Over the past 30 years, studies aimed at understanding the acupuncture point/meridian system from a “Western” perspective mainly have searched for distinct histological features that might differentiate acupuncture points from surrounding tissue. Seveal structures, such as neurovascular bundles (Rabischong et al., [1975](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib28); Senelar, [1979](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib30); Bossy, [1984](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib4)), neuromuscular attachments (Liu et al., [1975](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib20); Gunn et al., [1976](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib12); Dung, [1984](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib10)), and various types of sensory nerve endings (Shanghai Medical University, [1973](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib31); Ciczek et al., [1985](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib8)), have been described at acupuncture points. However, none of these studies included statistical analyses comparing acupuncture points with appropriate “nonacupuncture” control points.

Other studies have turned their attention to possible physiological differences between acupuncture points and surrounding tissues. Skin conductance has been reported by several investigators to be greater at acupuncture points compared with control points (Reishmanis et al., [1975](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib29); Comunetti et al., [1995](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib9)). Several factors, on the other hand, are known to affect skin conductance (e.g., pressure, moisture, skin abrasion; Noordegraaf and Silage, [1973](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib23); McCarroll and Rowley, [1979](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib22)), and to date, no study has both controlled for these factors and included sufficient numbers of observations to confirm these findings. Attempts to identify anatomical and/or physiological characteristics of acupuncture points, therefore, have remained mostly inconclusive.

Ancient acupuncture texts contain several references to “fat, greasy membranes, fasciae and systems of connecting membranes” through which qi is believed to flow (Matsumoto and Birch, [1988](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib21)), and several authors have suggested that a correspondence may exist between acupuncture meridians and connective tissue (Matsumoto and Birch, [1988](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib21); Oschman, [1993](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib26); Ho and Knight, [1998](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib13)). Recent work done in our laboratory has begun to provide experimental evidence in support of this hypothesis. We have characterized a connective tissue response to acupuncture needling that is quantitatively different at acupuncture points compared with control points (Langevin et al., [2001b](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib18)) and that may constitute an important clue to the nature of acupuncture points and meridians.

#### BIOMECHANICAL RESPONSE TO NEEDLING: “NEEDLE GRASP”

An important aspect of traditional acupuncture treatments is that acupuncture needles are manually manipulated after their insertion into the body. Needle manipulation typically consists of rapid rotation (back-and-forth or one direction) and/or pistoning (up-and-down motion) of the needle (O'Connor and Bensky, [1981](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib25)). During needle insertion and manipulation, acupuncturists aim to elicit a characteristic reaction to acupuncture needling known as “de qi” or “obtaining qi.” 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” (Yang, [1601](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib35)). We refer to this biomechanical phenomenon as “needle grasp.”

According to traditional teaching, de qi is essential to acupuncture's therapeutic effect (O'Connor and Bensky, [1981](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib25)). One of the most fundamental principles underlying acupuncture is that acupuncture needling is thought to be a way to access and influence the meridian network. The characteristic de qi reaction, perceived by the patient as a needling sensation and by the acupuncturist as needle grasp, is thought to be an indication that this goal has been achieved (Cheng, [1987](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib5)). The biomechanical phenomenon of needle grasp, therefore, is at the very core of acupuncture's theoretical construct.

Needle grasp is enhanced clinically by manipulation (rotation, pistoning) of the acupuncture needle. In previous human and animal studies using a computerized acupuncture-needling instrument (Langevin et al., [2001b](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib18), [2002](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib19)), we have quantified needle grasp by measuring the force necessary to pull the acupuncture needle out of the skin (pullout force). We have shown that pullout force is indeed markedly enhanced by rotation of the needle. Needle grasp, therefore, is a measurable tissue phenomenon associated with acupuncture needle manipulation. In a quantitative study of needle grasp in 60 healthy human subjects (Langevin et al., [2001b](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib18)), we measured pullout force 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. We found that pullout force was on average 18% greater at acupuncture points than at corresponding control points. We also found that needle manipulation increased pullout force at control points as well as at acupuncture points. Needle grasp, therefore, is not unique to acupuncture points, but rather is enhanced at those points.

Needle grasp is not unique to acupuncture points but rather is enhanced at those points.

#### ROLE OF CONNECTIVE TISSUE IN NEEDLE GRASP

Although previously attributed to a contraction of skeletal muscle, we have shown that needle grasp is not due to a muscle contraction but rather involves connective tissue (Langevin et al., [2001a](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib17), [2002](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib19)). In both in vivo and in vitro experiments, we have found that, during acupuncture needle rotation, connective tissue winds around the acupuncture needle, creating a tight mechanical coupling between needle and tissue. This needle-tissue coupling allows further movements of the needle (either rotation or pistoning) to pull and deform the connective tissue surrounding the needle, delivering a mechanical signal into the tissue.

Observation under a microscope of an acupuncture needle inserted into dissected rat subcutaneous tissue reveals that a visible “whorl” of tissue can be produced with as little as one turn of the needle (Figure [2](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig2)A). When the needle is placed flat onto the subcutaneous tissue surface and then rotated, the tissue tends to adhere to and follow the rotating needle for 180 degrees, at which point the tissue adheres to itself and further rotation results in formation of a whorl. This phenomenon can be observed to varying degrees with acupuncture needles of different materials (stainless steel, gold) as well as with other objects not customarily used as acupuncture tools such as regular hypodermic needles, glass micropipettes, siliconized glass, and Teflon-coated needles. An important factor appears to be the diameter of the rotating needle. Acupuncture needles are very fine (250–500 μm diameter). With needles greater than 1 mm in diameter, the tissue invariably follows the rotating needle for less than 90 degrees and then falls back, failing to stick to itself and initiate winding. Initial attractive forces between the rotating needle and tissue, thus, may be important to initiate the winding phenomenon. These may include surface tension and electrical forces and may be influenced by the material properties of the needle.

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#### Figure 2.

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**A:** Formation of a connective tissue “whorl” with needle rotation. Rat subcutaneous connective tissue was dissected and placed in physiological buffer under a dissecting microscope. An acupuncture needle was inserted through the tissue and progressively rotated. Numbers 0 through 7 indicate numbers of needle revolutions. A visible whorl of connective tissue can be seen with as little as one revolution of the needle. **B:** Scanning electron microscopy imaging of reusable gold (left) and disposable stainless steel (right) acupuncture needles. Original magnification, 350×. **C,D:** Scanning electron microscopy of gold (C) and stainless steel (D) needles. Original magnification, 3,500×. The surface of the gold needle is visibly rougher than that made of stainless steel. Scale bars = 2.5 mm in A, 100 μm in B, 10 μm in C,D.

When we compared two equal diameter acupuncture needles, one reusable needle made of gold (ITO, Japan) and one disposable made of stainless steel (Seirin, Japan), the gold needle appeared to initiate winding more readily than the stainless steel one. Scanning electron microscopy images of the two needles (Figure [2](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig2)B–D) showed that the gold needle had a rougher surface, which may have more successfully “engaged” the tissue during the initiation of winding. These observations also suggest that mechanical coupling between needle and tissue can occur even when the amplitude of needle rotation is very small (less than 360 degrees) as commonly used in clinical practice. We have also shown that, with back-and-forth needle rotation, which is generally preferred clinically over rotation in one direction, winding alternates with unwinding, but unwinding is incomplete, resulting in a gradual buildup of torque at the needle–tissue interface (Langevin et al., [2001b](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib18)).

The importance of establishing a mechanical coupling between needle and tissue is that mechanical signals (1) are increasingly recognized as important mediators of information at the cellular level (Giancotti and Ruoslahti, [1999](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib11)), (2) can be transduced into bioelectrical and/or biochemical signals (Banes et al., [1995](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib1); Lai et al., [2000](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib16)), and (3) can lead to downstream effects, including cellular actin polymerization, signaling pathway activation, changes in gene expression, protein synthesis, and extracellular matrix modification (Chicurel et al., [1998](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib6); Chiquet, [1999](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib7)). Changes in extracellular matrix composition, in turn, can modulate the transduction of future mechanical signals to and within cells (Brand, [1997](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib3)). Recent evidence suggests that both tissue stiffness and stress-induced electrical potentials are affected by connective tissue matrix composition (Bonassar et al., [1996](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib2)) and that changes in matrix composition in response to mechanical stress may be an important form of communication between different cell types (Swartz et al., [2001](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib32)). Acupuncture needle manipulation, thus, may cause lasting modification of the extracellular matrix surrounding the needle, which may in turn influence the various cell populations sharing this connective tissue matrix (e.g., fibroblasts, sensory afferents, immune and vascular cells).

In addition, we have hypothesized previously that, in the vicinity of the needle, acupuncture-induced actin polymerization in connective tissue fibroblasts may cause these fibroblasts to contract, causing further pulling of collagen fibers and a “wave” of connective tissue contraction and cell activation spreading through connective tissue (Langevin et al., [2001a](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib17)). This mechanism may explain the phenomenon of “propagated sensation,” i.e., the slow spreading of de qi sensation sometimes reported by patients along the course of an acupuncture meridian (Huan and Rose, [2001](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib14)).

#### CORRESPONDENCE OF ACUPUNCTURE POINTS AND MERIDIANS TO CONNECTIVE TISSUE PLANES

Acupuncture meridians tend to be located along fascial planes between muscles, or between a muscle and bone or tendon (Cheng, [1987](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib5)). A needle inserted at the site of a connective tissue cleavage plane will penetrate first through dermis and subcutaneous tissue, then through deeper interstitial connective tissue. In contrast, a needle inserted away from a connective tissue plane will penetrate dermis and subcutaneous tissue, then reach a structure such as muscle or bone. Because needle grasp involves interaction of the needle with connective tissue (Langevin et al., [2002](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib19)), the enhanced needle grasp response at acupuncture points may be due to the needle coming into contact with more connective tissue (subcutaneous plus deeper fascia) at those points. The presence of needle grasp at control points as well as at acupuncture points is consistent with some amount of connective tissue (subcutaneous) being present at all points. This concept is illustrated in Figure [3](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig3), which shows ultrasound images of the same acupuncture point and corresponding control point in two normal human subjects. The acupuncture point is located on the skin overlying the fascial plane separating the vastus lateralis and biceps femoris muscles. The control point, located 3 cm away from the acupuncture point, is located over the belly of the vastus lateralis muscle.

[<img class="inline-figure\_\_image" alt="Figure&nbsp;3. " src="http://onlinelibrary.wiley.com/store/10.1002/ar.10185/asset/image\_n/nfig003.jpg?v=1&amp;t=irrycw08&amp;s=864285ce5e11d291625cd465cfb642618a6e8805" />](http://onlinelibrary.wiley.com/enhanced/figures/doi/10.1002/ar.10185#figure-viewer-fig3)

#### Figure 3.

* [Open in figure viewer](http://onlinelibrary.wiley.com/enhanced/figures/doi/10.1002/ar.10185#figure-viewer-fig3)
* [Download Powerpoint slide](http://api.onlinelibrary.wiley.com/asset/v1/doi/10.1002/ar.10185/powerpoint/image_n/nfig003.jpg?l=SkaBT8QEx2oQvlmRbdVKIoGJN0u5BUimepF3Szv48vtYv6hWFyJRnn0R%2FFT0RJrv&s=%22a790f6d71fb84d7781cba5aa75cb1ff4%22&a=wol)

Ultrasound imaging of acupuncture (AP) and control (CP) points. Acupuncture point GB32 was located by palpation in two normal human volunteers, as well as a control point located 3 cm away from the acupuncture point. After marking both points with a skin marker, ultrasound imaging was performed with an Acuson ultrasound machine equipped with a 7 MHz linear probe. A visible connective tissue intramuscular cleavage plane can be seen at acupuncture points but not at control points. V.Lat, vastus lateralis; B.Fem, biceps femoris; Sc, subcutaneous tissue.

To investigate the hypothesis that acupuncture points are preferentially located over fascial planes, we marked the location of all acupuncture points and meridians in a series of gross anatomical sections through the human arm (Research Systems Visible Human CD, Boulder, CO) (Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4)). The interval between sections corresponded to one “cun” or anatomical inch (a proportional unit measurement used in acupuncture textbooks to locate acupuncture points) representing 1/9 of the distance between the elbow crease and the axially fold (in this case 2.5 cm). This section interval allowed us to include all acupuncture points located on the six principal meridians of the arm between the olecranon (Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4), section 0) and the superior edge of the humeral head (Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4), section 12). In each section, we marked all acupuncture points and the intersection of all meridians with the plane of section (meridian intersection).

[](http://onlinelibrary.wiley.com/enhanced/figures/doi/10.1002/ar.10185#figure-viewer-fig4)

#### Figure 4.

* [Open in figure viewer](http://onlinelibrary.wiley.com/enhanced/figures/doi/10.1002/ar.10185#figure-viewer-fig4)
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Location of acupuncture points and meridians in serial gross anatomical sections through a human arm. The interval between sections corresponds to one “cun” or anatomical inch representing 1/9 of the distance between the elbow crease and the axially fold (in this case, 2.5 cm). Sections begin at the olecranon (0) and end at the superior edge of the humeral head (12). Acupuncture points, meridian intersections, and specific meridians are labeled according to the legend.

Acupuncture points and meridian intersections were located according to written guidelines (based on anatomical landmarks and proportional measurements) and acupuncture charts provided in a major textbook of traditional Chinese acupuncture (Cheng, [1987](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib5)). Because connective tissue planes were visible on the anatomical sections, every attempt was made to minimize bias by adhering to these guidelines as objectively as possible. In a live subject, palpation is used to locate acupuncture points precisely once the approximate location has been determined by using anatomical landmarks and proportional measurements. For some points, body parts are manipulated and positioned in a specific way to perform this palpation. In the case of our postmortem sections, the points needed to be located in the anatomical position without the benefit of palpation. When written descriptions referred to anatomical landmarks palpable in the anatomical position (such as the olecranon or biceps tendon), we used the position of the bones, tendons, and muscles in the cross-sections to determine where these landmarks would have been palpable on the surface of the body. For those points where palpation is traditionally performed in a position other than the anatomical position, we guided ourselves on (1) charts from acupuncture textbooks drawn in the anatomical position, and (2) a live human model on which we located acupuncture points by palpating them in the position specified in the textbook, and then placed the model's arm in the anatomical position (Figure [1](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig1)). Textbook guidelines referring to proportional measurements (such as a fraction of the distance between the elbow crease and axially fold) are traditionally defined in the anatomical position. We, therefore, were able to apply these measurements directly to the postmortem tissue sections by determining appropriate section numbers based on the section interval, and making measurements on individual cross-sections.

By using these guidelines, we marked three acupuncture points on the heart meridian (H3, H2, H1), two points on the pericardium meridian (P3, P2), five points on the lung meridian (L5, L4, L3, L2, L1), five points on the large intestine meridian (LI11, LI12, L113, LI14), five points on the triple heater meridian (SJ10, SJ11, SJ12, SJ13, SJ14), and four points on the small intestine meridian (SI8, SI9, SI10, SI11) for a total of 24 acupuncture points. Meridians intersected with the plane of section at 51 other sites that were not acupuncture points.

As shown in Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4), three of six meridians included portions that followed fascial planes between muscles (biceps/triceps [heart meridian, Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4), sections 2–7], biceps/brachialis [lung meridian, Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4), sections 4–5], and brachialis/triceps [large intestine meridian, Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4), sections 3–5]). Some points on those meridians (H2, LI14, H1) also appeared to be located at the intersection of two or more fascial planes. Two other meridians included portions that followed intramuscular cleavage planes [between heads of biceps (pericardium meridian, Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4), sections 5–7) and triceps (triple heater meridian, Figure [4](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#fig4), sections 2–6)]. One meridian (small intestine meridian) did not itself follow any recognizable inter- or intramuscular plane. However, three out of the four acupuncture points on this portion of the meridian (SI9, 10, and 11) clearly coincided with the intersection of multiple fascial planes. 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.

To estimate the probability that such an event would be due to chance, we tested a model representing the middle portion of the arm (sections 2–7) approximated to a cylinder 12.5 cm long and 30 cm in circumference, and including eight acupuncture points and 28 meridian intersections. Assuming that the average width of the five major fascial planes of the arm (triceps/triceps, biceps/brachialis, brachialis/triceps, between heads of triceps, and between heads of biceps) is 1/60 of the circumference of the cylinder (or approximately 5 mm), 1/12 of the surface of the cylinder will intersect with a fascial plane. If we also assume that the “width” of an acupuncture point is 5 mm, the probability that a random point in any given section of the cylinder will fall on a fascial plane is 1/12 or 0.083. Using the hypergeometric distribution (sampling without replacement), the probability that either six or seven of eight points (75 or 87%) randomly distributed in six sections through the cylinder would fall on fascial planes is P < 0.001. Likewise, taking 5 mm as the “width” of a meridian, the probability of 14 of 28 meridian intersections (50%) falling on fascial planes is also P < 0.001.

These findings suggest that the location of acupuncture points, determined empirically by the ancient Chinese, was based on palpation of discrete locations or “holes” where the needle can access greater amounts of connective tissue. Some portions of meridians clearly follow one or more successive connective tissue planes, whereas others appear to simply “connect the dots” between points of interest. On the basis of these findings and our previous experimental results (Langevin et al., [2001b](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib18), [2002](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib19)), we propose that acupuncture charts may serve as a guide to insert the needle into interstitial connective tissue planes where manipulation of the needle can result in a greater mechanical stimulus. A greater therapeutic effect at acupuncture points may be at least partly explained by more powerful mechanical signaling and downstream effects at those points.

We chose the arm for this study because it offers relatively simple anatomy and widely spaced fascial planes (compared with, for example, the forearm) and also because the arm illustrates how both meridians and connective tissue planes “connect” the arm with the shoulder girdle and chest (see below). We, however, expect that similar results would be obtained in other body regions. In the forearm, leg, and thigh, meridians also appear to generally follow connective tissue planes separating muscles or within muscles. On the trunk, meridians close to the midline (kidney, stomach, spleen, and bladder) run longitudinally in the front and back, whereas more laterally placed meridians (liver, gall bladder) run obliquely, paralleling the orientation of main muscle groups and the connective tissue planes separating them. On the face, meridians criss-cross each other in an intricate pattern compatible with the complexity of facial muscular and connective tissue structures.

## MERIDIAN/CONNECTIVE TISSUE NETWORK

Acupuncture meridians are believed to form a network throughout the body, connecting peripheral tissues to each other and to central viscera (Kaptchuk, [2000](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib15)). Interstitial connective tissue also fits this description. Interstitial “loose” connective tissue (including subcutaneous tissue) constitutes a continuous network enveloping all limb muscles, bones, and tendons, extending into connective tissue planes of pelvic and shoulder girdles, abdominal and chest walls, neck, and head. This tissue network is also continuous with more specialized connective tissues such as periosteum, perimysium, perineurium, pleura, peritoneum, and meninges. A form of signaling (mechanical, bioelectrical, and/or biochemical) transmitted through interstitial connective tissue, therefore, may have potentially powerful integrative functions. Such integrative functions may be both spatial (“connecting” different parts of the body) as well as across physiological systems (connective tissue permeates all organs and surrounds all nerves, blood vessels, and lymphatics). In addition, because the structure and biochemical composition of interstitial connective tissue is responsive to mechanical stimuli, we propose that connective tissue plays a key role in the integration of several physiological functions (e.g., sensorineural, circulatory, immune) with ambient levels of mechanical stress.

One of the salient features of acupuncture theory is that the needling of appropriately selected acupuncture points has effects remote from the site of needle insertion, and that these effects are mediated by means of the acupuncture meridian system (O'Connor and Bensky, [1981](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib25)). To date, physiological models attempting to explain these remote effects have invoked systemic mechanisms involving the nervous system (Ulett et al., [1998](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib33); Pomeranz, [2001](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib27)). A mechanism initially involving signal transduction through connective tissue, with secondary involvement of other systems including the nervous system, is potentially closer to traditional Chinese acupuncture theory, yet also compatible with previously proposed neurophysiological mechanisms.

## CONCEPTUAL MODEL FOR ACUPUNCTURE POINTS AND MERIDIANS

Rather than viewing acupuncture points as discrete entities, we propose that acupuncture points may correspond to sites of convergence in a network of connective tissue permeating the entire body, analogous to highway intersections in a network of primary and secondary roads. One of the most controversial issues in acupuncture research is whether the needling of acupuncture points has “specific” physiological and therapeutic effects compared with nonacupuncture points (NIH Consensus Statement, [1997](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#bib24)). By using the road analogy, interaction of an acupuncture needle with connective tissue will occur even at the smallest connective tissue “secondary road.” Needling a major “highway intersection,” however, may have more powerful effects, perhaps due to collagen fiber alignment leading to more effective force transduction and signal propagation at those points.

In summary, the anatomical correspondence of acupuncture points and meridians to connective tissue planes in the arm suggests plausible physiological explanations for several important traditional Chinese medicine concepts summarized in Table [1](http://onlinelibrary.wiley.com/doi/10.1002/ar.10185/full#tbl1). We propose that acupuncture needle manipulation produces cellular changes that propagate along connective tissue planes. These changes may occur no matter where the needle is placed but may be enhanced when the needle is placed at acupuncture points. This conceptual model would be further strengthened by an expanded investigation of the whole body, including lower extremity, trunk, and head. The anatomy of acupuncture points and meridians, thus, may be an important factor that will begin to unravel the veil of mystery surrounding acupuncture.

Table 1. Summary of proposed model of physiological effects seen in acupuncture

| **Traditional Chinese medicine concepts** | **Proposed anatomical/physiological equivalents** |
| --- | --- |
| Acupuncture meridians | Connective tissue planes |
| Acupuncture points | Convergence of connective tissue planes |
| Qi | Sum of all body energetic phenomena (e.g. metabolism, movement, signaling, information exchange) |
| Meridian qi | Connective tissue biochemical/bioelectrical signaling |
| Blockage of qi | Altered connective tissue matrix composition leading to altered signal transduction |
| Needle grasp | Tissue winding and/or contraction of fibroblasts surrounding the needle |
| De qi sensation | Stimulation of connective tissue sensory mechanoreceptors |
| Propagated de qi sensation | Wave of connective tissue contraction and sensory mechanoreceptor stimulation along connective tissue planes |
| Restoration of flow of qi | Cellular activation/gene expression leading to restored connective tissue matrix composition and signal transduction |

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#### Biographical Information

Dr. Langevin is a Research Assistant Professor of Neurology at the University of Vermont College of Medicine, as well as a licensed acupuncturist. Her research interests are the mechanism of acupuncture, connective tissue-nervous system interactions, and pain mechanisms. Mr. Yandow is the Research Assistant who produced the photomontages shown in this study.

## LINKS

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