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BioEnergy Definitions and Research Guidelines

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Abstract

A model for the functional and observable interrelation among the various components in a physical bioenergy system is presented. The analogy is made between electric circuits and electromagnetic interactions, and contact and noncontact bioenergy transfer. It is postulated that there exists some form of bioenergy which has the capacity to do work and that this energy behaves in a manner similar to electricity in that the physical concepts of electromotive force, current, and impedance have their equivalents in bioenergy. It is further postulated that these analogous components are related by an equivalent to Ohm's and other physical laws of electricity. This is extended to a conjecture that bioenergy healing is the transfer of information from a practitioner to a healee.

Research guidelines for bioenergy measurements are presented including basic measurement practices for electrical and electromagnetic systems through direct measurements and the use of indirect measurement experiments for detecting these or other forms of bioenergy transfer. The research guidelines are divided into two sections: those involving direct measurement of the physical electrical properties of a practitioner, in particular the difficulties associated with electrical measurements of extremely low level signals outside of a Faraday shield or electromagnetic measurements outside of a radio frequency (RF) anechoic chamber; and those for conducting experiments in which the effects of bioenergy are being investigated on the healee or other target system without direct measurements of the means for bioenergy transfer.

Section 1. Introduction

It is clear that the concept of bioenergy is not well-defined and that various researchers and practitioners in the field of complementary and alternative medicine (CAM) have

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different intuitive understandings of the concept as a result of their diverse educational and experiential backgrounds. While the concept is broadly meant to describe the basis of healing in a varied set of practices, including external qigong, reiki, therapeutic touch and distant healing, it does not identify a particular type of energy, *per se*. In fact, it has been argued that several CAM practices, *e.g.* distant healing, appear to act in a manner described as nonlocal, nontemporal and nonmediated and thus do not conform to commonly accepted definitions of energy [Dossey, 1992]. The issue is further confounded in that several practices, *e.g.* external qigong, are performed both at close range (with the practitioner's hands held inches from the subject), where generally accepted rules of energy may be followed, as well as over a range of many miles [Sancier and Hu, 1991; Yan *et al.*, 1999], in a manner, similar to that of distant healing, that appears to defy spatial and temporal energetics. In the present paper, however, discussion is limited to that portion of the spectrum of bioenergy practices that do appear to follow conventional scientific concepts. To this end, the authors make the debatable assumptions that if there is a bioenergy, then it is detectable and measurable by physical instruments or biomarkers, that it is probably, at least in part, electrical, magnetic, and/or electromagnetic in nature, and that its transmission, reception and processing interface with cellular and molecular level events. Accordingly, our approach is to model the information signaling between practitioner and recipient, based first on principles of physics, and second on concepts of biology.

As a further caveat, this paper does not address consciousness and its associated concepts of spiritual energy that cannot fit into a conventional time, space, and information transmission framework. The authors are dealing with the concept of bioenergy as it manifests itself in real, measurable terms. A paper dealing with the issues of consciousness and non-energy related healing is being written by another group and so will not be considered further in this paper. In the sequel, the term bioenergy will be used to mean only the physically measurable dimension.

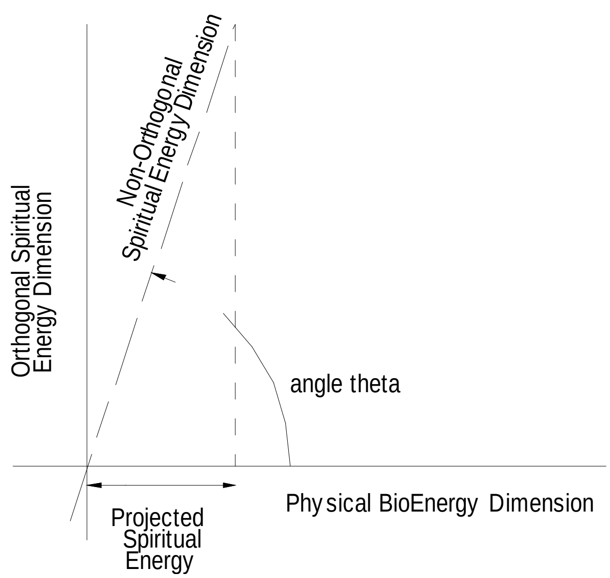

Figure 1 Dimensions of bioenergy and possible projection of spiritual energy on physical bioenergy.

The word bioenergy has been used to encompass a set of terms that may or may not belong in the same physical category. In western cultures, these terms include bioelectromagnetics and biofields when applied to energy medicine. The term subtle energy is also sometimes used, as are vital force and L-energy (for life energy). In eastern cultures, energy terms include qi or chi (China), ki (Japan), as well as prana (India) and mana (Hawaii / Philippines).

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There has been considerable work done in the past thirty years on measurement of external qi as physical energy. Apparently the majority of publications in this field are in Chinese and therefore are not easily accessible to the American scientific community. The few English language references dealing with bioenergy include a book by Lu [Lu, 1997] and a review of this book [Chen, 1997]. A more complete review by Chen is presently under review and another detailed one by L. Zha is in the Proceedings of the Samueli Hawaii Meeting of 2001. A thorough review of previous work on physical measurements of external qi is outside the scope of the present manuscript and the previous references are included as the most accessible material. It appears from these documents that the previous experiments had neither been done in a rigorously controlled way nor utilized instruments that are the current state-of-the-art. The documented experiments reveal, at best, very low levels of physical energy associated with external qi emission by qigong practitioners/healers.

In order to detect, measure, and analyze physical bioenergy, a descriptive framework which is internally consistent as well as consistent with physics is needed within which to formulate initial experiments as well as to interpret the results of those experiments. This methodology can also be used to explore the interactions between the postulated two forms of bioenergy in order to determine whether they do, in fact, form an orthogonal relationship and if not, the degree (angle theta in Figure 1) to which the spiritual bioenergy projects onto the physical bioenergy dimension. If the bioenergy analogies of the basic laws of electricity can be shown to hold, then there is motivation to assume that even more sophisticated laws hold providing the basis for a more complete understanding of bioenergy. Essentially, the authors hypothesize that at least an equivalence relation exists between electrical energy and bioenergy. This paper presents bioenergy related definitions and shows their relationship to electrical terms.

Once the descriptive framework and a working vocabulary is established, the second half of this paper discusses the research guidelines which should be used to insure reliable, reproducible, accurate, and supportable results. The research guidelines are further subdivided into the laboratory practices associated with the actual measurement of bioenergy (if the bioenergy is in the form of some electricity-related phenomena) and the laboratory practices that quantify the effects of bioenergy whether or not the effects are due to any particular causative mechanism.

Section 1 is this introduction. In Section 2 the basic concepts of electricity and electromagnetic fields are summarized with a concise expansion in the Appendix. In Section 3, bioenergy and analogous terms are defined. Research guidelines for the laboratory measurement of electrical and electromagnetic observables associated with bioenergy are presented in Section 4. Research guidelines associated with the design and analysis of experimental protocols for the measurement of the influence of bioenergy on various systems that do not directly measure the electrical and electromagnetic observables are presented in Section 5. Section 6 is a summary. Absent from this paper is any discussion of quantum or retro-causal events since they are being covered elsewhere.

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Section 2. Definitions of Common Physical Terms

In order to improve the exchange of information in the field of bioenergy, an agreed upon set of definitions of bioenergy related terms is required. The following is a brief review of concepts of energy from physics [Feynman, 1963] and an extension of these concepts to bioenergy. The interested reader is referred to the Appendix to this paper which has a more detailed explanation of the relationships among the following concepts and terms from electricity and basic physics. The definitions are listed here to prepare the reader for the subsequent discussion of bioenergy related definitions. Table 1juxtaposes these definitions from physics and electrical engineering with their associated biological definitions for easy comparison. The biological definitions in this table are expanded later in this paper but summarized in the table for convenience.

While these terms form the physical basis for equivalent or at least analogous terms in bioenergy, another level of abstraction can be used based on the concepts of information sources, information carrying signals, and receivers. In this view, the underlying physical layer of transferring information is intentionally hidden in order to allow the discussion of the transfer of bioinformation without deciding *apriori* what the physical mechanism is for that transfer to occur.

Figure 2 Block diagram of bioenergy transport mechanism components.

In this model we can define a bioenergy system as one which is comprised of:

- a source which generates energy and modulates it in some manner such that it conveys information
- a coupling mechanism connecting the bioenergy source to a transfer medium
- a transfer medium through which the bioenergy flows
- a coupling mechanism connecting the transfer medium bioenergy sink
- a terminal sink which includes a mechanism for the perception of information

The input and output coupling depend on properties of the source and the transfer medium, likewise for the sink. Perception is used rather than reception to imply some active process which uses some form of perceptual reasoning in processing the information based on its content.

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Table 1 Juxtaposed physical and biological definitions.

Physical Definition	Biological Definition
Energy: The capacity to do work (*i.e.*, to have an effect), usually expressed as the integral of power and the time over which that power is applied (*e.g.*, in electricity, kilowatt-hours as read by a home electrical meter).	**Bioenergy**: Energy generated by a biological system (*e.g.*, electrical, acoustic, thermal, chemical).
Motive Force: A force which causes something to move or flow.	
Electromotive force (EMF): A force which causes electrons to flow, usually measured in Volts (*e.g.*, a 1.5 Volt battery).	**Biomotive Force** (BMF): A force generated by a biological system which acts on living or non-living systems.
Current: The flow of electrons.	**Biocurrent**: The flow of electrons caused by a Biomotive force.
Power: A force and an entity on which it acts (*e.g.*, the electromotive force measured in Volts acting on electrons measured in Amperes of current yielding instantaneous Watts of electrical power. A 100 Watt (power) light bulb lit for one hour consumes 0.1 kilowatt-hours (energy) of electricity).	**Biopower**: The biomotive force (BMF) and the living or nonliving system on which it acts.
Field: A force which can cause action at a distance.	**Biofield:** A force associated with a biological system which can cause action at a distance.
Electric (Magnetic) Field: A static or slowly changing field associated with electric charge (magnetic dipoles).	**Bioelectric (Biomagnetic) Field**: A static or slowly changing electric (magnetic) field associated with a biological system.
Electromagnetic Field: A changing electric field and its associated orthogonal magnetic field which propagate in free space.	**Bioelectromagnetic Field**: An electromagnetic field generated by a living system which propagates in free space and is capable of transferring energy and information from one system to another.
Impedance: The proportionality constant relating the complex valued motive force and the movement of the entity on which it acts.	**Bioimpedance:** The proportionality constant relating the complex valued BMF and the entity on which it acts.
Electrical Impedance: The relationship between the EMF and current in a circuit $$Z = \frac{E}{I}$$ (*e.g.*, the impedance, *Z*, is measured in Ohms; the EMF, *E*, is measured in Volts; and the current, *I*, is measured in Amperes)	
Entropy: (thermodynamics, information theory) A measure of the disorderedness of a system. The higher the entropy, the more disordered it is.	**Bioentropy**: A measure of the disorderedness of a living system. The lower the bioentropy, the more organized it is.
Information: The decrease in uncertainty about a system usually expressed as a change in entropy or a ratio of *apriori* and *aposteriori* probability density functions.	**Bioinformation**: An entropy reducing signal generated by a biological system.

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Section 3. Definitions of Bioenergy and Analogous Terms

From the discussion of Section 1, it can be seen that the simple term bioenergy may not be sufficient to represent the transfer of healing power from one entity to another. One needs either to propose a new term or to define or postulate supporting terminology which is measurable and testable. In the following, analogies will be made between the electrical engineering terminology and the interaction between a practitioner and recipient. We begin with a definition of bioenergy

> **Bioenergy**: Energy generated by a biological system.

Since energy is the capacity to do work or cause an effect, the prefix here only limits the energy based on its source. This energy can be in the form of acoustic, thermal, electrical, kinetic, or other common forms. Bioenergy can also be chemical rather than physical in nature. The main example of chemical bioenergy is that stored in the high energy bond between the terminal phosphate and the next phosphate in the adenosine triphosphate (ATP) molecule. This energy is released upon hydrolysis of ATP to ADP and inorganic phosphate. In fact in the discipline of biochemistry, the field of bioenergetics deals mainly with ATP synthesis and hydrolysis in living systems. One example is that during muscle contraction, this energy drives the conformational change of the myosin molecule (an ATPase), resulting in the sliding of myosin filaments against actin filaments in the myofibrils. Another example of chemical bioenergy is the Na^+/K^+ ATPase, which pumps the ions using energy derived from hydrolysis of ATP. While external bioenergy (*e.g.,* emitted by the qigong practitioner/healer) is more easily explained in terms of physical energy, internal bioenergy (*e.g.,* internal qi circulated by the qigong practitioner/healer) could very well involve chemical energy. Detailed discussion of the chemical and mechanisms other than electrical is outside of the scope of this paper although these other forms of bioenergy are acknowledged.

Electrical Analogy

Let's begin by postulating that the practitioner possesses bioenergy, namely the capacity to do work, and in particular, the capacity to utilize that energy to transfer power to a recipient either by direct contact or through radiation and that the mechanism is electrical in nature. Since energy is the product of power and time, let's assume that time remains unchanged and any other constant of proportionality will be included in the measure of power. This implies that the total transfer of energy from the practitioner to the recipient is a linear function of the amount of time during which the practitioner directs energy to the recipient. We must, however, begin with the definition of a force which causes the energy to flow.

> **Biomotive Force** (BMF): A force generated by a biological system which acts on living or non-living systems.

Although the present discussion is focused on a force that causes electrical current to flow, the term is defined in a general sense allowing for other forces to readily fall within this definition of biomotive force. Since the force must act on an entity, we assume that that entity is electrons and hence we have a Biocurrent defined as:

> **Biocurrent**: The flow of electrons caused by a Biomotive force.

Having both a force (BMF) and an entity on which it acts (electrons), a bioimpedance can be defined which is related to the flow of Biocurrent.

> **Bioimpedance:** The proportionality constant relating the complex valued BMF and the entity on which it acts.

The importance of defining this as a complex valued quantity will become more apparent later in this paper.

If we further postulate that different practitioners have different abilities to heal given that they direct their energy for the same amount of time, then this leads to a definition of biopower as

> **BioPower**: The biomotive force (BMF) and the living or nonliving system on which it acts.

For example, if a practitioner "intends" his bioenergy to a certain recipient, then the practitioner's energy will flow to that recipient via some energy carrying entity such as electrons in the electrical analogy. Not wanting to limit the definition of biopower to electrical means, this definition is intentionally vague as to what the “living or nonliving system on which it acts” is. The BMF may be an electromotive force which acts on electrons, but it may equally well be another force which acts on something else. This “something else” is an energy transport mechanism which may be living or non-living. Only further experimentation will be able to allow for a more precise definition of biopower.

BioCircuits

Following the electrical analogy of circuits and equating this to therapeutic touch (as opposed to non-contact therapeutic touch), the driving force is BMF, the energy carrying entity is the electron, and the ability to transfer bioenergy from the recipient depends both on the internal impedance of the practitioner and the internal impedance of the recipient. There may be two components to each of these impedances. The two components which are assumed to be vector additive are the biochemical physical interface (touch) between the two and the intentions of the individuals. This can be drawn as a circuit as shown in Figure 3. With reference to the practitioner, this source of energy is comprised of the BMF_{pract}, the practitioner’s associated intentional impedance $R_{intent\text{-}p}$, and biochemical impedance $R_{biochem\text{-}p}$. On the right side in the figure is the recipient comprised of a biochemical impedance $R_{biochem\text{-}r}$, an intentional impedance $R_{intent\text{-}r}$, and a self-BMF BMF_{rec} which can enhance or decrease the flow of bioenergy.

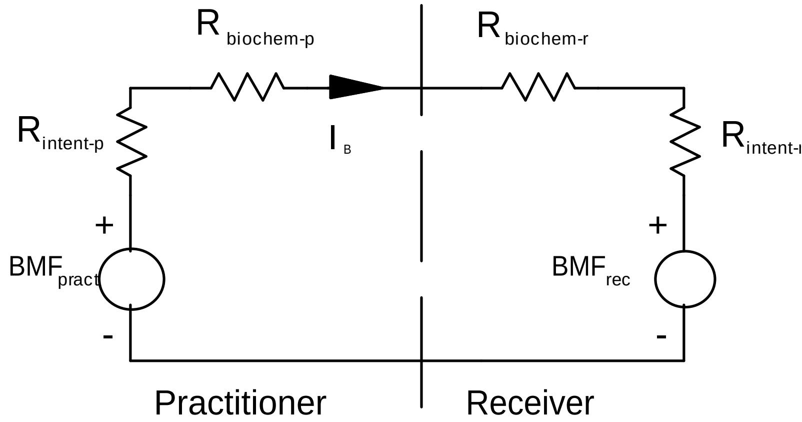

Figure 3 Bioenergy equivalent circuit.

As with electrical circuits, the maximum transfer of biopower from the practitioner to the recipient will occur when the impedances are matched (biopower is the rate at which bioenergy flows). There is an additional component which was not discussed in the earlier electrical explanation for the sake of simplicity and that is the interaction between the BMFs of the practitioner and recipient. Without proof, it is assumed that there exists a bioenergy equivalent of Kirkhoff's EMF law which states that the sum of the EMFs, or in this case BMFs, around a closed loop is zero. That is, the BMFs of both the practitioner and recipient can enhance or retard the transfer of bioenergy from the practitioner depending on their relative amplitudes and phase as well as that of the complex bioimpedances. This leads to the natural definition of the bioimpedance Z_B as the proportionality constant relating the complex valued BMF and the entity on which it acts, or, in the form of Ohm's law,

$$BMF = I_B * Z_B$$

Maximizing BioEnergy Transfer in a Circuit

Assuming that there is some way to measure the BMF and biocurrent (Voltage and current, or power), one can calculate the bioimpedances of the practitioner and recipient. It would be expected that if the previous relations hold, that is, the existence of BMF and biocurrent which have a proportional linear relation between them which is the bioimpedance, then the maximum transfer of biopower from the practitioner to the recipient would occur when there is a match between the impedances of the two. That is, the practitioner has the correct intention and biochemical makeup for the recipient's intention and biochemical makeup. The practitioner must need or desire or be motivated to heal and the recipient must need or desire or be motivated to be healed; the recipient must be, at least to some degree, either actively or passively receptive. Perhaps one can even extend this to include the concept of a transformer (facilitator) who helps to match the impedances of the practitioner and recipient through counseling or providing the right healing environment.

Mechanisms Of Bioenergy Coupling To Biological Systems

In the context of providing definitions and a model for bioenergy effects on living systems, the present section comprises a brief examination of the physiological basis of these phenomena. What is needed as a start, just as when setting out to understand the biological action of a molecular signal, is to identify the bioenergy receptor or receptive system, the transduction events, and the process being regulated. Subsequently, one hopes to know how the bioenergy-induced effects relate to other regulatory processes, including those mediated by endogenous bioenergy fields, so that the emerging field of energy medicine is provided with a base of support in an energy physiology. This brief overview will focus on three broad, overlapping categories of putative bioenergy receptors:

1. *molecular-level receptors,* including specific domains of cell membrane proteins and DNA;
2. *charge flux sites,* including ion conductance at and through the cell membrane, and moving electrons along protein fibers and DNA; and,
3. *energy field sites,* including endogenously-generated electric and electromagnetic fields.

Brief consideration will also be given to the possibility that water and small bioactive molecules serve as potential receivers and carriers of bioenergy signals. In light of the profusion of already identified conventional biological receptor types, it seems unlikely for there to be a single category of receptor that mediates bioenergy effects on living systems.

The mechanisms that cells evolved for detecting and responding to molecular signals have properties, *e.g.*, sensitivity, amplification and transduction, similar to those expected for reacting to bioenergy, *e.g.*, electromagnetic signals [Luben, 1995]. In both cases, for signals to affect intracellular activity, they must pass the high resistance barrier represented by the cell membrane. One possibility is that bioenergy fields act via known molecular signal transduction pathways, initiated via interactions with cell surface domains of membrane-spanning receptor proteins. This casts bioenergy in the role of ligand or affector that interfaces with receptors to induce a shape change. Such conformational changes modify the activity of neighboring membrane proteins, the best characterized of which are ion channel proteins, enzymes that mediate protein phosphorylation, and so-called G proteins that initiate cascades of intracellular events. Extremely low frequency (ELF) electromagnetic fields, for example, alter transmembrane Ca^{2+} concentrations [Walleczek, 1992; McLeod, 1995] and induce relatively rapid phosphorylation of specific receptor proteins in T-cell membranes [Lindstrom *et al.*, 2001]. While such ligands most commonly take the form of small molecules such as peptide hormones, cytokines and neurotransmitters, recent research suggests that diffusible gases (NO, CO), fatty acids (arachidonic acid, anandamide) and metals (zinc) can also serve this function. Since skin contains specialized cell surface receptors that respond to changes in mechanical energy (pressure), thermal energy (temperature) and UV irradiation [Rittie, Fisher, 2002], it is reasonable to generalize such response mechanisms to other types of bioenergy.

Other classes of molecular ligands that are lipophillic, notably steroids, pass through the cell membrane to regulate gene expression by coupling to intracellular receptors that subsequently bind to specific regions of DNA. Electromagnetic fields also appear capable of acting on specific regions of DNA, but not as a consequence of binding to either cell surface or intracellular receptors. Rather, “electromagnetic response elements” have been identified on "promoter" regions of DNA that regulate expression of several proteins in cultured cells [Lin *et al*., 2001]. Removal of the relevant base pair sequences eliminates the response to EM fields, while splicing the sequence into a gene otherwise unresponsive to EM fields leads to increased synthesis of the encoded protein.

A second means by which bioenergy may affect biological systems is by altering ionic fluxes. Direct perturbation of calcium conductivity at the cell surface is proposed as a generic mechanism by which ELF fields affect biological systems [McLeod, 1995]. Similarly, charge transfer in specific regions of the membrane-based ion pump, Na^+/K^+-adenosine triphosphatase, is altered by both electric and magnetic fields (Blank 1995). Activity of this enzyme, and of the electron transfer enzyme, cytochrome oxidase, are both increased by low frequency magnetic fields, but with optimal frequencies that differ by an order of magnitude [Blank, Soo 2001a]. That low frequency EM fields affect biological processes by interacting with moving electrons is the basis of a proposed "moving charge interaction" model [Blank, Soo 2001b]. In this model, for example, EM field-DNA interactions are described as occurring through acceleration of electrons moving within the helical chains.

Another general model that couples weak EM fields to charge flux focuses on actin microfilaments, which serve as ubiquitous components of the structural matrix within cells [Gartzke, Lange, 2002]. The polyelectrolyte nature of actin enables it to regulate intracellular calcium signaling along the length of the microfilaments and provides the basis for a bioenergy-biochemistry transduction system. Moreover, in their role as components of the cytoskeletal matrix, actin microfilaments are linked at the inner face of the cell membrane to a family of membrane-spanning proteins, the integrins [Giancotti and Ruoslahti, 1999]. Integrins are linked, in turn, at the outer face of the membrane to the collagen-based extracellular matrix. The triple helical collagen fibers, for their part, are proposed to function as liquid crystals and semiconductors providing proton conduction pathways for rapid communication throughout the body [Ho, Knight, 1998]. While this model describes the collagen network as responsive to endogenously generated DC fields, such a system also has the potential to respond to exogenous bioenergy. Further, via integrin coupling to the intracellular matrix, as described above, the collagen system can transmit integrated output signals to cellular control sites including DNA strands in the nucleus [Oschman, 2000].

Endogenously-generated electrical, magnetic, and electromagnetic magnetic fields that may be modulated by exogenous bioenergy include:

1. DC electrical fields, probably generated by glial cells (CNS) and Schwann cells (PNS) [Becker, 1991].
2. EM fields, *e.g.*, EEG, ECG, from all tissues that may have diagnostic potential. Examples include:
    a. EEG/ECG synchrony between interviewer and subject (and by extension, practitioner and client) [Russek and Schwartz, 1994].
    b. EEG synchrony between bioenergy practitioner and client during healing [Fahrion *et al*., 1992]
3. Coherent EM radiation (biophotons) [Popp *et al.*, 1988; Popp *et al.*, 1992].

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A final consideration in this overview of possible biological receptor sites for bioenergy is based in current concepts of homeopathy. Since the effectiveness of ultrahigh dilutions appears to defy generally accepted molecular theory, an alternate explanation posits the homeopathic remedy (the solute) imprinting an electromagnetic or other energetic signal to molecules of the solvent (usually considered as water) in a manner that is readily transferable to all similar molecules, thus creating a dilution-proof signal [Rubik, 1995]. If an EM signal is transferable from solute to solvent, a similar imprint, in theory, may be transferred just as readily from bioenergy to cellular water molecules. Extending the argument, if solute molecules can accept bioenergy imprints, then other molecules, including conventional ligands such as hormones or cytokines, may also act as receivers and carriers of bioenergy signals [Eskinazi, 2001]. Ligands able to accept bioenergy signals may exist in a variety of "bioenergized states."

BioFields

There are reported cases of healing at a distance and this phenomenon cannot be explained or modeled through the concept of a closed bioenergy circuit in which the practitioner and recipient are in direct physical contact. In the preceding, it has been postulated that the bioenergy is at least partly electrical in nature. Continuing with that analogy, a changing bioelectric field can lead to closed loops of electric field with an associated orthogonal magnetic field which can propagate through free space from a practitioner to a recipient. A natural extension of the definition of a field is to define several types of fields relative to biological phenomena.

> **Biofield:** A force associated with a biological system which can cause action at a distance.
>
> **Bioelectric (Biomagnetic) Field**: A static or slowly changing electric (magnetic) field associated with a biological system.
>
> **Bioelectromagnetic Field**: An electromagnetic field generated by a living system which propagates in free space and is capable of transferring energy and information from one system to another.

In the case of a biocircuit, the flow of biocurrent is constrained to the conducting circuit and the associated fields are enhanced or degraded based on the magnitude and direction of the flow. That is, a practitioner can direct his bioenergy by intentionally redirecting the internal flow of biocurrent in his body. The underlying assumption is that an undirected practitioner's bioenergy is distributed throughout his body in a nonrandom (organized) manner but that the net biofield generated is either zero or radiating more or less uniformly in space (referred to as isotropic radiation). When healing, the practitioner does not have any more energy than normal but rather focuses his internal energy or focuses an external source of energy to a specific purpose.

Remembering that energy is the product of power and time, the practitioner directs his biopower to radiate in a particular direction leading to the concept of effective radiated biopower (ERBP) which takes into account both the magnitude of the biomotive force and the effectiveness in directing the radiation in a particular direction. This has implications when measurement is considered since one would have to intercept some of this power which is directed at a recipient or have the practitioner direct the energies at a physical bioenergy receiver. Questions then arise such as “What is the correct receiving impedance to achieve the maximum transfer of power from the practitioner to the measuring equipment?” and “What is a non-biological bioenergy receiver?” If bioenergy is electric in nature, then this is scrutable. That is, the electromagnetic impedance of free space is known and the practitioner must match to this to maximize the transfer of power. Receiving antennas are already available which match to this free space impedance and hence should be able to receive this radiated bioenergy.

Just as a practitioner can maximize the transfer of energy to the recipient by focusing his attention (intention) and or posture to increase the ERBP of the bioelectromagnetic field, so can the recipient increase his reception of this energy by focusing his attention (intention) and posture to receive the energy with the minimal mismatch of impedance. We refer to this method of energy transfer as the “transmit-receive antenna” model. In the above description the “antenna” model assumes single receive and transmit beams, *i.e.*, the practitioner and the recipient each have a single focal point. It can also be conjectured that both the practitioner and the recipient can have a “multi-beam antenna” in which multiple beams are directed to different parts of the recipient body. Furthermore, the practitioner could control the information content and the ERBP in each beam.

Similar to the circuit analogy, the practitioner causes a biofield to radiate into free space. This free space has its own complex impedance which the practitioner must first match. Once the biofield is in space, the recipient must match his receiving impedance to this free space impedance in order to maximize the reception of the transmitted power. This implies that practitioners can be taught to radiate power, at least for non-contact therapeutic touch, in a uniform manner independent of the internal bioimpedances of the recipient. Likewise, a recipient should be able to be taught uniform ways of matching their bioenergy receivers to the free space impedance.

BioInformation and Modulation

Up to this point, no mention has been made of the significance of temporal changes in the magnitude or frequency of biocurrent flow or its associated fields. This is analogous to the case of radiating thermal energy at a body which then heats up as measured by the increase in the average velocity of molecules which are constantly in motion, *i.e.*, its temperature rise. It is unlikely that this form of energy transfer is sufficient to promote healing (thermal radiation does, however, have a healing effect). It would seem that healing is more likely to occur due to a practitioner’s conducted or radiated energy rearranging the relationship among the various biological subsystems in the recipient. This could properly be considered as a reduction in the entropy or uncertainty in the motion or behavior of the LE in the recipient. The practitioner is causing the LE or the biomotive forces within the recipient to change their configuration, from a state of relative disorder to one of less disorder. Because of this, the healing process is more likely one of transferring information from the practitioner to the recipient; a process of decreasing the randomness in the recipient by the active intervention and transfer of organized energy from the practitioner to the recipient. Extending the definition of entropy we have

> **Bioentropy**: A measure of the disorderedness of a living system. The lower the bioentropy, the more organized it is.

An example of entropy applied to biological systems is the probability distribution of the heart beat. While it is commonly thought of as a single rate, under a given static condition, the pulse has a normal variability about some mean value. A change in this variability, not the mean, but the variance of the distribution, can be viewed as an entropy change and a gain or loss of information about the heart rate. It is conjectured that there is an optimum entropy for each of the biological subsystems of a healthy person. That is, a pulse with small variability is just as unhealthy as one which has too much variability. Furthermore, it is conjectured that the transmission of bioenergy is a means for transferring bioinformation so as to effect healing by restoring a biological system to a state of health or "optimum variability."

This definition of bioentropy leads to a natural definition of bioinformation relative to creating or maintaining the organization of a system at the correct level of uncertainty as

> **Bioinformation**: An entropy reducing signal generated by a biological system.

While it may appear at first that there is a discrepancy between the physics concept of energy and bioenergy, one cannot organize a system without expending energy. In fact, Brillouin [Brillouin, 1971] has calculated the energy content of 1-bit of information to be 10^{-39} Joules. That is, in order to change one bit which is used to specify some quantity from one state to another (*e.g.,* from a "1" to a "0") in one second requires a minimum of 10^{-39} Joules/second. A Joule/second is work/time which equals power. For power to flow, there must be an energy present which in this case is bioenergy. Hence, bioenergy has the capacity to produce work. The work which is being expended to change the organization of something is just not work in the embodiment in which we are used to sensing it such as heat or light. It is, nevertheless, physical work. This energy/organization relationship implies that there is a direct physical energy measure of the information organizing capability of a system and/or the amount of energy expended in doing the organizing.

Bioenergy may be further subdivided into self-bioenergy which is the capacity to maintain one's own organization and external-bioenergy which is the capacity to transfer one's bioenergy to an external receiver. The degree of organization is representative of health. As was previously stated when discussing heart rates and bioentropy, it is likely that there is some optimal entropy of a living system.

As opposed to the transfer of energy (such as thermal radiation for heating) at a constant strength or frequency, one can modulate that energy transfer by systematically changing the amplitude of the driving force, namely the biomotive force, or its frequency or phase.

Since the impedance of the practitioner, the transfer medium (whether it is a circuit or free space), and the recipient are considered for the purpose of this discussion to be constant and time invariant relative to the modulation, the changes in signal strength of the practitioner result in changes in bioenergy in the recipient. These changes in BMF (amplitude modulation) or frequency or phase (frequency or phase modulation) of the practitioner cause the transfer of information to the recipient.

This leads to the conjecture that there are at least three elements of the healing process. The first is the physical transfer of energy either through direct contact or bioenergy related fields at a distance. The second is the ability of the practitioner to transmit his bioenergy at an appropriate carrier frequency (frequency of the electromagnetic radiation which "carries" the modulation or signal) and the recipient to "tune" to this frequency, and third, the ability of the practitioner to appropriately modulate his BMF or carrier frequency and the recipient to decode this modulation. The first was described as impedance matching. The second can also be considered a type of impedance matching as in the case of tuning a resonant circuit. The third can also be considered as impedance matching, however it is a more abstract type in that it is a coding and decoding problem and not directly related to physical phenomena. This is essentially a more detailed explanation of the processes which occur in Figure 2.

Another form of passing information associated with bioenergy transfer is that due to resonance, or the inducing of a synchronizing effect in a recipient. In the process of radiated information transfer it is also conjectured that the information content transferred by the practitioner may create a self-resonance or self-reinforcement phenomena within the recipient such that the effect increases above (essentially independently) of the transferred energy level as long as the level exceeds a detection (discernment) threshold of the recipient. This effect is information content dependent and behaves similar to a tuned radio circuit where one is able to receive a weak station when properly tuned. One can also view coherent energy transfer as specifically modulated energy to achieve the resonance effect while minimizing the amount of energy transfer. This could allow a greater separation between the practitioner and the recipient and provide "healing" over longer distances. As an alternative it would allow the practitioner to subdivide his total energy efficiently and direct it with specific information content to different parts of the recipients body each reinforced by self-resonance.

An example of the importance of information content has been shown by the well-documented effects of learning enhancement associated with listening to Mozart's Piano Sonata in D Major, K 448 [Rauscher, 1993 and 1999]. Apparently this composition has unique features which stimulate neurons and thereby enhance learning. The interesting part is that the effect is not source level (in this case acoustic power level coupling into the ear and possibly through bone conduction) dependent as long as it's above the threshold of hearing.

An example of coding is when one hears the tones associated with two computers communicating with each other using frequency shift keying over a telephone modem. The modulation is produced by alternately switching between two frequencies. We hear it, but we can't decode it. A similar case occurs in telephones where the telephone numbers that are dialed are transmitted to the switching network by simultaneously transmitting pairs of tones. Initially it is difficult to understand what these tones mean; however with some practice, one can "hear" the number that is being dialed and decode it into the actual number. In one case the coded message is being sent but not decoded. In the other case it is being sent and with a bit of practice, can be decoded correctly.

Bioenergy Prospects

Should some or all of these relationships and components exist, then there is the further implication that one could store bioenergy mimics in non-biological entities as well as create non-biological circuitry for amplifying and modifying bioenergy for useful applications. One could create non-biological devices to provide biofeedback to practitioners to allow them to increase their effective radiated biopower and enhance their ability to use intention to match bioimpedances to that of the transmitting medium.

Section 4. Bioenergy Direct Measurement Best Research Practices

Assuming that biomotiveforce, bioenergy, and bioimpedance are electrical in nature, one can establish common engineering criteria for insuring that the direct physical measurements of these phenomena are not subject to external influence. Unless extraordinary precautions are taken, the environment is cluttered with a multiplicity of confounding electric, magnetic, and electromagnetic signals. The earth itself has a self electric field on the order of Volts/meter in altitude as well as the well-known weak, but readily detectable, magnetic field sensed by compasses. In addition to these non-man-made interfering phenomena, the environment is polluted with a number of other man-made sources. To briefly name a few:

- Static electric fields generated by the relative motion of dissimilar insulators such as walking on a rug in conditions of low humidity
- 60 Hz electric and magnetic fields near high-power electric machinery (*e.g.*, elevator motors, laboratory equipment, heating, ventilation and air conditioning (HVAC) equipment) and/or proximate high-voltage power transmission lines and transformers
- Higher frequency electromagnetic fields generated by computers, computer monitors, cell-phones, inter-regional microwave transceivers, and radio/television stations

The effects of many of these man-made signals can be reduced by post experiment data analysis such as those caused by 60 Hz interference. However it is not clear that this ambient radiation may not be the carrier of the information between a practitioner and a receiver and that the practitioner may simply modulate this already existing energy rather than radiate his own energy.

It should be pointed out that electromagnetic (EM) fields are coarsely classified in a manner which gives the appearance that they are different entities produced by different physical phenomena; however this is not true. Examples of EM fields are radio waves of various frequencies (ELF, VLF, MF, HF, VHF, UHF, *etc*.), microwaves, infrared, visible light, ultraviolet, X-rays, gamma-rays, *etc*. Electromagnetic waves are given these different names due to their different interactions with other materials, yet they are all simply different manifestations of EM fields at different frequencies (wavelengths). For the purpose of the discussion which follows, three major distinctions will be made based on the frequency of electromagnetic radiation: radio frequency (RF), optical (infrared, visual, ultraviolet), and ionizing radiation (X-rays, gamma-rays, and other high-energy particles).

Shielding

In order to eliminate the confounding effects of ambient EM radiation, there are two approaches which are commonly used, the Faraday shield and the electromagnetic anechoic chamber. Faraday shields are based on the principle that an electrical field cannot exist inside of a conductor. That is, a Faraday shield is an enclosure which is completely enclosed with a conductor, typically a copper screen or sheet. The “porosity” of the screen determines the frequency of the fields which the Faraday shield will keep out and in the best case, the enclosure is shielded with solid copper sheeting. Faraday shields are effective at eliminating strong, low-frequency electric fields which usually are not radiated as a closed electromagnetic field into free space, but rather are a near-field effect of large current flowing in a proximate conductor or a slowly changing static electric field. For example, a theramin is an example of a piece of equipment whose oscillating frequency (the sound produced) is changed by the changing proximity of a musician’s hands to a set of electrodes. The musician is actually changing the dielectric in an electric field produced between the electrodes which act like a capacitor. This change in dielectric causes a change in capacitance, and hence a change in the oscillating frequency. Because of the earth’s static electric and magnetic fields, motions of practitioners could cause the same type of effect in measurement equipment. One way to eliminate this is to perform experiments inside of a Faraday shield, also sometimes called a screen room.

The anechoic chamber is a Faraday shielded enclosure, usually a large room (some large enough to hold entire aircraft), which is lined with electromagnetic absorbent material of a shape and thickness to effectively absorb and prevent the reflection of electromagnetic energy from the walls of the enclosure. The net effect of this is to also shield the equipment (or in the bioenergy case, the practitioner) in the anechoic chamber from external electromagnetic fields. Isolations on the order of 120 dB (deciBels, effective reductions in external ambient electromagnetic signals by a factor of 10^{12}) are achievable. By placing a practitioner in an anechoic chamber during an experiment, two things are accomplished. The effects of ambient electromagnetic fields on the experiment are virtually eliminated and sensitive electromagnetic receiving equipment can be used to measure the expected low-level radiation from the practitioner. It should be mentioned that anechoic chambers are typically used to measure electromagnetic radiation levels and patterns from a piece of electronic equipment in order to characterize its behavior. The chamber’s equipment usually covers a broad range of frequencies and the receivers have adjustable bandwidth such that extremely weak, narrow band signals can be detected.

An approach similar to Faraday shielding can be taken relative to ambient magnetic fields by lining or creating an enclosure with the high nickel content Mumetal [Wolff *et al*., 1999]. While there is no equivalent to Faraday shielding for magnetics, high permeability metals can be used to create an enclosure with significantly reduced internal magnetic fields by concentrating the magnetic field lines in the shielding and effectively routing the field lines around the enclosure. Additional consideration must be given to the shape of the enclosure with a difficult to realize spherical shape being the optimum, a cylinder with endcaps having a length to diameter ratio of 4:1 being acceptable, and a flat sided enclosure with large radius of curvature corners being the least desirable. The concept of magnetic shielding need only be considered below frequencies of 100 kHz. Above that frequency, normal electromagnetic shielding as discussed in the previous paragraphs is sufficient.

The measurement of electrical and electromagnetic energy needs also to be with reference to the distance that the observer is from the source of radiation. This is not a fixed physical distance, but is dependent on the frequency of the radiating signal. Near field measurements are usually considered to be those taken within $2*d^2/\lambda$ of the radiating source where d is the physical size of the antenna. For example, an FM radio station broadcasting at 88 MHz would radiate at a wavelength of 3.41 meters ($\lambda = c / f$ = ($3x10^8$ meters/second) / ($88x10^6$ Hz)). If one assumes that the physical size of the antenna is 1 meter, a measurement device would be considered to be in the near field of the antenna out to a distance of $(2 * (1 \text{ m})^2 / 3.41 \text{ m})$ which is 0.58 meters (1.93 feet). Assuming the same 1 meter diameter antenna, at a frequency of 14 GHz (satellite television transmitters), the wavelength is 0.0214 meters leading to near field measurements out to 93.3 meters (306 feet). This transition from near to far field is not abrupt and occurs over a significant distance starting at $\pi d^2 / 8\lambda$.

The significance of the near field/far field distinction is that the radiated electromagnetic wave is not considered to be coming from a single point source until one is approximately 10λ away from the radiating source. In the near field, one can significantly affect the measured radiated power by movements of the individual elements which do the radiating or changing the location of the receiving antenna. In the case of a practitioner, the movement of hands could affect the measurements in the near field, where they may not be perceived or have minimal effect in the far field. This is not to say that near or far field measurements are better or worse than the other, only that it is important to know whether one is measuring the net effective radiated power (ERP) from an assumed point source (the practitioner) or whether one is measuring the power of the individual radiators associated with a source (the body parts of the practitioner). In the near field there may be significant variations in measured power at different physical locations of the measuring device relative to the radiator (the practitioner) while far field measurements may yield entirely different variations in a more organized pattern.

Baseline Field Measurements

If the bioenergy measurements cannot be made in an anechoic chamber or a Faraday shield, then it is extremely important that measurements be taken of the electric, magnetic, and electromagnetic ambient environment as a baseline with which to compare measurements taken during an experiment. These measurements must be taken immediately before and after the experiment to give even a minimal degree of confidence that no external signals interfered with the data acquisition process. Having said that, this is a practice which is fraught with risks as a significant number of potentially interfering signals are not under the control of the researchers and are of short duration. These include nearby electric equipment, uncontrolled electromagnetic radiators such as cell-phones, pagers, or other intermittent radio transmitters. A level of confidence can be gained by instrumenting the environment around the practitioner sufficiently far away from him to receive minimal practitioner power or with directional antennas whose null (direction of receiving minimum energy) is aimed at the practitioner yet able to receive other energy impinging on the experimental site from other directions. Although it is possible to provide this sort of instrumented environment, it is costly and difficult to do well, hence the strong recommendation to employ anechoic chambers and/or screen rooms to prevent interfering signals from corrupting the collection of bioenergy data.

Range of Frequency Measurement

The colloquial term for broad band electromagnetic measurements is “DC to daylight” meaning all frequency from direct current which effectively radiates static electric fields to the highest frequencies of non-ionizing electromagnetic radiation including visible, ultraviolet, and infrared light (but not higher frequency ionizing radiation such as X-rays which are discussed later). While the goal of a research project may be to detect bioelectromagnetic radiation from a practitioner, at what frequency does one look? It is clear that humans radiate electromagnetic energy in the infrared band, but do they radiate at any other frequencies? The measurement difficulty associated with this is that there is no such thing as a wide band, extremely sensitive electromagnetic energy receiver. There are wide band receivers and there are extremely sensitive receivers, but no instruments are capable of both types of reception simultaneously. The usual technique for creating extremely sensitive receivers is to make the receiver’s instantaneous bandwidth very narrow and slowly sweep across all frequencies. The net result of this limitation is that one must insure that the receiver is tuned to the right frequency when the practitioner is radiating at that frequency. Until it is determined what the frequency is that practitioners radiate at, sweeping all frequencies with extremely sensitive receivers will be a laborious and time-consuming process. This assumes, of course, that all practitioners radiate at the same frequency, else each practitioner will need to be swept for his particular radiating frequencies.

An initial approach to determining which frequencies to investigate can be based on applying known electromagnetic antenna theory to estimate the effectiveness of matching the physical size and shape of the human body and its appendages to the free space impedance just as one would do with any antenna. The height of a human starts approximating the wavelength of electromagnetic radiation in the FM broadcast band around 100 MHz so this might be a useful lower bound as a starting point. A detailed antenna analysis of the size and shape of the human body and its various appendages is outside of the scope of this document, but it is calculable. It is also measurable. That is, reciprocity applies to antennas and they reradiate energy in the same manner in which it is received. In addition to measuring the self radiation of a person, one could radiate a person inside an anechoic chamber at power levels below those considered harmful (10 mw/cm^2) and measure the reflected (reradiated) energy. This would measure the biochemical and biophysiological antenna aperture of the human body which would not require any transmission of information or intent on the part of the subject.

Equipment and Site Documentation

It goes without saying that a suitable protocol for bioenergy measurements requires the documentation of the measurement suite which is used to make the measurements. If experiments are performed in a commercial or government anechoic chamber it, would be standard practice to not only list the equipment used, but the range of frequencies over which measurements were made, the settings of the receivers in terms of instantaneous bandwidth and sweep rates, the receiving antennas used, and the basic characteristics of the enclosure itself. As a matter of course, the enclosure is usually swept before any measurements are taken to insure that the baseline for the enclosure has not changed and that all equipment is functioning properly. The sweep also establishes the level of the minimum detectable signal by measuring the noise which is inherent in the system. This means that the measurements cannot confirm that a practitioner did not radiate but only that he did not radiate electromagnetic energy above a certain minimum detectable level. It is important to know what this level is as advances in measurement equipment may lower the minimum detectable level suggesting a replication of an experiment with this more sensitive equipment at a later time.

Some measurement facilities are also certified under various civilian and military programs to conduct particular types of measurements. Statements as to the certifications of the measurement facility serve to establish the credibility of the measurements and the level of expertise of the personnel who were involved in making the measurements.

Optical Radiation

Since optical radiation is just a higher frequency of EM radiation, it will only be discussed in the context of its properties which necessitate different or additional measurement controls than those previously discussed. Just as with lower frequency (RF) radiation, there are two aspects of the measurement of optical radiation which concern us, namely interfering signals and the spatial distribution of optical energy associated with a practitioner. In the case of visual and ultraviolet (UV) radiation, interfering signals are easy to control since many enclosure construction materials are opaque to optical radiation at these frequencies. Near- and far-infrared (3-5 and 8-12 μ wavelength, respectively) interference is more difficult to control since these are the radiations normally referred to as heat, thermal, or infrared (IR) radiation. Measurements can be influenced by the practitioner's own metabolism as well as the mean temperature of the room. Of particular concern is the random cycling of HVAC equipment which can disturb measurements as well as the heating caused by incident insolation. Even a hot cup of coffee will show obvious thermal gradients above the cup, and equipment is now so sensitive that it can detect the hotspots on walls left by momentary touching with body parts and even one person's handprints on another. Fortunately, except for the air currents associated with forced air heating/cooling which can be manually controlled or directed away from the experimental area, it is the very short wavelength of this thermal radiation which ameliorates this problem and will be covered in the next paragraph.

By the time the wavelength is short enough to be called IR radiation, appropriately small sensors can be used to detect this radiation. These sensors are small enough such that they can be created in the form of rectangular arrays of pixels (picture elements) on integrated circuits. Coupled with this small size, lenses with an appropriate refractive index can be used to focus the energy such that an instantaneous image of the practitioner can be projected onto the integrated circuit and electronically captured. For example, a normal television camera made of a silicon charge coupled device (CCD) is sensitive in the IR band. If the normal glass is fitted with a visual light filter, the camera can be used to form IR images. The spatial resolution of the image as measured in pixels/linear measurement is determined by the number of pixels in each linear direction on the array (which is usually not square) and the optics. It is not unrealistic to capture thermal images with 100's of pixels/inch resolution. With this kind of resolution, which can easily be interpreted as a thermal image of a practitioner, the effects of the background can be easily masked out. What can't be masked out are the thermal currents which occur between the practitioner and the imaging system. These must be controlled so as not to introduce confounding signals which cannot be removed through normal filtering.

Ultraviolet radiation should also be mentioned because of its peculiar ability to cause certain materials to fluoresce. Black light, as it is sometimes called, can cause various common compounds to fluoresce such as starch in clothing. This leads to the possibility of detecting UV radiation by secondary emissions in the visual band rather than by direct measurement with UV imaging systems.

Another issue associated with optical radiation is the possibility of using active rather than passive sensors. Reradiation (reflection) of incident electromagnetic energy from an object starts to become effective when the size of the object approaches several wavelengths of the incident radiation. Utilizing the previously calculated wavelength of a 14 GHz satellite television transmitter, the wavelength is 0.021 meters or less than an inch. Reflected energy measurements above this frequency become reasonable. There are radars which operate at 54 and 94 GHz which can contour people. Certainly active optical imaging equipment is in common use in taking photographs or conventional videos in the visual band. Likewise, static or moving images can be taken in visual darkness of subjects by using UV or IR wavelength illumination,; however, this would only measure the changes in the spatial distribution of the absorption or reflection of these energies about the person of the practitioner.

Ionizing Radiation

Ionizing radiation is typified by X-rays, Gamma-rays, cosmic rays, and other high energy particles although they are just another, albeit yet higher frequency, form of EM radiation. The confounding effect of ionizing radiation is that, depending on the type of particle, they can penetrate and travel through solid objects. The higher the energy of the particle as measured in electron-Volts, the thicker the shielding required to reduce the effects of ambient radiation to acceptable levels.

Aside from ambient ionizing radiation which can be effectively shielded from the experimental enclosure by an appropriate thickness of radiation absorbing material, there are two other ambient signals which the experimenter must contend with. First there is a component of background radiation due to the shielding material itself. Even though lead is the most common shielding material because of its density and low cost, it has its own self-radiation due to the fact that lead is the final decay product of many radioactive elements and hence there are many impurities in it which are still emitting particles. This can be accounted for by making detailed background level measurements before beginning the experiments and not moving the shielding material once this baseline is established. The second component is the self-radiation of human subjects. Two radioactive elements are found in sufficient quantities in humans such that they radiate decay elements which can be detected with normal X-ray detectors. These elements are potassium and strontium, the latter of these two being a residue of the above ground nuclear tests which has entered the environment.

The fact that humans have self radiation which does not appear to be under the control of metabolic processes, implies that the background characteristics must be measured in a sequence of steps. The first is to measure the environment with shielding in place. The second is to measure the practitioner and the shielding. The third is to measure the practitioner while he is practicing yet not changing his position relative to the shielding and measurement equipment. That is, it is differential measurements of the ionizing radiation from a practitioner which are indicative of his bioenergy radiation, not simply the fact that he radiates. If it is hypothesized that the ionizing radiation from a practitioner is due to the interaction of the practitioner with external ionizing radiation, then careful measurements must be made of the enclosure with shielding in place, shielding not in place, as well as with and without the practitioner in a non-therapeutic state.

Recent research suggests that emotional and intentional states of humans may modulate the degree of self-radiation of high frequency X rays [Schwartz, 2002] as well as the degree of self-absorption and/or scatter of gamma rays [Schwartz, 2002; Benford *et al.*, 2000]. Future research may reveal that these high frequency energies play an important role in the bioenergy and bioinformation of healing as well as practices such as meditation and qigong.

Blinding of Technicians

If bioenergy measurements are made in a facility established solely for that purpose, there seems to be little need to blind the technicians to the experiment. This is primarily due to the fact that the measurements are automated or performed according to a predetermined script and that the observed values are objective quantifications of physical phenomena which do not have a subjective interpretation.

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Section 5. Best Research Practices for Indirect Measurement of Bioenergy

Indirect measurement of the influence of healing in the laboratory allows for careful control of the parameters that might influence outcomes. Strict control of experimental conditions is especially useful in an attempt to test mechanistic theories and demonstrate proof of principle. This section offers suggestions for best research practices associated with the design and analysis of experimental protocols for measuring the influence of bioenergy on various systems that do not directly measure the electrical and electromagnetic observables. Illustrations of the necessity of several such practices are offered from exploratory studies conducted at the California Pacific Medical Center Research Institute.

In vitro models can be used as the objects of healing intentionality to test for direct effects. A few of the distinct advantages of such models over clinical models are that

- objective outcome measures can be rapidly acquired
- a homogeneous target population can be "recruited" inexpensively
- a pure control group (*e.g*., without extraneous healing intentions) can be established
- tools available to biochemistry and molecular biology can be applied

Establishing the objectives and goals is the first step when conducting scientific investigations of any type. Once experimental design is established, the experimental variables should be controlled in order to limit the observer variation and bias. Techniques employed for specific experiments need to consider the type of sample to be analyzed, which depends on the biological materials observed (*i.e*., blood cells, cultured cells, organ biopsy, *etc*.). It is important for the investigator to adequately assess the type of preparation, revelatory technique, and final quality of the sample. The study should include appropriate controls for comparison and should be replicable with sufficient power to accept or reject the null hypothesis. Furthermore, plans for data acquisition and reporting should include descriptive analyses (*e.g*., basis for tests chosen) and confounding factors and measurement errors need to be addressed.

Dozens of *in vitro* model systems have been used in healing experiments ranging from random event generating machines [Radin and Nelson, 1989] to small organisms [Grad, 1965; Rubik and Rauscher, 1980; Nash, 1982; Barry, 1968] and human cells [Sancier and Hu, 1991]. Although *in vitro* model systems have the advantages previously listed, they also present unique experimental design challenges. The remainder of this section is organized according to the following categories of experimental design aspects: (1) randomization, blinding, and control conditions, (2) optimal target systems, and (3) quantification of variability intrinsic to the model system.

Randomization, Blinding, and Control Conditions

The preparation of multiple samples as targets necessarily involves some degree of nonidentical treatment of samples. Randomization of samples at each decision point in the protocol is important to rule out conscious or subconscious experimenter bias. In preparing multiple cell culture plates as targets, for example, it is necessary to place each plate in a unique position in the cell culture incubator. Because of the possibility of minor variations in temperature associated with position on the incubator shelf, each cell culture plate should be assigned randomly to a position in the incubator. A computer program that uses a random number generator to assign plates to positions on a grid marked on the incubator shelf can be used to assure that each plate has equal likelihood of assignment to any incubator position. Considerations such as these are needed in addition to the typical randomization of treatment group assignment, sequence of treatments, and so on. Blinding is an essential aspect of most experiments involving biological samples because of the subjectivity associated with outcome measures. Moreover, blinding of all participating scientists, not just of the data collector, is necessary. To avoid suspicion of falsification of data, it is also advisable to have independent peers keep the blinding codes until after data collection and analysis are complete. A detailed example of randomization and blinding protocols for investigating the responsiveness of cultured cells to treatment by a bioenergy practitioner is presented in [Schlitz, 2003].

In experiments that involve healing treatment from short distances, it is important to include specific conditions to control for the possibility that physical parameters associated with the proximity of a human body (practitioner) are sufficient to influence samples. Pheromones or other chemical signals carried in sloughed skin cells, for example, might stimulate biological samples. The recent demonstration that single cells in mice respond to pheromones at concentrations below 10^{-11} molar [Leinders-Zufall *et al*., 2000] has increased speculation along these lines.

Experimental control conditions to evaluate the specificity of a purported biofield effect are also important. Through years of devotion to the healing process, healing practitioners may possess a unique biofield that can influence nearby cells (and patients) independently of healing intentionality, for example. Likewise, meditating on healing itself might cause physiological changes that somehow influence nearby *in vitro* targets. Examples of appropriate control conditions include the presence of a healer who does not deliver healing treatment, the presence of a nonhealer "confederate" who does or does not mimic the healer's behavior, and the inclusion of a sham control in which nobody is present but in which samples experience all the physical manipulations involved in the experiment.

Control conditions appropriate to a given experimental design vary as a function of the theories being tested. The use of parallel targets with different numbers of independent samples would allow a test of the decision augmentation theory [May *et al.*, 1995], for example. Careful attention to the quality of the environment of the samples during treatment sessions and randomizing the sequence of treatments is necessary to address hypotheses such as the possibility that bioenergy may linger in the area of a healing treatment [Kiang *et al.,* 2002] or that healing activity may alter the physics of a particular location.

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Optimal Target Systems

Model systems with an aspect of instability may provide the most sensitive targets for measuring subtle effects of healing intention [Pleass and Dey, 1990]. An analogy often used to convey this point is that it is easier to move a penny by blowing on it if the penny is standing on end than if it is lying flat. Accordingly, the brain tumor cells used in the experiments depicted in Figure 4 (described in next section) were synchronized in the cell cycle by mitotic selection and allowed to progress to G_1-phase, the phase in which mammalian cells are most receptive to external signals. In addition, the tumor cells were grown in an extremely low concentration of growth serum, with the idea that stressing the cell cultures by minimizing the growth signals available to the cells might render them more sensitive to a biofield influence. Pilot data obtained with parallel samples grown in the same experiment in low growth serum and in a higher concentration of serum support this notion. The apparent responsiveness of the tumor cells in 0.1% serum to external qigong treatment was not seen in samples grown in 1% growth serum exposed to simultaneous treatment (data not shown).

With the use of multiple samples in a series of experiments comes the need to maintain uniformity among the samples. This consideration is particularly important when biological samples are used because they are open systems in a constant process of change. Human cells grown in culture, for example, acquire genetic mutations over time. Even a single genetic mutation can alter a cell’s responsiveness to external stimuli and so might also alter a cell’s responsiveness to potential biofield influences. To avoid this variance, target cells must be expanded to a large population size, aliquoted, and frozen viably for long-term storage. A fresh aliquot can then be thawed at the start of each experimental trial, thus ensuring uniformity in the genetic profile of the target cells throughout a series of experiments.

Quantification of Variability Intrinsic to the Model System

Variability associated with healing interventions can be expected because of the reliance on human operators who are subject to psychological influences such as expectation and to physical influences such as fatigue. Indeed, as seen in Figure 4, repeated experiments working with the same practitioner can produce highly variable results. In this series of three independent experiments, the first in the series showed a dramatic inhibition of tumor cell growth following the qigong treatment, but the apparent effect waned over the subsequent replicate experiments (see Figure 4). Interestingly, precedent exists in the literature for a similar decline effect observed in research on mind-matter interactions with random event generators [Dunne, *et al*., 1994]. Without knowing how much variability is intrinsic to the model system however, it is difficult to rule out experimental artifact as the cause of the apparent effect in the first experiment.

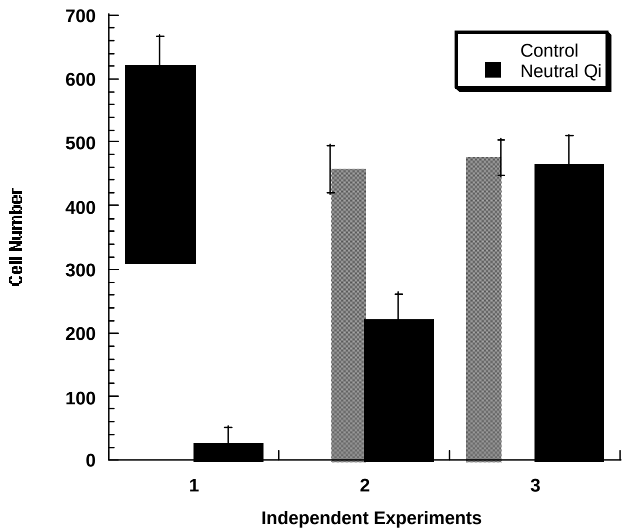

Figure 4 Human Brain Tumor Cells Treated with Neutral Qi in Three Independent Experiments. Glioblastoma cells (U-87 MG cell line) were synchronized in a receptive phase of the cell cycle (G1) and grown in 36 individual culture plates with a low concentration of growth serum (0.1%). After the cells were randomly assigned either to a "neutral" Qigong treatment group or to a no-treatment control group, the practitioner delivered external Qi for 20 minutes with hands held approximately 6 inches from the culture plates. Cell number was assessed in a blinded fashion using randomly assigned identifying codes three weeks following treatment (n = 18 for each group; bar = standard deviation).

The issue of variability in the apparent effect of bioenergy treatment presents one of the most important challenges in the field. Beyond the variability introduced by human operators, logistics often prevent control of some parameters of the target system. Without the use of anechoic chambers, for example, geomagnetic field activity might influence laboratory samples [Braud and Dennis, 1989]. Protocols incorporating systematic negative controls are helpful in this regard because they allow assessment of the variability intrinsic to the experimental system [Walleczek, *et al*., 1999].

A series of exploratory experiments conducted with a second qigong practitioner illustrates the value of quantifying the variability of the model system. This practitioner had worked with scientists in China and had come with documentation of prior experiments in which he had demonstrated the ability to influence the pH of water samples through external qigong treatment. An attempt was made to replicate these experiments with the addition of systematic negative controls (*i.e*., each time a treated sample was compared to an untreated control sample (qi/sham trial), an untreated control sample was also compared to another untreated control sample (sham/sham trial)). Results from 10 qi/sham trials interspersed with 10 sham/sham trials revealed that the pH of samples from both types of trials fluctuated occasionally and that these fluctuations were all within the same range of magnitude. Without systematic negative controls, errors associated with the methodology during a qi/sham trial may have been interpreted as specific to the qigong treatment.

Fluctuations in ambient temperature in the microenvironment of target samples may also be unavoidable, particularly in protocols involving the close proximity of healers. Reports of infrared emissions from the hands of qigong practitioners [Gu *et al*., 1978] underscore the need to consider this variable. A thermistor probe that accompanies the samples through all experimental manipulations permits quantification of differences in ambient temperature. Automatically recording the ambient temperature (*e.g.*, to 1/100^{o}C in 30-second intervals) allows formal testing of the likelihood that temperature fluctuations might influence the results of the main hypothesis of this experiment.

Section 6. Summary and Further Research

Direct and indirect measurement methods for evaluating the effects of bioenergy on living organisms have been discussed. If the physical mechanism for energy transfer is electrical in nature, techniques and best research practices for making this type of measurement are well known in the electrical engineering discipline. If there is another underlying mechanism, then this can be studied after having eliminated electricity as the mechanism. Indirect measures, particularly those associated with *in vitro* experiments have the additional capability of removing human intentionality and psychological influences from the ability to demonstrate healing mediated by bioenergy. This healing can be demonstrated independently of whether the underlying mechanism is electrical or not.

Published effects of external qi on physical and biological systems frequently involve a single (or a very small number) qigong master. While there are reasons why such studies are necessary and perhaps even desirable, it should be pointed out that there are serious issues of conflict of interest involved in such situations. Since almost all qigong masters make a living based on their perceived ability to emit bioenergy for healing, a positive result in a laboratory study would greatly increase the person's monetary worth. Therefore, it is highly recommended that the subject not be involved in the design of the study and be blinded during the measurements (to minimize opportunities of fraud). The common practice of including the qigong master as co-author in the publication is to be highly discouraged.

The following is a summary in bulleted format of the research guidelines relevant to direct electric/magnetic/electromagnetic measurements:

- Utilize efficient shielding to minimize the effects of ambient static and radiated fields
- Establish a baseline of ambient static and dynamic fields
- Measure the noise threshold of measuring equipment and minimum detectable signals as a function of frequency
- Calculate the error bounds on all measurements
- Document any statistical methods used to process the observations to arrive at measurement results
- Document the physical test setup, equipment used, and environment including computer programs used to drive automatic test equipment
- Document the positioning of practitioner and degree and range of movements during measurements
- Document types of demodulation detectors used and characterize the information content of radiated signals

- Calculate whether the measurements of electromagnetic radiation are near field or far field
- Document the calculations, formulas, and assumptions used to determine the requisite measurement parameters (*e.g.*, sweep range, sweep time, instantaneous bandwidth, *etc*.)
- Document certifications of the laboratory doing the measurements
- Verify calibration dates on test equipment traceable to a primary or secondary standard

Additional guidelines relevant to indirect measurements:

- Randomize samples at each decision point in the protocol
- Blind all participating scientists, not just of the data collector
- Include specific conditions to control for the possibility that physical parameters associated with the proximity of a human body may influence the measurements
- Include experimental control conditions to evaluate the specificity of a purported biofield effect
- Consider using model systems which have an aspect of instability in them and which may provide the most sensitive targets
- Maintain uniformity among samples
- Assess the variability intrinsic to the experimental system

Appendix. Supporting Concepts of Electricity and Physics

While all the forces in physics can be reduced to the four fundamental forces of

- electromagnetism,
- gravity,
- the strong nuclear force, and
- the weak nuclear force,

it is more convenient when dealing with electricity to work in a classical framework of electromotive force (EMF) and electromagnetic force (field). The distinction between EMF and the electromagnetic force as they are used here is that EMF is confined to a circuit made up of discrete devices with their physical interconnecting conductors and can be thought of as a local, contained phenomenon although static fields may also be associated with these circuits. The electromagnetic force is a radiated field which can cause action at a distance and can be transmitted from one place to another with no intervening physical medium.

Physics provides several fundamental definitions which form the basis for the following discussion, particularly the concepts of energy, power, entropy, and field. These definitions will not be repeated here as they are in the introductory section to this paper. This appendix is intended to give the interested reader without an electrical background some additional information to aid in understanding the bioenergy and related definitions which are extensions of these concepts.

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Closed Electrical Circuits
The EMF as measured in units of Volts is the force in a closed circuit which causes electrons to flow. This flow of electrons, or rather the reverse of the direction of flow of electrons due to a historical quirk, is called current and is measured in Amperes. The third and final element in closed circuits is impedance or the complex resistance to the flow of current. The relationship among these three components is shown in Figure 5 with the impedance drawn as a simple resistance (R) representing capacitive or inductive reactance. It is helpful to think of the EMF (E1) *across* an impedance causes a current (I) to flow *through* the impedance (R), particularly when we make the bioenergy analogy.

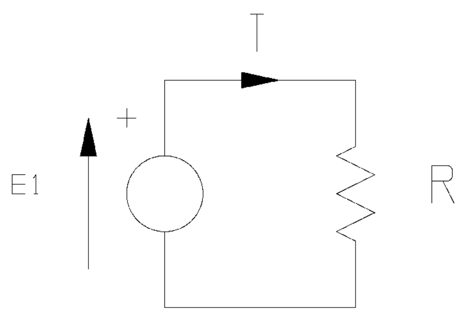

Figure 5 Simple electric circuit.

If the EMF is a constant value such as that produced by a battery (ignoring transients when a circuit is energized or deenergized), it produces direct current (DC). If the EMF is varying, it produces alternating current (AC). Both of these cases behave in accordance with Ohm's law which relates the EMF, current, and impedance.

$$E = I\ Z$$

For DC circuits, the complex number Z, composed of a real and imaginary part, is replaced with the real part, *R*, leading to the familiar $E = I\ R$ relation. An intuitive difference between resistance and impedance is that a resistance only dissipates energy whereas an impedance has the additional capability of being able to store energy and affect the temporal relationship (phase angle) between the EMF and current.

Although AC circuits can create fields and radiate energy, that attribute will be considered to fall under the section on electric fields.

Electric Fields
Electric fields can be divided into static and dynamic since their behaviors are different although the basic phenomenon is the same. Static fields are just that, an unchanging EMF between two electrodes, one labeled "+", the other labeled "-". In the terminology of closed electric circuits, one would normally consider the gap between the +/-electrodes to be a high resistance with a (usually negligibly) small current flowing through that high resistance. Since there is an assumed negligible current flowing, there is an associated negligible static magnetic field. That is, when talking about an electric field, one is more

concerned with the effect of the electromotive force on a charged entity in the field rather than the current which is flowing in the circuit. For example, an electron in an electric field will have a force on it which attracts it to the positive electrode with a strength proportional to the field strength as measured in Volts/meter. This is an example of action at a distance where there is some physical distance between the electrodes which are the source of the field and the electron which will move if unrestrained. There is essentially no magnetic field associated with this static electric field except the (negligible) small one due to the movement of current between the two electrodes.

Of far more interest is the effect of a changing electromagnetic field associated with a changing electric field. Starting with a static electric field, one can change the direction of that field such that with the proper electrode design (antenna), closed loops of electric field lines are created due to the inability of changes in the field to propagate to distances from the antenna at faster than the speed of light. Associated with these changing electric field lines are orthogonal magnetic fields, hence the name electromagnetic (EM) fields. One thinks of EM fields as radiating through space and propagating from one place to another. On the other hand, static electric fields just “are” and don’t propagate.

Just as with closed electric circuits, there is a relationship among the changing EMF, the changing current, and complex impedance. In this case, impedance must be considered as a complex number since the electric and magnetic fields are not in phase with each other. The complex number notation allows us to quantify this phase difference between the two.

Energy

Energy is the capacity to do work and therefore has some measure of time associated with it. In the case of electricity, one measure is current multiplied by time (*e.g.*, Ampere-hours at a constant Voltage). That is, for how long can a source of energy supply a specified quantity of current at a fixed voltage? For example, assume that the energy stored in a 1.5 V AA battery is 1 A-h. If the terminals (electrodes) of the battery are connected in a circuit such that they produce a 1.5 Volt EMF across a resistance of 3 Ohms, a current of 0.5 Ampere will flow for 2 hours. At the end of that time, the EMF decreases below a useful level and the battery is considered to be “dead.” While one would expect this idealized relationship between current drawn from a battery and its “life” to hold under all conditions, it doesn’t. This will be pursued later in the discussion of source and load internal impedances.

The important point here is that energy is not a force; it is not the electromotive force. Energy is a measure of a capacity to supply an EMF and a current to a circuit over time. How much power is determined by the source and load impedances and EMFs. More generally, energy is power multiplied by time where electrical power is the product of current and voltage (the 3rd and 4th elements in this equation are created by replacing EMF and current with their Ohm’s law equivalents)

$$P = IE = i^2 Z = \frac{E^2}{Z}$$

so energy is

$$E = \int P\, dt$$

That is, the transfer of energy from one entity to another depends on the impedances which connects them.

Impedance
While it may seem like a circular definition since Ohm's law has already been introduced, impedance is defined as the proportionality constant relating the complex current and EMF in a circuit. Mathematically this is

$$Z = \frac{E}{I}$$

where the impedance (Z), the EMF (E), and the current (I), are all represented by complex number consisting of a real and an imaginary part. The complex numbers only reflect the fact that the 3 components may be temporally skewed relative to each other.

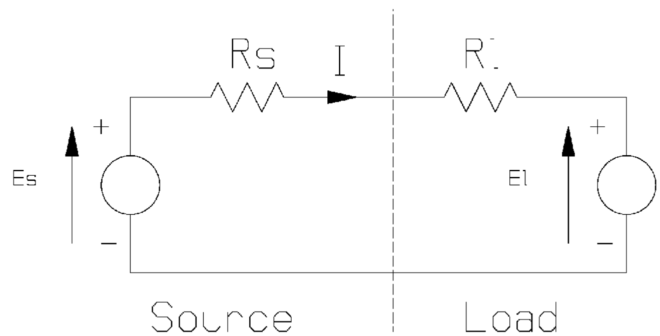

Figure 6 Power transfer from source to load.

Well, the importance of this relates to circuit as shown in Figure 6. It can be shown that the maximum transfer of power from one part of the circuit (the source) to another part of the circuit (the load) occurs when the impedances are identical (*i.e.*, matched, where $R_s = R_l$ for DC circuits, and $Z_s = Z_l$ for AC circuits). If power transfer is maximized with matched impedances, then energy transfer over a given time is maximized since energy is the product of power and time. In some circuits, impedances are not identical and devices such as transformers are used to cause the impedances to appear the same. That is, transformers are impedance matching devices in electric circuits; antennas are impedance matching devices in electromagnetic circuits.

Information
At its core, information is a measure of the reduction in uncertainty about something. Notice that information is the *change* about something; it is a dynamic quantity. This is usually represented by borrowing the concept of entropy from thermodynamics. Entropy is a measure of the randomness or disorder in a system. The higher the entropy, the higher the disorder. In order for one system to decrease its uncertainty about another system, energy must be transferred between them. Since there is always noise associated with a transfer of energy, there is a limit to the amount of information which can be

transferred from one system to another based on the signal (the desired information carrying power) to noise (undesired interfering power) ratio. For more information to be transferred from a source to a load in a given unit of time, more power must be transmitted under a given noise condition.

So how does one maximize the transfer of information from one system to another? The first answer is by coding it properly to maximize the information transfer under a given signal to noise power ratio. The second answer is to maximize the signal to noise ratio by matching impedances which causes the maximum transfer of power. The third answer is by maximizing the energy which causes the signal to flow.

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