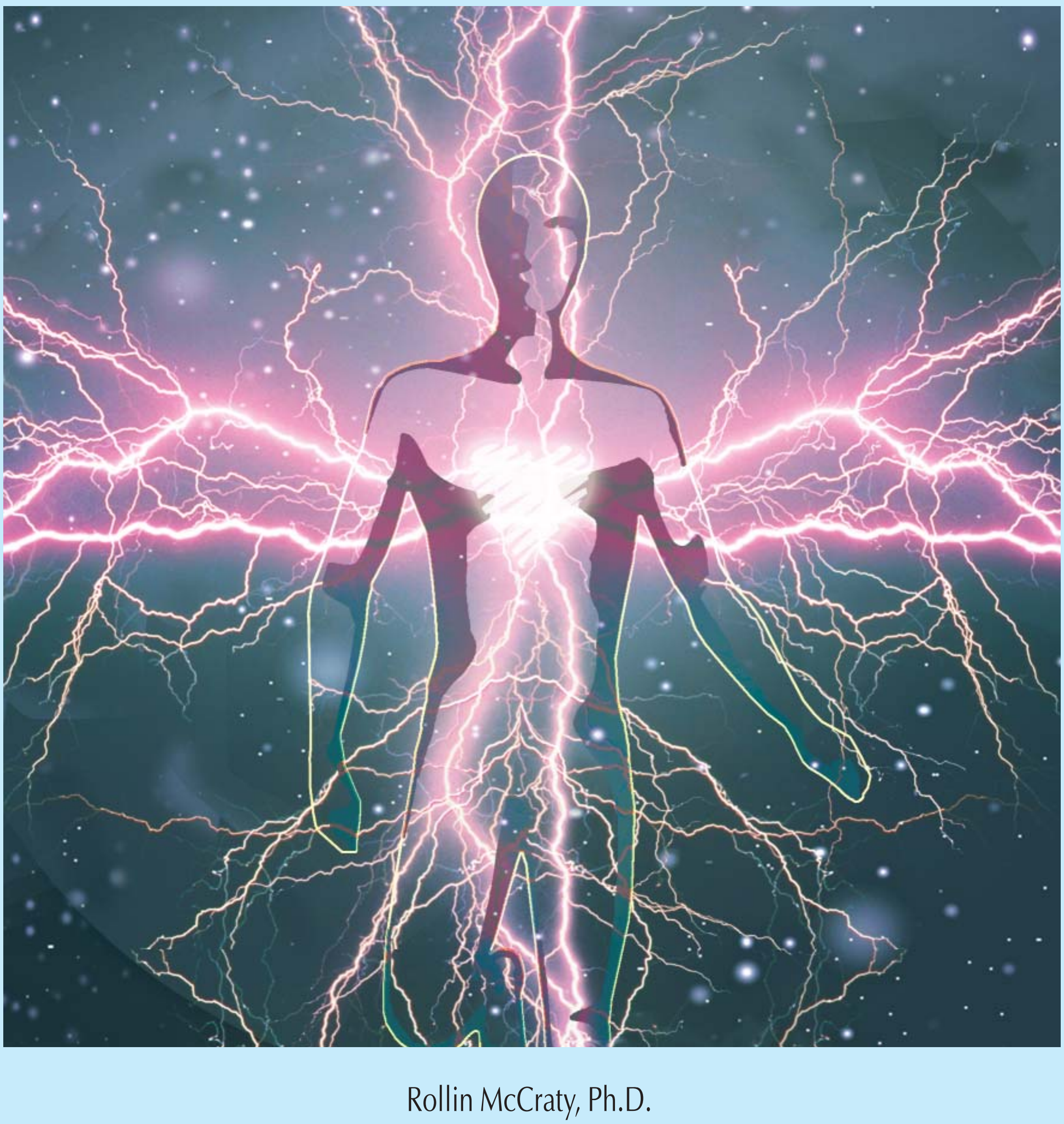
# The Energetic Heart

## Bioelectromagnetic Interactions Within and Between People



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# The Energetic Heart: Bioelectromagnetic Interactions Within and Between People

Rollin McCraty, Ph.D.

***Man's perceptions are not bounded by organs of perception; he perceives far more than sense (tho' ever so acute) can discover.*** —William Blake

This paper will focus on electromagnetic fields generated by the heart that permeate every cell and may act as a synchronizing signal for the body in a manner analogous to information carried by radio waves. Particular emphasis will be devoted to evidence demonstrating that this energy is not only transmitted internally to the brain but is also detectable by others within its range of communication. Finally, data will be discussed indicating that cells studied *in vitro* are also responsive to the heart's bioelectromagnetic field.

The heart generates the largest electromagnetic field in the body. The electrical field as measured in an electrocardiogram (ECG) is about 60 times greater in amplitude than the brain waves recorded in an electroencephalogram (EEG). The magnetic component of the heart's field, which is around 5000 times stronger than that produced by the brain, is not impeded by tissues and can be measured several feet away from the body with Superconducting Quantum Interference Device (SQUID)-based magnetometers.[1] We have also found that the clear rhythmic patterns in beat-to-beat heart rate variability are distinctly altered when different emotions are experienced. These changes in electromagnetic, sound pressure, and blood pressure waves produced by cardiac rhythmic activity are "felt" by every cell in the body, further supporting the heart's role as a global internal synchronizing signal.

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## Biological Patterns Encode Information

One of the primary ways that signals and messages are encoded and transmitted in physiological systems is in the language of patterns. In the nervous system, it is well established that information is encoded in the time intervals between action potentials—patterns of electrical activity—and this may also apply to humoral communications. Several recent studies have revealed that biologically relevant information is encoded in the time interval between hormonal pulses.[2-4] As the heart secretes a number of different hormones with each contraction, there is a hormonal pulse pattern that correlates with heart rhythms. In addition to the encoding of information in the space between nerve impulses and in the intervals between hormonal pulses, it is likely that information is also encoded in the interbeat intervals of the *pressure* and *electromagnetic* waves produced by the heart. Karl Pribram has proposed that the low-frequency oscillations generated by the heart and body in the form of afferent neural, hormonal, and electrical patterns are the carriers of emotional information, and that the higher frequency oscillations found in the EEG reflect the conscious perception and labeling of feelings and emotions.[5]

### *Detecting Bioelectromagnetic Patterns Using Signal Averaging*

A useful technique for detecting patterns in biological systems and investigating a number of bioelectromagnetic phenomena is signal averaging. This is accomplished by superimposing any number of equal-length epochs, each of which contains a repeating periodic signal. This emphasizes and distinguishes any signal that is time-locked to the periodic signal while eliminating variations that are not time-locked to the periodic signal. This procedure is com-



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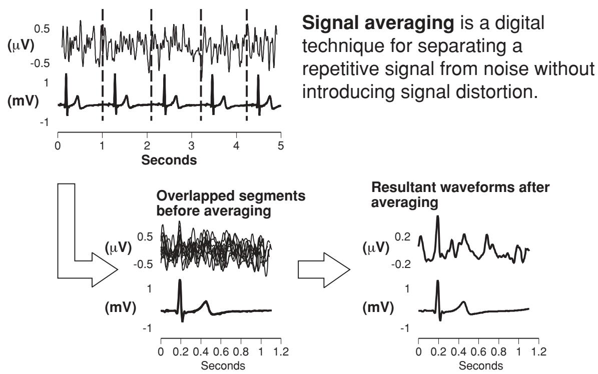


**Figure 1. Signal averaging.**
*The sequence of the signal averaging procedure is shown above. First, the signals recorded from the EEG and ECG are digitized and stored in a computer. The R-wave (peak) of the ECG is used as the time reference for cutting the EEG and ECG signals into individual segments. The individual segments are then averaged together to produce the resultant waveforms. Only signals that are repeatedly synchronous with the ECG are present in the resulting waveform. Signals not related to the signal source (ECG) are eliminated through this process.*

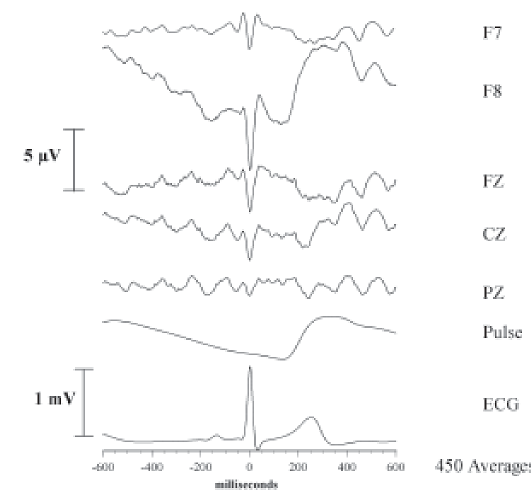


**Figure 2. Heartbeat evoked potentials.**
*This figure shows an example of typical heartbeat evoked potentials. In this example, 450 averages were used. The pulse wave is also shown, indicating the timing relationship of the blood pressure wave reaching the brain. In this example, there is less synchronized alpha activity immediately after the R-wave. The time range between 10 and 250 milliseconds is when afferent signals from the heart are impinging upon the brain, and the alpha desynchronization indicates the processing of this information. Increased alpha activity can be clearly seen later in the waveforms, starting at around the time the blood pressure wave reaches the brain.*

monly used to detect and record cerebral cortical responses to sensory stimulation.[6] When signal averaging is used to detect activity in the EEG that is time-locked to the ECG, the resultant waveform is called the ***heartbeat evoked potential.***

## The Heartbeat Evoked Potential

In looking at heartbeat evoked potential data, it can be seen that the electromagnetic signal arrives at the brain instantaneously, while a host of different neural signals reach the brain starting about 8 milliseconds later and continue arriving throughout the cardiac cycle. Although the precise timing varies with each cycle, at around 240 milliseconds the blood pressure wave arrives at the brain and acts to synchronize neural activity, especially the alpha rhythm. It is also possible that information is encoded in the shape (modulation) of the ECG wave itself. For example, if one examines consecutive ECG cycles, it can be seen that each wave is slightly varied in a complex manner.

As indicated, the heart generates a powerful pressure wave that travels rapidly throughout the arteries much faster than the actual flow of blood that we feel as our pulse. These pressure waves force the blood cells through the capillaries to provide oxygen and nutrients to cells and expand the arteries, causing them to generate a relatively large electrical voltage. These waves also apply pressure to the cells in a rhythmic fashion that can cause some of their proteins to generate an electrical current in response to this "squeeze." Experiments conducted in our laboratory have shown that a change in the brain's electrical activity can be seen when the blood pressure wave reaches the brain around 240 milliseconds after systole.

There is a replicable and complex distribution of heartbeat evoked potentials across the scalp. Changes in these evoked potentials associated with the heart's afferent neurological input to the brain are detectable between 50 to 550 milliseconds after the heartbeat.[7] Gary Schwartz and colleagues at the University of Arizona believe the earlier components in this complex distribution cannot be explained by simple physiological mechanisms alone and suggest that an energetic interaction between the heart and brain also occurs.[8] They have confirmed our findings that heart-focused attention is associated with increased heart-brain synchrony, providing further support for energetic heart-brain communications. Schwartz and colleagues also demonstrated that

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when subjects focused their attention on the perception of their heartbeat, the synchrony in the preventricular region of the heartbeat evoked potential increased. From this they concluded that preventricular synchrony may reflect an energetic mechanism of heart-brain communication, while postventricular synchrony most likely reflects direct physiological mechanisms.[8]

## The Heart's Role in Emotion

Throughout the 1990s, the view that the brain and body work in conjunction in order for perceptions, thoughts, and emotions to emerge gained momentum and is now widely accepted. The brain is an analog processor that relates whole concepts (patterns) to one another and looks for similarities, differences, or relationships between them, in contrast to a digital computer that assembles thoughts and feelings from bits of data. This new understanding of how the brain functions has challenged several longstanding assumptions about the nature of emotions. While it was formerly maintained that emotions originated only in the brain, we now recognize that emotions can be more accurately described as a product of the brain and body acting in concert. Moreover, evidence suggests that of the bodily organs, the heart may play a particularly important role in emotional experience. Research in the relatively new discipline of neurocardiology has confirmed that the heart is a sensory organ and acts as a sophisticated information encoding and processing center that enables it to learn, remember, and make independent functional decisions that do not involve the cerebral cortex.[9] Additionally, numerous experiments have demonstrated that patterns of cardiac afferent neurological input to the brain not only affect autonomic regulatory centers, but also influence higher brain centers involved in perception and emotional processing.[10-13]

Heart rate variability (HRV), derived from the ECG, is a measure of the naturally occurring beat-to-beat changes in heart rate that has proven to be invaluable in studying the physiology of emotions. The analysis of HRV, or *heart rhythms*, provides a powerful, noninvasive measure of neurocardiac function that reflects heart-brain interactions and autonomic nervous system dynamics, which are particularly sensitive to changes in emotional states.[14, 15] Our research, along with that of others, suggests that there is an important link between emotions and changes in the patterns of both efferent (descending) and afferent (ascending) autonomic activity.[12, 14, 16-18] These changes in autonomic activity are associated with dramatic changes in the *pattern* of the heart's rhythm that often occur without any change in the *amount* of heart rate variability. Specifically, we have found that during the experience of negative emotions such as anger, frustration, or anxiety, heart rhythms become more erratic and disordered, indicating less synchronization in the reciprocal action that ensues between the parasympathetic and sympathetic branches of the autonomic nervous system (ANS).[14, 16] In contrast, sustained positive emotions, such as appreciation, love, or compassion, are associated with highly ordered or *coherent* patterns in the heart rhythms, reflecting greater synchronization between the two branches of the ANS, and a shift in autonomic balance toward increased parasympathetic activity[14, 16, 17, 19] (Figure 3).

### *Physiological Coherence*

Based on these findings, we have introduced the term ***physiological coherence*** to describe a number of related physiological phenomena associated

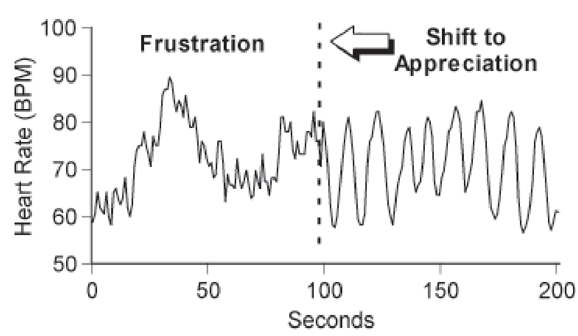


**Figure 3. Emotions are reflected in heart rhythm patterns.** *Real-time heart rate variability (heart rhythm) pattern of an individual making an intentional shift from a self-induced state of frustration to a genuine feeling of appreciation by using a positive emotion refocusing exercise known as the Freeze-Frame technique. It is of note that when the recording is analyzed statistically, the* amount *of heart rate variability is found to remain virtually the same during the two different emotional states; however, the* pattern *of the heart rhythm changes distinctly. Note the immediate shift from an erratic, disordered heart rhythm pattern associated with frustration to a smooth, harmonious, sine wave-like (coherent) pattern as the individual uses the positive emotion refocusing technique and self-generates a heartfelt feeling of appreciation.*



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with more ordered and harmonious interactions among the body's systems.[20]

The term *coherence* has several related definitions. A common definition of the term is "the quality of being logically integrated, consistent, and intelligible," as in a coherent argument. In this context, thoughts and emotional states can be considered "coherent" or "incoherent." Importantly, however, these associations are not merely metaphorical, as different emotions are in fact associated with different degrees of coherence in the oscillatory rhythms generated by the body's various systems.

The term "coherence" is used in physics to describe the ordered or constructive distribution of power within a waveform. The more stable the frequency and shape of the waveform, the higher the coherence. An example of a coherent wave is the sine wave. The term *autocoherence* is used to denote this kind of coherence. In physiological systems, this type of coherence describes the degree of order and stability in the rhythmic activity generated by a single oscillatory system. Methodology for computing coherence has been published elsewhere.[14]

Coherence also describes two or more waves that are either phase- or frequency-locked. In physiology, coherence is used to describe a functional mode in which two or more of the body's oscillatory systems, such as respiration and heart rhythms, become *entrained* and oscillate at the same frequency. The term *cross-coherence* is used to specify this type of coherence.

All the above definitions apply to the study of both emotional physiology and bioelectromagnetism. We have found that positive emotions are associated with a higher degree of coherence *within* the heart's rhythmic activity (autocoherence) as well as increased coherence *between* different oscillatory systems (cross-coherence/entrainment).[14, 20] Typically, entrainment is observed between heart rhythms, respiratory rhythms, and blood pressure oscillations; however, other biological oscillators, including very low frequency brain rhythms, craniosacral rhythms, electrical potentials measured across the skin, and, most likely, rhythms in the digestive system, can also become entrained.[20]

We have also demonstrated that physiological coherence is associated with increased synchronization between the heartbeat (ECG) and alpha rhythms in the EEG. In experiments measuring heartbeat evoked potentials, we found that the brain's alpha activity (8-12 hertz frequency range) is naturally synchronized to the cardiac cycle. However, when subjects used a positive emotion refocusing technique to consciously self-generate feelings of appreciation, their heart rhythm coherence significantly increased, as did the ratio of the alpha rhythm that was synchronized to the heart.[20, 21]

Another related phenomenon associated with physiological coherence is *resonance*. In physics, resonance refers to a phenomenon whereby an unusually large vibration is produced in a system in response to a stimulus whose frequency is identical or nearly identical to the natural vibratory frequency of the system. The frequency of the vibration produced in such a state is said to be the *resonant frequency* of the system. When the human system is operating in the coherent mode, increased synchronization occurs between the sympathetic and parasympathetic branches of the ANS, and entrainment between the heart rhythms, respiration and blood pressure oscillations is observed. This occurs because these oscillatory subsystems are all vibrating at the resonant frequency of the system. Most models show that the resonant frequency of the human cardiovascular system is determined by the feedback loops between the heart and brain.[22, 23] In humans and in many animals, the resonant frequency is approximately 0.1 hertz, which is equivalent to a 10-second rhythm.

In summary, we use *coherence* as an umbrella term to describe a physiological mode that encompasses entrainment, resonance, and synchronization—distinct but related phenomena, all of which emerge from the harmonious activity and interactions of the body's subsystems. Correlates of physiological coherence include: increased synchronization between the two branches of the ANS, a shift in autonomic balance toward increased parasympathetic activity, increased heart-brain synchronization, increased vascular resonance, and entrainment between diverse physiological oscillatory systems. The coherent mode is reflected by a smooth, sine wave-like pattern in the heart rhythms (heart rhythm coherence) and a narrow-band, high-amplitude peak in the low frequency range of the heart rate variability power spectrum, at a frequency of about 0.1 hertz.

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### *Benefits of Coherence*

Coherence confers a number of benefits to the system in terms of both physiological and psychological functioning. At the physiological level, there is increased efficiency in fluid exchange, filtration, and absorption between the capillaries and tissues; increased ability of the cardiovascular system to adapt to circulatory demands; and increased temporal synchronization of cells throughout the body.[24, 25] This results in increased system-wide energy efficiency and conservation of metabolic energy. These observations support the link between positive emotions and increased physiological efficiency that may partially explain the growing number of documented correlations between positive emotions, improved health, and increased longevity.[26-28] We have also shown that practicing certain techniques that increase physiological coherence is associated with both short-term and long-term improvement in several objective health-related measures, including enhanced humoral immunity[29, 30] and an increased DHEA/cortisol ratio.[17]

Increased physiological coherence is similarly associated with psychological benefits, including improvements in cognitive performance and mental clarity as well as increased emotional stability and well-being.[20, 31] Studies conducted in diverse populations have documented significant reductions in stress and negative affect and increases in positive mood and attitudes in individuals using coherence-building techniques.[17, 19, 29, 31, 32]

Improvements in clinical status, emotional well-being and quality of life have also been demonstrated in various medical patient populations in intervention programs using coherence-building approaches. For example, significant blood pressure reductions have been demonstrated in individuals with hypertension;[33] improved functional capacity and reduced depression in congestive heart failure patients;[34] improved psychological health and quality of life in patients with diabetes;[35] and improvements in asthma.[36] Another study reported reductions in pathological symptoms and anxiety and significant improvements in positive affect, physical vitality, and general well-being in individuals with HIV infection and AIDS.[37]

Additionally, patient case history data provided by numerous health care professionals report substantial improvements in health and psychological status and frequent reductions in medication requirements in patients with such medical conditions as cardiac arrhythmias, chronic fatigue, environmental sensitivity, fibromyalgia, and chronic pain.[38] Finally, techniques that increase physiological coherence have been used effectively by mental health professionals in the treatment of emotional disorders, including anxiety, depression, panic disorder, and post-traumatic stress disorder.[38]

### *Drivers of Physiological Coherence*

Although physiological coherence is a natural state that can occur spontaneously during sleep and deep relaxation, sustained episodes during normal daily activities are generally rare. While specific rhythmic breathing methods can induce coherence for brief periods, cognitively directed, paced breathing is difficult for many people to maintain. On the other hand, our findings indicate that individuals can produce extended periods of physiological coherence by actively generating and sustaining a feeling of appreciation or other positive emotions. Sincere positive feelings appear to excite the system at its resonant frequency, allowing the coherent mode to emerge naturally. This typically makes it easier for people to sustain a positive emotion for much longer periods, thus facilitating the process of establishing and reinforcing coherent patterns in the neural architecture as the familiar reference. Once a new pattern is established, the brain strives to maintain a match with the new program, thus increasing the probability of maintaining coherence and reducing stress, even during challenging situations.[12]

Doc Childre, founder of the Institute of HeartMath, has developed a number of practical positive emotion refocusing and emotional restructuring techniques that allow people to quickly self-generate coherence at will.[39, 40] Known as the HeartMath system, these techniques utilize the heart as a point of entry into the psychophysiological networks that connect the physiological, mental, and emotional systems. In essence, because the heart is a primary generator of rhythmic neural and energetic patterns in the body—influencing brain processes that control the ANS, cognitive function and emotion—it provides an access point from which system-wide dynamics can be quickly and profoundly affected. Research studies and the experience of numerous health care pro-

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fessionals indicate that HeartMath coherence-building techniques are easily learned, have a high rate of compliance, and are highly adaptable to a wide range of demographic groups.

### *Promoting Physiological Coherence Through Heart Rhythm Coherence Feedback Training*

Used in conjunction with positive emotion-based coherence-building techniques, heart rhythm feedback training can be a powerful tool to assist people in learning how to self-generate increased physiological coherence.[41] We have developed a portable heart rhythm monitoring and feedback system that enables physiological coherence to be objectively monitored and quantified. Known as the Freeze-Framer® coherence-building system (HeartMath LLC, Boulder Creek, CA), this interactive hardware/software system monitors and displays individuals' heart rate variability patterns in real time as they practice the positive emotion refocusing and emotional restructuring techniques taught in an on-line tutorial. Using a fingertip sensor to record the pulse wave, the Freeze-Framer plots changes in heart rate on a beat-to-beat basis. As people practice the coherence-building techniques, they can readily see and experience the changes in their heart rhythm patterns, which generally become more ordered, smoother, and more sine wave-like as they experience positive emotions. This process reinforces the natural association between the physiological coherence mode and positive feelings. The software also analyzes the heart rhythm patterns for coherence level, which is fed back to the user as an accumulated numerical score or success in playing one of three on-screen games designed to reinforce the coherence-building skills. The real-time physiological feedback essentially takes the guesswork and randomness out of the process of self-inducing a coherent state, resulting in greater consistency, focus, and effectiveness in shifting to a beneficial psychophysiological mode.

Heart rhythm coherence feedback training has been successfully used in clinical settings by physicians, mental health professionals and neurofeedback therapists to facilitate health improvements in patients with numerous physical and psychological disorders. It is also increasingly being utilized in corporate, law enforcement, and educational settings to enhance physical and emotional health and improve performance.

### *Heart Rhythms and Bioelectromagnetism*

The first biomagnetic signal was demonstrated in 1963 by Gerhard Baule and Richard McFee in a magnetocardiogram (MCG) that used magnetic induction coils to detect fields generated by the human heart.[42] A remarkable increase in the sensitivity of biomagnetic measurements was achieved with the introduction of the Superconducting Quantum Interference Device (SQUID) in the early 1970s, and the ECG and MCG have since been shown to closely parallel one another.[43]

The heart generates a series of electromagnetic pulses in which the time interval between each beat varies in a complex manner. These pulsing waves of electromagnetic energy create fields within fields and give rise to interference patterns when they interact with magnetically polarizable tissues and substances.

Figure 4 shows two different power spectra derived from an average of 12 individual 10-second epochs of ECG data recorded during differing psychophysiological modes. The plot on the left was produced while the subject was in a state of deep appreciation, whereas the plot on the right was generated while the subject experienced recalled feelings of anger. The difference in the patterns, and thus the information they contain, can be clearly seen. There is a direct correlation between the patterns in the heart rate variability rhythm and the frequency patterns in the spectrum of the ECG or MCG. Experiments such as these indicate that psychophysiological information can be encoded into the electromagnetic fields produced by the heart.[14, 44]

## Bioelectromagnetic Communication Between People

The human body is replete with mechanisms for detecting its external environment. Sense organs, the most obvious example, are specifically geared to react to touch, temperature, select ranges of light and sound waves, etc. These organs are acutely sensitive to external stimuli. The nose, for example, can detect one molecule of gas, while a cell in the retina of the eye can detect a single photon of light; and if the ear were any more sensitive, it would pick up the sound of the random vibrations of its own molecules.[45]

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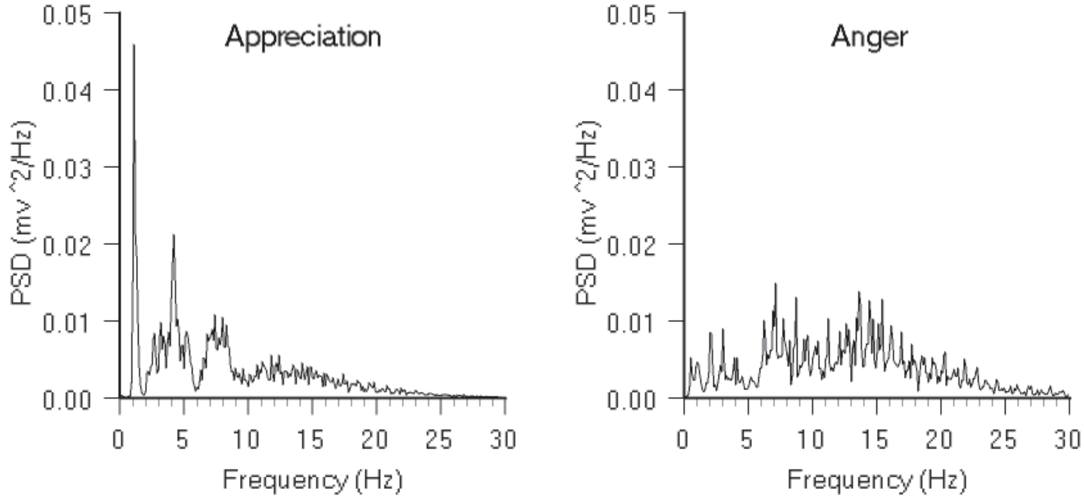


**Figure 4. ECG spectra during different emotional states.**
*The above graphs are the average power spectra of 12 individual 10-second epochs of ECG data, which reflect information patterns contained in the electromagnetic field radiated by the heart. The lefthand graph is an example of a spectrum obtained during a period of high heart rhythm coherence generated during a sustained heartfelt experience of appreciation. The graph on the right depicts a spectrum associated with a disordered heart rhythm generated during feelings of anger.*

The interaction between two human beings—for example, the consultation between a patient and her clinician—is a very sophisticated dance that involves many subtle factors. Most people tend to think of communication solely in terms of overt signals expressed through facial movements, voice qualities, gestures and body movements. However, evidence now supports the perspective that a subtle yet influential electromagnetic or "energetic" communication system operates just below our conscious level of awareness. The following section will discuss data suggesting that this energetic system contributes to the "magnetic" attractions or repulsions that occur between individuals. It is also quite possible that these energetic interactions can affect the therapeutic process.

The concept of energy or information exchange between individuals is central to many of the Eastern healing arts, but its acceptance in Western medicine has been hampered by the lack of a plausible mechanism to explain the nature of this "energy information" or how it is communicated. However, numerous studies investigating the effects of healers, Therapeutic Touch practitioners, and other individuals have demonstrated a wide range of significant effects including the influence of "energetic" approaches on wound healing rates,[46, 47] pain,[48, 49] hemoglobin levels,[50] conformational changes of DNA and water structure,[51-52] as well as psychological states.[53] Although these reports show beneficial results, they have been largely ignored because of the lack of any scientific rationale to explain how the effects are achieved.

## *Physiological Linkage and Empathy*

The ability to sense what other people are feeling is an important factor in allowing us to connect or communicate effectively with others. The smoothness or flow in any social interaction depends to a great extent on the establishment of a spontaneous entrainment or linkage between individuals. When people are engaged in deep conversation, they begin to fall into a subtle dance, synchronizing their movements and postures, vocal pitch, speaking rates, and length of pauses between responses,[54] and, as we are now discovering, important aspects of their physiology can also become linked and entrained.

Several studies have investigated different types of physiological synchronization or entrainment between individuals during empathetic moments or between clinician and patient during therapeutic sessions. One study by Levenson and Gottman at the University of California at Berkeley looked at


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physiological synchronization in married couples during empathetic interactions. Researchers examined couples' physiological responses during two discussions: a neutral "How was your day?" conversation, to establish a baseline, and a second conversation containing more emotional content in which the couples were asked to spend fifteen minutes discussing something about which they disagreed. After the disagreement, one partner was asked to leave the room while the other stayed to watch a replay of the talk and identify portions of the dialogue where he or she was actually empathizing but did not express it. Both spouses individually engaged in this procedure. Levenson was then able to identify those segments of the video where empathy occurred and match the empathetic response to physiological responses in both partners. He found that in partners who were adept at empathizing, their physiology mimicked their partner's while they empathized. If the heart rate of one went up, so did the heart rate of the other; if the heart rate slowed, so did that of the empathic spouse.[55] Other studies observing the psychophysiology of married couples while interacting were able to predict the probability of divorce.[56]

Although studies that have examined physiological linkages between therapists and patients have suffered from methodological challenges, they do support a tendency to autonomic attunement during periods of empathy between the therapist and patient.[57] Dana Redington, a psychophysiologist at the University of California, San Francisco, analyzed heart rate variability patterns during therapist-patient interactions using a nonlinear dynamics approach. Redington and colleagues used phase space maps to plot changes in the beat-to-beat heart rate of both the therapist and patient during psychotherapy sessions. They found that the trajectories in the therapist's patterns often coincided with the patient's during moments when the therapist experienced strong feelings of empathy for the patient.[58] Carl Marci at Harvard University found evidence of a more direct linkage between patients and therapists using skin conductance measures. During sessions of psychodynamic psychotherapy, Marci observed a quantifiable fluctuation and entrainment in the pattern of physiological linkage within patient-therapist dyads, which was related to patient perception of the therapist's empathy. In addition, the preliminary results of his studies indicate that during periods of low physiological linkage there are fewer empathetic comments, more incidents of incorrect interpretations, less shared affect, and fewer shared behavioral responses when compared to episodes of high physiological linkage.[59]

### *Cardioelectromagnetic Communication*

An important step in testing our hypothesis that the heart's electromagnetic field could transmit signals between people was to determine if the field and the information modulated within it could be detected by other individuals.

In conducting these experiments, the question being asked was straightforward. Namely, can the electromagnetic field generated by the heart of one individual be detected in physiologically relevant ways in another person, and if so does it have any discernible biological effects? To investigate these possibilities, we used signal-averaging techniques to detect signals that were synchronous with the peak of the R-wave of one subject's ECG in recordings of another subject's electroencephalogram (EEG) or brain waves. My colleagues and I have performed numerous experiments in our laboratory over a period of several years using these techniques,[60] and several examples are included below to illustrate some of these findings. In the majority of these experiments, subjects were seated in comfortable, high-back chairs to minimize postural changes with the positive ECG electrode located on the side at the left sixth rib and referenced to the right supraclavicular fossa according to the International 10-20 system. The ECG and EEG were recorded from both subjects simultaneously so that the data (typically sampled at 256 hertz or higher) could be analyzed for simultaneous signal detection in both.

To clarify the direction in which the signal flow was analyzed, the subject whose ECG R-wave was used as the time reference for the signal averaging procedure is referred to as the "signal source," or simply "source." The subject whose EEG was analyzed for the registration of the source's ECG signal is referred to as the "signal receiver," or simply "receiver." The number of averages used in the majority of the experiments was 250 ECG cycles (~ 4 minutes). The subjects did not consciously intend to send or receive a signal and, in most cases, were unaware of the true purpose of the experiments. The results

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of these experiments have led us to conclude that the nervous system acts as an antenna, which is tuned to and responds to the magnetic fields produced by the hearts of other individuals. My colleagues and I call this energetic information exchange *cardioelectromagnetic communication* and believe it to be an innate ability that heightens awareness and mediates important aspects of true empathy and sensitivity to others. Furthermore, we have observed that this energetic communication ability can be enhanced, resulting in a much deeper level of non-verbal communication, understanding, and connection between people. We also propose that this type of energetic communication between individuals may play a role in therapeutic interactions between clinicians and patients that has the potential to promote the healing process.

From an electrophysiological perspective, it appears that sensitivity to this form of energetic communication between individuals is related to the ability to be emotionally and physiologically coherent. The data indicate that when individuals are in the coherent mode, they are more sensitive to receiving information contained in the fields generated by others. In addition, during physiological coherence, internal systems are more stable, function more efficiently, and radiate electromagnetic fields containing a more coherent structure.[14]

*The Electricity of Touch*

The first step was to determine if the ECG signal of one person could be detected in another individual's EEG during physical contact. For these experiments we seated pairs of subjects 4 feet apart, during which time they were simultaneously monitored. An initial 10-minute baseline period (no physical contact) was followed by a 5-minute period in which subjects remained seated but reached out and held the hand of the other person (like shaking hands). Figure 5 shows a typical example of the results.

Prior to holding hands, there was no indication that Subject 1's ECG signals were detected in Subject 2's EEG. However, upon holding hands, Subject 1's ECG could be clearly detected in Subject 2's EEG at all monitored locations. While in most pairs a clear

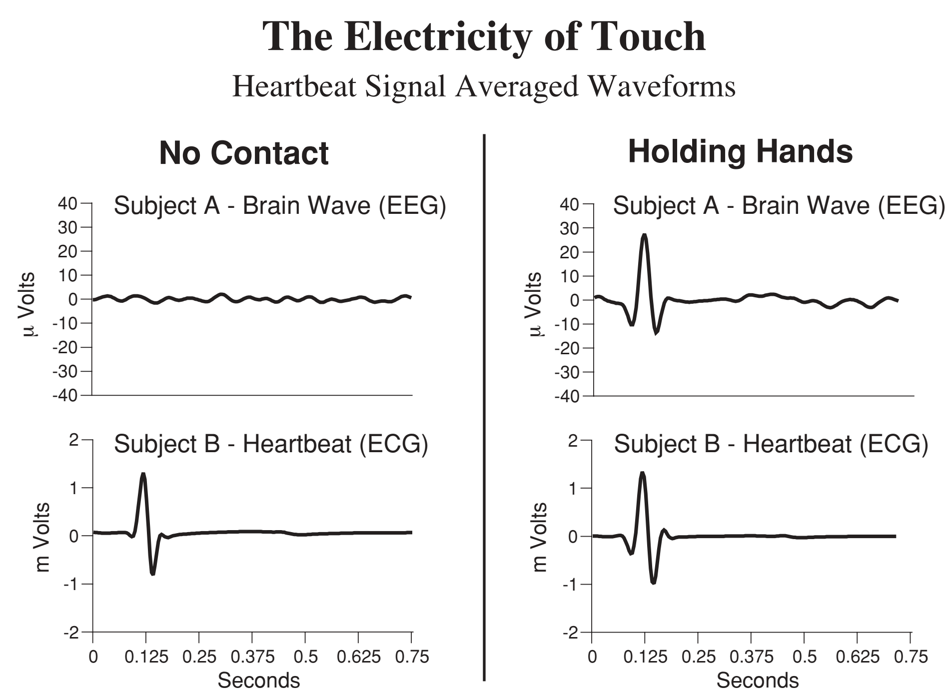


**Figure 5.**
*Signal averaged waveforms showing the detection of electromagnetic energy generated by the source's heart in the receiving subject's EEG. The baseline recording (left side) is from a 10-minute period during which time the subjects were seated 4 feet apart without physical contact. The right column shows the recording from the 5-minute period during which the subjects held hands. The EEG data shown here were recorded from the C3 site of the EEG.*



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signal transfer between the two subjects was measurable in one direction, it was only observed in both directions simultaneously in about 30 percent of the pairs (*i.e.*, Subject 2's ECG could be detected in Subject 1's EEG at the same time that Subject 1's ECG was detectable in Subject 2's EEG). From other experiments we have concluded that this phenomenon is not related to gender or amplitude of the ECG signal. As shown later, an important variable appears to be the degree of physiological coherence maintained.

After demonstrating that the ECG from one individual could be detected in another's EEG during physical contact, we completed a series of experiments to determine if the signal was transferred via electrical conduction through the skin alone or if it was also radiated. In one set of experiments subjects were recorded holding hands under two sets of conditions: barehanded and wearing form-fitting, latex lab gloves. The ECG signal of one subject could be clearly detected in the EEG of the other subject even when they were wearing the gloves; however, the signal amplitude was reduced approximately tenfold. This suggests that while a significant degree of the signal transfer occurs through skin conduction, the signal is also radiated or capacitively coupled between individuals. When conductive gel was used to decrease skin-to-skin contact resistance, the signal amplitude was unaffected. For additional detail, the protocols and data from these and related experiments are described elsewhere.[60]

We also conducted several experiments to determine if the transfer of cardiac energy and information is affected by the orientation of the subjects' hand-holding (*i.e.*, source's left hand holding receiver's right hand vs. source's right hand holding receiver's left hand, etc.). The subjects were instructed to hold hands in each of the four possible orientations for 5 minutes. Since we only performed this experiment with three subject pairs, the results should be interpreted with a degree of caution; however, we did find that consistent and measurable differences could be observed. The source's ECG appeared with the largest amplitude in the receiver's EEG when the receiver's right hand was held by either the source's left or right hand. When the receiver's left hand was held by the source's right hand, the signal appeared at a lower amplitude. Finally, when the receiver's left hand was held by the source's left hand, the ECG signal was either very low in amplitude or undetectable.[60]

The possibility exists that in some cases the signal appearing in the receiving subject's recordings could be the receiver's own ECG rather than that of the other subject. Given the signal averaging procedure employed, this could only occur if the source's ECG was continually and precisely synchronized with the receiver's ECG. To definitively rule this out, the data in all experiments were checked for this possibility.

Simultaneously and independently, Russek and Schwartz at the University of Arizona conducted similar experiments in which they were also able to demonstrate the detection of an individual's cardiac signal in another's EEG recording in two people sitting quietly, without physical contact.[61] In a publication entitled "Energy Cardiology," they discuss the implications of their findings in the context of what they call a "dynamical energy systems approach" describing the heart as a prime generator, organizer, and integrator of energy in the human body.[62]

### *Heart-Brain Synchronization During Nonphysical Contact*

Since the magnetic component of the field produced by the heartbeat is radiated outside the body and can be detected several feet away with SQUID-based magnetometers,[1] we further tested the transference of signals between subjects who were not in physical contact. In these experiments, the subjects were either seated side by side or facing each other at varying distances. In some cases, we were able to detect a clear QRS-shaped signal in the receiver's EEG, but not in others. Although the ability to obtain a clear registration of the ECG in the other person's EEG declined as the distance between subjects was increased, the phenomenon appears to be nonlinear. For instance, a clear signal could be detected at a distance of 18 inches in one session but was undetectable in the very next trial at a distance of only 6 inches. Although transmission of a clear QRS-shaped signal is uncommon at distances over 6 inches in our experience, this does not preclude the possibility that physiologically relevant information can be communicated between people at longer distances.

Because of the apparent nonlinear nature of the phenomenon and the growing body of data suggesting that the detection of weak periodic signals can be enhanced in biological systems via a mecha-


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nism known as stochastic resonance, we investigated the possibility that physiological coherence may be an important variable in determining whether the cardiac fields are detected past the 6-inch distance. The nonlinear stochastic resonance model predicts that under certain circumstances, very weak *coherent* electromagnetic signals are detectable by biological systems and can have significant biological effects.[63-66] Stochastic resonance will be discussed in more detail in a subsequent section.

Figure 6 shows the data from two subjects seated facing one another at a distance of 5 feet, with no physical contact. The subjects were asked to use the Heart Lock-In technique,[39, 40] an emotional restructuring exercise that has been demonstrated to produce sustained states of physiological coherence when properly applied.[17] There was no intention to "send energy" and participants were not aware of the purpose of the experiment. The top three traces show the signal-averaged waveforms derived from the EEG locations along the medial line of the head.

Note that in this example, the signal averaged waveforms do not contain any semblance of the QRS complex shape as seen in the physical contact experiments; rather they reveal the occurrence of an alpha wave synchronization in the EEG of one subject that is precisely timed to the R-wave of the other subject's ECG. Power spectrum analysis of the signal averaged EEG waveforms was used to verify that it is the alpha rhythm that is synchronized to the other person's heart. This alpha synchronization does not imply that there is increased alpha activity, but it does show that the existing alpha rhythm is able to synchronize to extremely weak external electromagnetic fields such as those produced by another person's heart. It is well known that the alpha rhythm can synchronize to an external stimulus such as sound or light flashes, but the ability to synchronize to such a subtle electromagnetic signal is surprising. As mentioned, there is also a significant ratio of alpha activity that is synchronized to one's own heartbeat, and the amount of this synchronized alpha activity is significantly increased during periods of physiological coherence.[20, 21]

Figure 7 shows an overlay plot of one of Subject 2's signal averaged EEG traces and Subject 1's signal averaged ECG. This view shows an amazing degree of synchronization between the EEG of Subject 2 and Subject 1's heart. These data show that it is possible for the magnetic signals radiated by the heart of one individual to influence the brain rhythms of another. In addition, this phenomenon can occur at conversational distances. As yet, we have not tested this effect at distances greater than 5 feet.

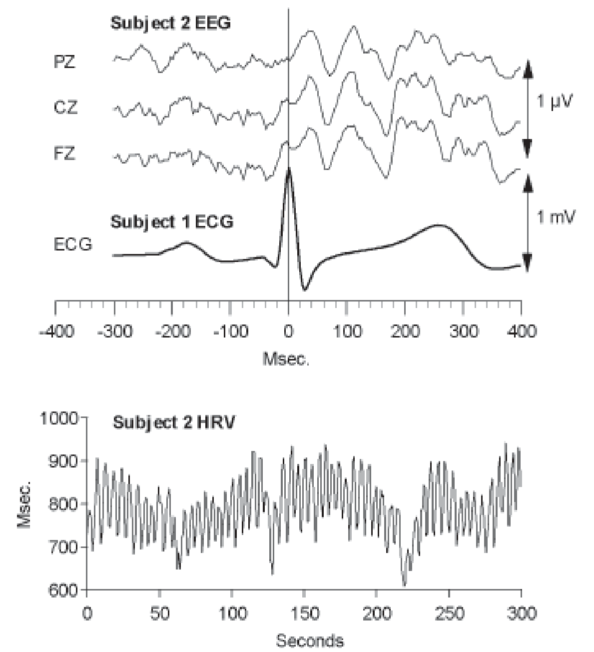


**Figure 6. Heart-brain synchronization between two people.** *The top three traces are Subject 2's signal averaged EEG waveforms, which are synchronized to the R-wave of Subject 1's ECG. The lower plot shows Subject 2's heart rate variability pattern, which was coherent throughout the majority of the record. The two subjects were seated at a conversational distance without physical contact.*

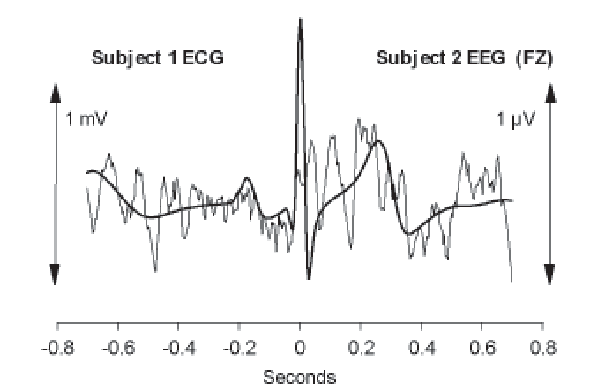


**Figure 7. Overlay of signal averaged EEG and ECG.** *This graph is an overlay plot of the same EEG and ECG data shown in Figure 6. Note the similarity of the wave shapes, indicating a high degree of synchronization.*

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Figure 8 shows the data from the same two subjects during the same time period, only it is analyzed for alpha synchronization in the opposite direction (Subject 1's EEG and Subject 2's ECG). In this case, we see that there is no observable synchronization between Subject 1's EEG and Subject 2's ECG. The key difference between the data shown in Figure 6 and Figure 8 is the high degree of physiological coherence maintained by Subject 2. In other words, the degree of coherence in the *receiver's* heart rhythms appears to determine whether his/her brain waves synchronize to the other person's heart.

This suggests that when one is in a physiologically coherent mode, one exhibits greater sensitivity in registering the electromagnetic signals and information patterns encoded in the fields radiated by the hearts of other people. At first glance these data may be mistakenly interpreted as suggesting that we are more vulnerable to the potential negative influence of incoherent patterns radiated by those around us. In fact, the opposite is true, because when people are able to maintain the physiological coherence mode, they are more internally stable and thus less vulnerable to being negatively affected by the fields emanating from others. It appears that it is the increased internal stability and coherence that allows for the increased sensitivity to emerge.

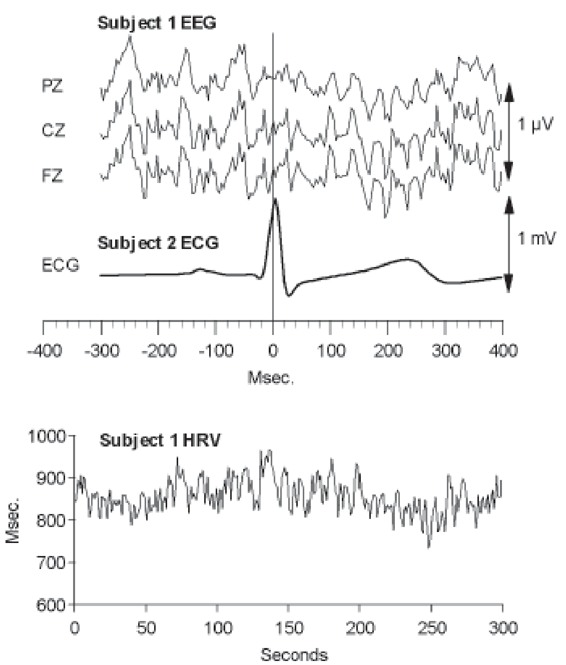


**Figure 8.**
*The top three traces are the signal averaged EEG waveforms for Subject 1.There is no apparent synchronization of Subject 1's alpha rhythm to Subject 2's ECG. The bottom plot is a sample of Subject 1's heart rate variability pattern, which was incoherent throughout the majority of the record.*

This fits quite well with our experience in training thousands of individuals in how to self-generate and maintain coherence while they are listening to others during conversation. Once individuals learn this skill, it is a common experience that they become much more attuned to other people and are able to detect and understand the deeper meaning behind spoken words. They are often able to sense what someone else really wishes to communicate even when the other person may not be clear about that which he is attempting to say. This technique, called Intuitive Listening, helps people to feel fully heard and promotes greater rapport and empathy between people.[67]

Our data are also relevant to Russek and Schwartz's findings that people who are more accustomed to experiencing positive emotions such as love and care are better receivers of cardiac signals from others.[61] In their follow-up study of 20 college students, those who had rated themselves as having been raised by loving parents exhibited significantly greater registration of an experimenter's ECG in their EEG than others who had perceived their parents as less loving. Our findings, which show that positive emotions such as love, care, and appreciation are associated with increased physiological coherence, suggest the possibility that the subjects in Russek and Schwartz's study had higher ratios of physiological coherence, which could explain the greater registration of cardiac signals.

### *Heart Rhythm Entrainment Between Subjects*

When heart rhythms are more coherent, the electromagnetic field that is radiated outside the body correspondingly becomes more organized, as shown in Figure 4. The data presented thus far indicate that signals and information can be communicated energetically between individuals, but so far have not implied a literal entrainment of two individuals' heart rhythm patterns. We have found that entrainment of heart rhythm patterns between individuals is possible, but usually occurs only under very specific conditions. In our experience, true heart rhythm entrainment between individuals is very rare during



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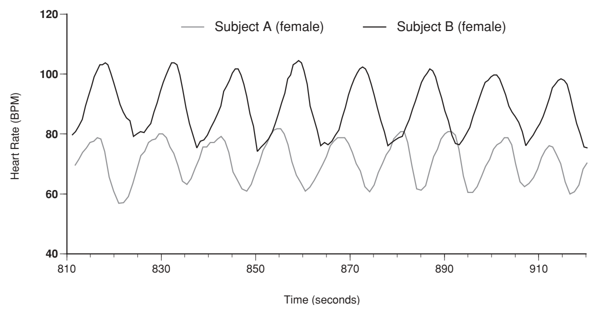


**Figure 9. Heart rhythm entrainment between two people.** *These data were recorded while both subjects were practicing the Heart Lock-In emotional restructuring technique and consciously feeling appreciation for each other. It should be emphasized that in typical waking states, entrainment between people such as in this example is rare.*

normal waking states. We have found that individuals who have a close living or working relationship are the best candidates for exhibiting this type of entrainment. Figure 9 shows an example of heart rhythm entrainment between two women who have a close working relationship and practice coherence-building techniques regularly. For this experiment, they were seated 4 feet apart, and, although blind to the data, were consciously focused on generating feelings of appreciation for each other.

A more complex type of entrainment can also occur during sleep. Although we have only looked at couples who are in long-term stable and loving relationships, we have been surprised at the high degree of heart rhythm synchrony observed in these couples while they sleep. Figure 10 shows an example of a small segment of data from one couple. These data were recorded using an ambulatory ECG (Holter) recorder with a modified cable harness that allowed the concurrent recording of two individuals on the same tape. Note how the heart rhythms simultaneously change in the same direction and how heart rates converge. Throughout the recording, clear transition periods are evident in which the heart rhythms move into greater synchronicity, maintain the entrainment for some time, and then drift out again. This implies that unlike in most wakeful states, entrainment between the heart rhythms of individuals can and does occur during sleep.

We have also found that a type of heart rhythm entrainment or synchronization can occur in interactions between people and their pets. Figure 10 shows the results of an experiment looking at the heart rhythms of my son Josh (15 years old at the time of the recording) and his dog, Mabel. Here we used two Holter recorders, one fitted on Mabel and the other on Josh. We synchronized the recorders and placed Mabel in one of our labs. Josh then entered the room and sat down and proceeded to consciously feel feelings of love towards Mabel. Note the synchronous shift to increased coherence in the heart rhythms of both Josh and Mabel as Josh consciously feels love for his pet.

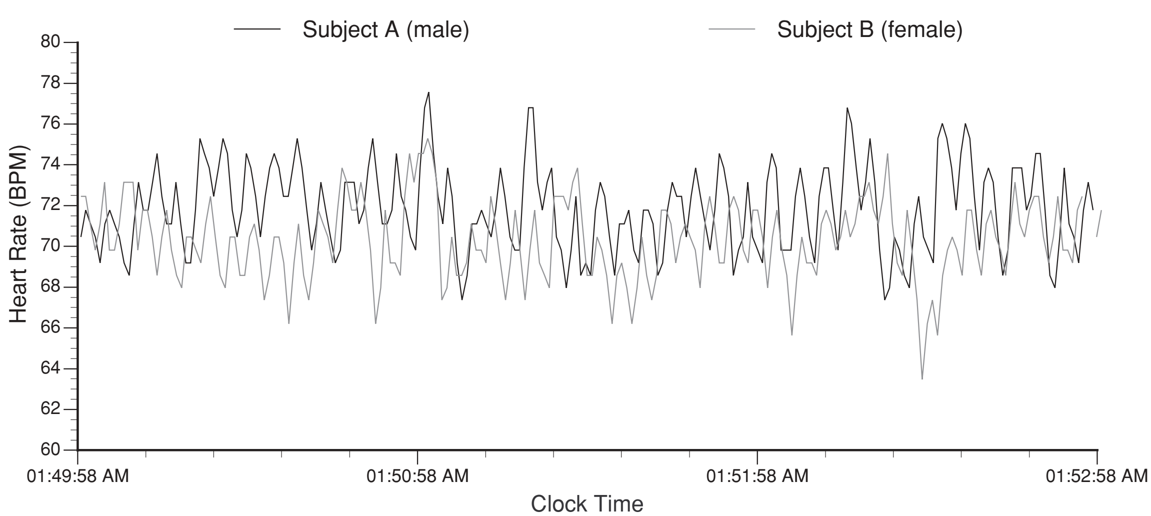


**Figure 10. Heart rhythm entrainment between husband and wife during sleep.**



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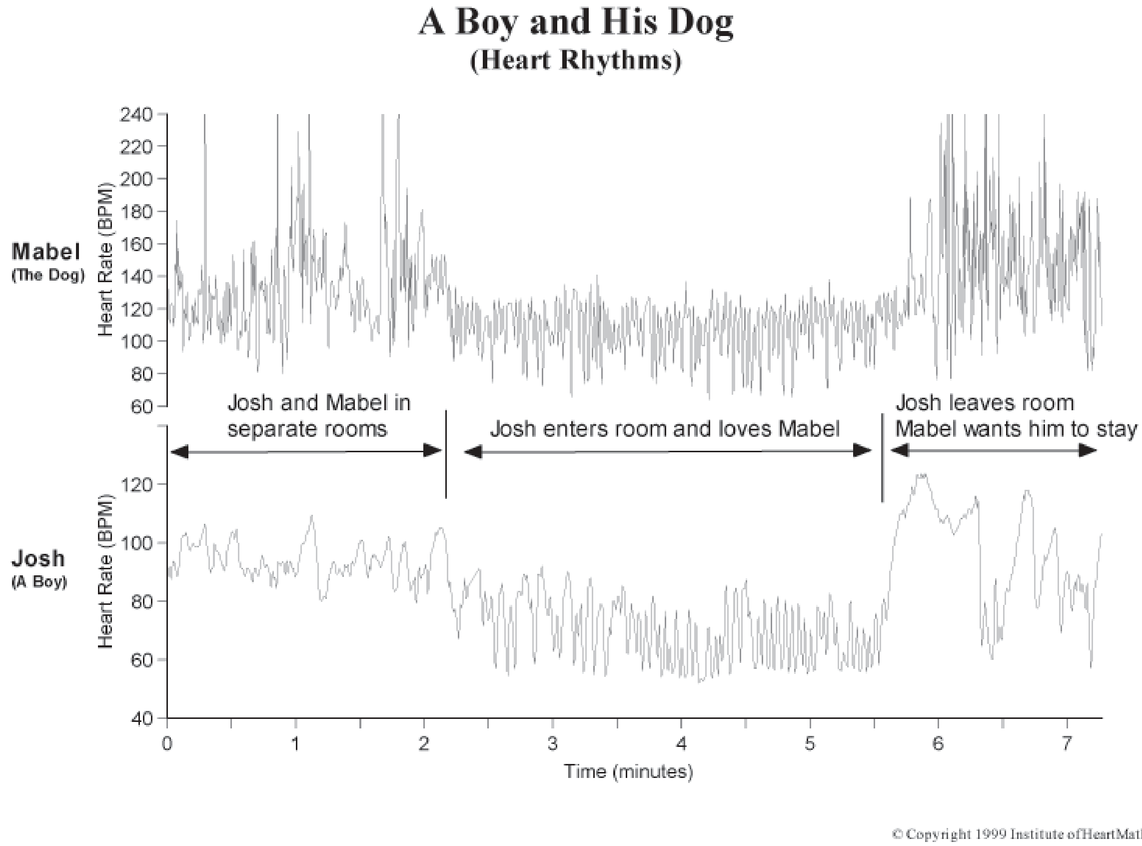


**Figure 11. Heart rhythm patterns of a boy and his dog.**
*These data were obtained using ambulatory ECG (Holter) recorders fitted on both Josh, a boy, and Mabel, his pet dog. When Josh entered the room where Mabel was waiting and consciously felt feelings of love and care towards his pet, his heart rhythms became more coherent, and this change appears to have influenced Mabel heart rhythms, which then also became more coherent. When Josh left the room, Mabel's heart rhythms became much more chaotic and incoherent, suggesting separation anxiety!*

## Influence of the Heart's Bioelectromagnetic Field on Cells

The idea that information can be communicated between biological systems and cause an effect in another living system is far from a new concept. This phenomenon has been examined in many different biological systems. A review of this literature is beyond the scope of this paper, but the subject has been reviewed recently by Marilyn Schlitz, Director of Research at the Institute of Noetic Sciences. In her review, both intention and how it is focused (*i.e.*, attitude) are considered important variables in affecting outcomes.[68] Further, studies conducted in our laboratory suggest that emotional state and the degree of coherence in the electromagnetic fields produced by the heart are also important variables.

We have long suspected that one aspect of the heart's electromagnetic field acts as a carrier wave for information that can affect the function of cells in our own body as well as other biological systems in proximity. In the early 1990s, we undertook a series of experiments to test this hypothesis. This project evolved over several years and extended into many types of experiments. We were able to demonstrate that individuals can cause changes in the structure of water,[51] in cell growth rate, and in the conformational state of DNA.[52] In general, we found that in order to produce these effects in a reliable manner, both a high degree of heart rhythm coherence and an intention to produce a given change were critical.

Much scientific research has attempted to determine the effects, if any, of electromagnetic fields (particularly the 50 and 60-hertz fields generated by power lines) on cells, and has yielded largely inconclusive results. However, comparatively little effort has been made to understand the effects of the body's


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endogenous fields, those that actually comprise the bioelectromagnetic environment in which our cells are continuously bathed. The most consistent and strongest source of an endogenous electromagnetic field is of course the heart.

In order to test the hypothesis that the electromagnetic field generated by the heart may have direct effects at the cellular level, we performed a series of cell culture experiments in which we exposed several different cell lines to simulated heart fields. To do this, we first acquired ECG data at a 10-kilohertz sample rate from people in various emotional states, generating correspondingly different heart rhythm patterns. We then used a digital-to-analog converter to recreate these ECG signals, which were fed into a specially built amplifier that could accurately recreate the low frequency portions of the ECG along with the higher frequencies. The output of the amplifier was used to drive a coil in which cell cultures were placed. For the experiment described here, a 2-inch diameter solenoid coil 15 inches high was placed vertically inside a 5% carbon dioxide incubator. Human fibroblasts (skin cells) were placed in 35-millimeter petri dishes inside the center section of the coils where the field was uniform. Typically, 10 individual petri dishes, each containing the same number of cells, were placed inside the coils. Identical cells were placed in a mock coil in a separate incubator and served as controls for each experiment. The field strength to which the cells in the human body are exposed from a normal heartbeat was determined. The output of the amplifier was adjusted so that the cells placed in the coil were exposed to approximately the same field strength as they would be in the body. While the cells were growing in the incubator over a 6-day period, they were continuously exposed to the ECG signals.

After exposure, the growth rates of the cells in the active and control coils were measured using a colorimetric staining assay. After many trials and variations of this basic experiment, we found that fibroblast cells exposed to the heart's field exhibited a mean increase in growth rate of 20% as compared to the controls. We also performed several trials in which we exposed the same type cells to a 60-hertz field of the same average magnitude of the heart's field. In this case, there was no significant change in the growth rate when compared to the controls. We did find a slight difference in the growth rate in cells exposed to coherent versus incoherent ECG signals. The coherent field yielded a higher growth rate; however, this effect did not reach statistical significance in this set of experiments. Thus, it appears that the presence or absence of a cardiac field was the primary variable to influence growth rate in these experiments.

One particularly intriguing experiment was performed in which healthy human fibroblasts and human fibrosarcoma cells (tumor cells from the same lineage) were both exposed to the same coherent ECG signal. We found that the growth of the healthy cells was facilitated by 20%, as expected, while *the growth of the tumor cells was inhibited by 20%.* These results may relate to work conducted in Germany by Ulrich Randoll with cancer patients. He has found that by monitoring a patient's own heartbeat and using it to trigger the application of an externally applied pulsed field, he has been able to successfully treat a number of patients with advanced carcinomas.[69] Dr. Randoll's therapeutic goal is to "regenerate and stabilize the basic autonomic rhythm of the organism." He has also used ultrastructural tomographic images of living cells to visualize temporal rhythms in the structural elements at the subcellular level. This technique shows clear differences in the temporal rhythms of cancer cells as compared to normal cells.[70] He is convinced that his treatments are helping to restore the normal pattern of activity at the cellular level, which facilitates recovery from disease, and believes that the rhythm of the heart and the field it produces are the key to this healing process.

### *Mechanisms of Weak Electromagnetic Field Effects in Biological Systems*

A biological response to an external field (signal) implies that the signal has caused changes in the system greater than those caused by random fluctuating events, or noise. Theoretical estimates of the limitations on the detection of very small signals by sensory systems imposed by the presence of thermal noise (thermal noise limit) were traditionally made using linear approximation under the assumption that the system is in a state of equilibrium.[71] Traditional linear theory predicted that weak, extremely low frequency electromagnetic fields, such as that radiated from the human heart, could not generate enough energy to overcome the thermal



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noise limit and thus affect biological systems. However, more recently it has been recognized that a linear and equilibrium approach is not appropriate for modeling biological systems, which are intrinsically nonlinear, nonequilibrium, and noisy. A number of experiments have revealed cellular responses to electromagnetic field magnitudes far smaller than the theoretical estimates arrived at by linear modeling for the minimum field strength required to overcome the thermal noise limit in these systems.[72]

It has been proposed that this discrepancy can in part be accounted for by biological cells' capacity to rectify and essentially signal average weak oscillating electromagnetic fields through field-induced variation in the catalytic activity of membrane-associated enzymes or in the conformation of membrane channel proteins.[66, 72] In addition to signal averaging by the cells, it has also been established that the noise in biological systems can play a constructive role in the detection of weak periodic signals via a mechanism known as stochastic resonance.[63-66] *Stochasm* is a Greek word that describes a system that is random but purposeful. In essence, stochastic resonance is a nonlinear cooperative effect in which a weak, normally sub-threshold periodic (coherent) stimulus entrains ambient noise, resulting in the periodic signal becoming greatly enhanced and able to produce large-scale effects. The signature of stochastic resonance is noted by the signal-to-noise ratio in the system rising to a maximum at some optimal noise intensity, corresponding to the maximum cooperation between the signal and the noise. Essentially, the noise acts to boost a coherent, sub-threshold signal to a level above the threshold value, enabling it to generate measurable effects. Stochastic resonance is now known to occur in a wide range of biological systems and processes, including sensory transduction, neural signal processing, oscillating chemical reactions,[63, 64] and intracellular calcium signaling.[73] In addition, coherent electromagnetic fields have been shown to produce substantially greater effects than incoherent signals on enzymatic pathways, such as the ornithine decarboxylase pathway.[74] Remarkably, experimental studies have documented effects of subthermal, coherent signals in different biological systems for signal amplitudes as small a one-tenth or even one-hundredth the amplitude of the random noise component.[75-77] As a weak signal becomes more coherent, the greater its capacity becomes to entrain ambient noise and thus produce significant effects.

Thus, cellular signal averaging and nonlinear stochastic resonance provide potential mechanisms by which increased heart rhythm coherence may produce significant biological effects, both within and between people. For example, through such mechanisms, the consistent self-induction of sustained states of physiological coherence by an individual may give rise to changes at the cellular level that may enhance health and healing. Alternatively, a clinician's coherent cardiac field, which is detected by a patient, may be amplified in such a way as to positively affect the patient's physiology. The importance of signal coherence in this model also suggests that further attention be given to the contribution of heartfelt positive emotions and attitudes, as drivers of coherence, in the healing process. It is possible that the generation of physiological coherence and biological effects produced by this beneficial mode may in part explain the observed relationship between positive emotions and favorable health outcomes, as well as the emphasis that many therapeutic practices place on the development of a mutually caring relationship between practitioner and patient.[60] Furthermore, it is likely that the therapeutic value of interventions that facilitate the generation and maintenance of sustained feelings of appreciation, care, and love may derive in part from bioelectromagnetically-mediated effects on cellular physiology.

## Conclusions and Implications for Clinical Practice

Bioelectromagnetic communication is a real phenomenon that has numerous implications for physical, mental, and emotional health. This paper has focused on the proposition that increasing the coherence within and between the body's endogenous bioelectromagnetic systems can increase physiological and metabolic energy efficiency, promote mental and emotional stability, and provide a variety of health rewards. It is further proposed that many of the benefits of increased physiological coherence will ultimately prove to be mediated by processes and interactions occurring at the electromagnetic or energetic level of the organism.

With the many physiological and psychological benefits that increased coherence appears to offer, helping patients learn to self-generate and sustain this psychophysiological mode with increased

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consistency in their day-to-day lives provides a new strategy for clinicians to assist their patients on multiple levels. There are several straightforward ways to help patients increase their physiological coherence. Teaching and guiding them in the practice of positive emotion refocusing and emotional restructuring techniques in conjunction with heart rhythm feedback has proved to be a simple and cost-effective approach to improving patient outcomes. These coherence-building methods are not only effective therapeutic tools in and of themselves, but by increasing synchronization and harmony among the body's internal systems, may also help increase a patient's physiological receptivity to the therapeutic effects of other treatments.

Coherence-building approaches may also help health care practitioners increase their effectiveness in working with patients. In self-generating a state of physiological coherence, the clinician has the potential to facilitate the healing process by establishing a coherent pattern in the subtle electromagnetic environment to which patients are exposed. Since even very weak coherent signals have been found to give rise to significant effects in biological systems, it is possible that such coherent heart fields may provide unsuspected therapeutic benefits. Furthermore, by increasing coherence, clinicians may not only enhance their own mental acuity and emotional stability, but may also develop increased sensitivity to subtle electromagnetic information in their environment. This, in turn, could potentially enable a deeper intuitive connection and communication between practitioner and patient, which can be a crucial component of the healing process.

In conclusion, I believe that the electromagnetic energy generated by the heart is an untapped resource within the human system awaiting further exploration and application. Acting as a synchronizing force within the body, a key carrier of emotional information, and an apparent mediator of a type of subtle electromagnetic communication between people, the cardiac bioelectromagnetic field may have much to teach us about the inner dynamics of health and disease as well as our interactions with others.

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