ORIGINAL PAPER

ENTRAINMENT AND THE CRANIAL RHYTHMIC IMPULSE

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Entrainment is the integration or harmonization of oscillators. All organisms pulsate with myriad electrical and mechanical rhythms. Many of these rhythms emanate from synchronized pulsating cells (eg, pacemaker cells, cortical neurons). The cranial rhythmic impulse is an oscillation recognized by many bodywork practitioners, but the functional origin of this impulse remains uncertain. We propose that the cranial rhythmic impulse is the palpable perception of entrainment, a harmonic frequency that incorporates the rhythms of multiple biological oscillators. It is derived primarily from signals between the sympathetic and parasympathetic nervous systems. Entrainment also arises between organisms. The harmonizing of coupled oscillators into a single, dominant frequency is called frequency-selective entrainment. We propose that this phenomenon is the modus operandi of practitioners who use the cranial rhythmic impulse in craniosacral treatment. Dominant entrainment is enhanced by "centering," a technique practiced by many healers, for example, practitioners of Chinese, Tibetan, and Ayurvedic medicine. We explore the connections between centering, the cranial rhythmic impulse, and craniosacral treatment. (Alternative Therapies in Health and Medicine. 1997;3(1):40-45)

What is now called cranial-sacral treatment (CST) was developed by William Garner Sutherland, DO. Sutherland's years of studying cranial anatomy began in 1899,[1] and he started teaching "cranial osteopathy" in 1929.[2] He developed his methods de novo, apparently unaware that ancient Greeks had practiced therapeutic cranial manipulation.[3] Gehin[4] maintained that cranial manipulation was also practiced in Asia, but this claim has been disputed.[5] Parallel and contemporary to Sutherland's research on CST, craniopathy was developed by Nephi Cottam, DC.[6] The popularity of craniopathy among chiropractors has been surpassed by that of the sacro-occipital technique developed by Major Betrand DeJarnette, DC. The latter system has roots in both CST and craniopathy; DeJarnette met Sutherland around 1922[7] and Cottam thereafter.[6]

Sutherland's CST remained the esoteric tool of osteopaths for many decades, but in the past 10 years a simplified version has been used by many allopathic physicians, chiropractors, physical therapists, and massage therapists. This sudden surge in interest and use is primarily due to the Upledger Institute, which began teaching its trademarked CranioSacral Therapy™ in 1985.

The unique cornerstone of CST and craniosacral diagnosis is a palpable pulsation called the cranial rhythmic impulse (CRI). Palpable cranial pulsations are unique to Sutherland's work and were overlooked by Cottam and others. The CRI phenomenon is poorly understood, and its functional origin remains unknown, despite its significance in CST.

The Educational Council on Osteopathic Principles[8] recently provided a contemporary, generic definition of the CRI as "a palpable, rhythmic fluctuation" best perceived while palpating a person's head. This précis is derived from the work of Sutherland,[1,2,9,10] who repeatedly defined fluctuation as "the movement of a fluid contained within a natural or artificial cavity and observed by palpation or percussion." The purpose of this article is to review Sutherland's concepts, discuss subsequent ideas developed by other researchers, and explore a new hypothesis of the source of the CRI.

CRI THEORIES

Sutherland's early research focused on the articulations between cranial bones. He proposed that most cranial sutures do not ossify but remain mobile throughout a person's life. His attention then shifted to the intracranial ligaments and fascia, which he characterized as a "reciprocal tension membrane" that balanced motion within the skull. However, what force drives motion within the skull? As Sutherland[1] related, "The idea of bony movement taking place without muscular action is, to say the least, unique to a degree difficult to follow." About 1924,[2] he began describing a "primary respiratory mechanism." He proposed that the brain involuntarily and rhythmically moves within the skull, causing dilation and contraction of cerebral ventricles. This pumping action of the ventricles generates a

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pulse wave of cerebrospinal fluid (CSF) that transfers movement to the reciprocal tension membrane and dural meninges, causing movement from the cranium down to the sacrum.

Seven years after Sutherland died, the term CRI was coined by John and Rachel Woods.[11] Another name for the CRI is the Sutherland wave,[12] named after its discoverer (craniosacral fluctuation was not discovered by Upledger as suggested in a recent interview[13]). Clinical studies have found a palpable CRI rate of 6 to 12 cycles per minute in healthy humans, independent of cardiac or diaphragmatic rhythms.[11,12,14] Recordings of the CRI have been made in clinical laboratories by using mechanical and electronic instruments.[15-17]

Modern research corroborates Sutherland's hypotheses. Histological studies have shown that most cranial sutures do not ossify at any age but remain supple with ligaments, blood vessels, and nerves; hence, motion at sutures is possible.[18-20] In experiments with anesthetized cats, artificial fluctuations in intracranial pressure (induced by establishing hypercapnia or by injecting fluid into the ventricles) produced expansion and contraction of cranial sutures.[21,22]

The source of brain motility is more uncertain. Sutherland[1] proposed a chemical-electrical source and cited Dwight Kenney, DO: "The brain is now known to be a powerhouse, maintaining a rate of twelve pulsations a second. Each of the brain's millions of molecules is an electron dynamo." Magoun[12] elaborated on this hypothesis, suggesting that direct current carried within the brain creates an electrical or magnetic field, causing the neural tube to cyclically coil and uncoil as the field collects and discharges.

Alternatively, an oft-cited study[23] states that individual glial cells pulsate in vitro and that the summation of these pulsations translates into the CRI. However, glial cells pulsate at a rhythm completely different from that of the CRI, and they lack the tensile strength to form contractile tissue within the brain.

A third theory is based on hydraulics. Magoun[12] suggested that rhythmic variations in the production of CSF by the choroid plexus might contribute to brain motility. Upledger and Vredevoogd[14] expanded the choroid plexus hypothesis with several secondary neurological and mechanical mechanisms. Their "pressurestat" model surmises that CSF is produced in waves and that this pulsation drives brain movement, a reversal of Sutherland's hypothesis.

In support of the pressurestat hypothesis, fluctuations in CSF and rhythmic brain motility have been measured,[24-26] but these pulsations are much quicker than those of the CRI and appear to be synchronous with cardiac systole. Ferguson[27] criticized the pressurestat model, noting that movement of the CRI from head to foot shows no delay as might be expected if the impulse were generated hydraulically. He postulated that the CRI is generated by extracranial muscles. Previously, Becker[28] speculated that the CRI is generated by extracranial muscles that are involved in making moment-to-moment postural adjustments. Other extracranial sources of the CRI have been hypothesized, for example, cutaneous tissues[29] and a total-body energy pattern.[30]

CLINICAL ASPECTS OF THE CRI

The CRI is usually assessed with the patient supine. The practitioner sits comfortably at the head of the table with his or her hands cradling either side of the patient's head; palms centered on the posterior aspects of the parietal bones; fingers lightly contacting the occiput, the tempora, and sometimes the sphenoid bones. Tension in the practitioner's hands, forearms, and shoulders must be avoided. The practitioner should visualize "a state of rapport in the fluid continuity between the physician and the patient"[12] by "melding the hands with the head" and "shifting into right-brained thinking."[14] This visualization is often done with the eyes closed. Once the technique of assessing the CRI is learned, the practitioner feels a subtle motion, much like the respiratory excursion of the chest, that is sensed as a broadening and narrowing of the head between the hands. More experienced practitioners can palpate the CRI anywhere on the body.[14]

The rate of the CRI decreases in a variety of conditions, for example, psychological disturbances,[11] traumatic brain injuries,[31] and in neonates after a difficult birth.[32] Low CRI rates have also been reported in patients who are comatose[14] and in children with developmental delays.[14,33] Anecdotal reports suggest that the CRI also decreases in other circumstances, for example, emotional exhaustion, malnutrition, metastasis,[14] and many other maladies. The CRI rate is increased in patients who have acute fever[12] and in hyperkinetic and autistic children.[14]

The CRI amplitude must also be assessed; this quality is more difficult to appraise than the rate. Low CRI amplitude has been variously described as a palpable sensation of low volume[12] and as a labored, low-energy, or lethargic effort.[14] Excess amplitude has been characterized as "the profound repercussion of a wave striking a rock-bound coast"[12] and as a wave "in a rigid container fighting against its boundaries."[14]

CRI fluctuations should be bilaterally symmetrical,[12,14] even though many body rhythms are lateralized, with the left and right sides oscillating in different phases.[34] Nonsymmetrical CRI findings are interpreted as signs of restrictions in the articulations in the cranial sutures or as membranous tension within the intracranial falx cerebri, falx cerebelli, and paired tentoria.[12,14] Besides its use in diagnosis, the CRI also provides a fulcrum for treating restrictions in cranial bones and fascial membranes. Treatment is accomplished by following sensed CRI motion with the hands (in any direction—broadening, narrowing, flexion, extension, torsions, and so forth) and then either exaggerating the motion or resisting it.[35] This treatment seems to balance the movement and make the motion symmetrical. Contraindications to CST are few (eg, recent skull fractures, acute intracranial hemorrhages, intracranial aneurysms),[14] and adverse reactions rarely occur.[31,36]

Skeptics of CST assume that the CRI is a manifestation of psychokinesis or ideomotor action. The latter is a long-recognized phenomenon[37] in which conscious thought gives rise to involuntary hand movements. Examples include movements of Ouija boards and their precursors, planchette boards[38]; dowsing and the involuntary "limb trance" movement described by Charcot[39]; and the "queer neuro-physiological pranks of automatic writing" described by Mühl.[40] Ideomotor action has been linked to excess activity of the autonomic nervous system.[39] The autonomic nervous system has also been tentatively linked to the CRI[14]; this linkage is the basis of our new hypothesis.

THE AUTONOMIC NERVOUS SYSTEM AND INTRINSIC RHYTHMS

Several parameters can be used to assess the autonomic nervous system.[41] One of the best, least invasive measures is variability in heart rate.[42] Heart rate varies on a rhythmic beat-to-beat basis, on a scale of milliseconds. Chronic loss of variability in heart rate is linked with aging,[43] diabetes,[44] increases in deaths due to cardiac disease,[45,46] and psychological disorders such as major depression and panic attacks.[47]

The variability in heart rate assumes a rhythmic, low-frequency sinusoidal pattern when sympathetic tone and parasympathetic tone are balanced.[42] This pattern resembles Traube-Hering modulation, a change in blood pressure that also varies on a beat-to-beat basis. Traube-Hering modulation causes a sinusoidal fluctuation of brain volume and depends on autonomic function.[48] Recordings of both variability in heart rate and Traube-Hering modulation resemble the rate and rhythm of the CRI as recorded by Frymann.[16] CRI-like oscillations in cerebral blood velocity have also been recorded, independent of systemic circulatory parameters.[49] These oscillations may be linked to changes in cerebral blood volume and oscillations in cortical oxidative metabolism, which occur at a rate of 9 cycles per minute.[50] Fluid pressure within lymphatic vessels also oscillates rhythmically, between 7.5 and 10 cycles per minute, asynchronously with diaphragmatic respiration.[51] The body is filled with tissues that intrinsically fluctuate or oscillate in chaotic ultradian (<1 day) rhythms, for example, cardiac, smooth, and skeletal muscles; neural tissue; and endocrine glands. The cells that produce these rhythms are called biological oscillators. Some of the cells are inherently rhythmic (eg, cardiac pacemakers); others must be connected in series to produce oscillations (eg, the complex of interneurons that generates respiratory cycles[52]).

McCraty et al[53] and Tiller et al[54] described a significant event that occurs in biological oscillators when sympathetic and parasympathetic systems become balanced. The body's myriad rhythms including variability in heart rate, Traube-Hering modulation, respiration rate, pulse transit time, and even brain waves all coordinate into harmonics with each other. A harmonic is a wave with a frequency that is an integral multiple of a fundamental frequency. This harmonic integration of biological oscillators is termed *entrainment.* Entrainment can be measured as a primary, fundamental rhythm. The entrainment frequency measured in healthy human subjects with balanced sympathetic and parasympathetic systems is about 0.125 Hz, or 7.5 cycles per minute.[53,54]

ENTRAINMENT AND THE CRI

We hypothesize that the CRI is the perception of entrainment, a palpable harmonic frequency of multiple biological oscillators. These oscillators include cardiac pulse and variability in heart rate, Traube-Hering modulation, diaphragmatic excursion, contractile lymphatic vessels, CSF production by the choroid plexus, pulsating glial cells, electrical fields generated by cortical neurons, cortical oxidative metabolism, and probably many other oscillators. Most of these oscillators, with the exception of brain waves, can be easily transduced into tissue movement (eg, palpable pulses in cardiac, smooth, and skeletal muscle): the palpable CRI. How brain waves and other field generators contribute to the CRI is unknown. They may be detected by "an undefined seventh sense."[39]

If our hypothesis and findings from entrainment studies[53,54] are correct, then the common denominator, and the underlying mechanism that generates the CRI, is the balance between the sympathetic and the parasympathetic nervous systems. If balance is present within the autonomic nervous system, then the body's many rhythms harmonize into a strong, coordinated, sinusoidally fluctuating entrainment frequency,[53,54] which can be palpated as a strong, healthy CRI. Therefore, health, as assessed by evaluating the CRI, depends on sympathovagal balance. Indeed, even the sympathetic nervous system has its own intrinsic rhythm.[55]

Our ability to palpate the CRI requires a corollary hypothesis: palpation may also be a harmonic of several senses—certainly within the practitioner's hands via mechanoreceptors (eg, Merkel's cells and Meissner's, Ruffini's, and Pacini's corpuscles) and proprioceptors (eg, muscle spindle fibers, Golgi's corpuscles). Temperature sensors in the skin may also contribute signals from the site of palpation. Unelucidated sensors may detect electrical fields, piezoelectricity, or changes in "body electricity" as described by yogic practitioners.[56] As Magoun[12] paraphrased Sutherland, "This calls for thinking, seeing, feeling, knowing fingers." The CRI can be palpated anywhere on the body, because the echoes of the autonomic nervous system reverberate in all tissues: "All animate tissues are in constant rhythmic motion."[9]

ENTRAINMENT VS THE TISSUE-PRESSURE MODEL

Our entrainment hypothesis resonates with the tissue-pressure model of Norton.[29] He proposed that CRI is a simple harmonic of four rhythms: the cardiovascular and respiratory oscillations of the patient and the practitioner. Norton tested this model with a computer simulator and produced patterns that resembled clinical CRI recordings made by Frymann.[16] However, in a subsequent study[57] with subjects and cranial practitioners, the tissue-pressure harmonic did not correlate with the practitioner's perception of the subject's CRI. Other studies[58-60] have also found poor correlation between the CRI rate and cardiovascular and respiratory activity.

Our entrainment model differs from Norton's model in four aspects. First, the tissue-pressure harmonic is manifested in cutaneous tissues, whereas entrainment is a summation of signals emitted from multiple sources—from the corpus callosum to cutaneous tissues. Second, Norton programmed "natural variability" into his computer model on a random basis. In entrainment studies in healthy subjects, cycles did not vary randomly but rather in a rhythmic, sinusoidal pattern.[42,53,54] Third, Norton's model correlates the CRI to cardiovascular and respiratory rhythms only. The entrainment model incorporates cardiovascular and respiratory rhythms, their calculus of variations, and many other biological oscillations. It approaches a Fourier series: a potentially endless series of variables multiplied by wave functions. This complexity (and redundancy) explains why the CRI can continue to be palpated while the patient holds a breath. Fourth, the tissue-pressure model states that the CRI is palpated via mechanoreceptors. The entrainment model suggests that mechanoreceptors are only a few of the many sources used in sensing the CRI.

CRI HARMONICS

Just as a Fourier series may approach infinity, the CRI may not be the final, fundamental harmonic. Deeper, more subtle, harder-to-detect rhythms may exist. We cannot speculate on the source of these rhythms now, but they warrant some consideration. Sutherland began alluding to slower rhythms about 1948, near the end of his life.[9,10] Using seaside metaphors, he poetically described fluctuations in the primary respiratory mechanism. He wrote about water, ocean waves that rhythmically move through water, and deeper tides that move through water and waves. He attributed a certain potency, a movement potential, to the fluctuation of waves and tides. He called this same potency in CSF the "breath of life, a fluid *within* a fluid."[10] He also described the CSF tide as a "liquid light," comparable to the cyclic, sweeping beam emitting from a lighthouse, "lighting up the ocean but not touching it."[9]

Sutherland's students have described rhythms that are slower, deeper, and more difficult to perceive than the CRI. Rollin Becker[61,62] has discussed the "slow tide," which oscillates with a frequency of 0.6 cycles per minute. Becker maintains that this rhythm requires much practice to perceive; physicians must enhance their sensory input by "participating" with the patient's rhythms. This technique is similar to the "melding" described as a prerequisite for palpating the CRI.[14]

Jealous[63] calls Becker's rhythm the "long tide." Jealous cites a third rhythm, which he simply calls the "2½ CPM rate," which has a frequency of 2.5 cycles per minute. He describes the 2½ CPM rate as an integration of information from the patient's whole system, echoing our entrainment hypothesis. Jealous has characterized the 2½ CPM rate and the CRI as harmonics, again echoing our hypothesis. According to him, the CRI is modulated by the patient's sympathetic nervous system, whereas the 2½ CPM rate is not. Thus, he says, the CRI is more erratic and unstable than the 2½ CPM rate. According to Jealous, the ability to detect these subtle rhythms requires "defacilitation" of the practitioner's central nervous system.[63] Defacilitation (also called "synchronizing one's attention") is accomplished by two methods: allowing the breath to become slow and regular and softening the muscles above the pubic bone. These actions reportedly synchronize the practitioner's cranial, thoracic, and pelvic diaphragms.[63] As defacilitation occurs, the practitioner senses deeper rhythms, and the harmonic signal shifts from the CRI rate to the 2½ CPM rate. With deeper defacilitation, perception of the 2½ CPM rate disappears into the long tide.[63]

ENTRAINMENT AND CST

Our entrainment hypothesis may also explain how CST practitioners bring about therapeutic changes in their patients. Entrainment was first noted in 1665 by Christiaan Huygens, inventor of the pendulum clock. He noted that clocks with the same length of pendulum began swinging in synchrony with each other.[64] This coupling between oscillators also occurs in living organisms (eg, cardiac pacemaker cells and insulin-secreting cells in the pancreas). Llinás[65] suggested that the entrained firing of thalamocortical neurons gives rise to what we call consciousness.

Coupled oscillations also arise between organisms, for example, synchronously flashing fireflies, harmoniously chirping crickets, and women whose menstrual phases cycle together. Huygens noted that the "strongest" clocks (those with the heaviest pendulums) established the eventual, overall rhythm. The harmonizing of coupled oscillators into a single, dominant frequency is called *frequency-selective entrainment.* Alternatively, *frequency-pulling entrainment* arises when the strong oscillator cannot cause full entrainment but is capable of pulling or displacing the frequency of the other oscillator.[66]

We hypothesize that these two phenomena—frequency-selective entrainment and frequency-pulling entrainment—are the basis of CST techniques that use the CRI. Practitioners transfer their "strong-clock" harmonic rhythms onto their patients. Skilled practitioners enhance this transfer by assuming a meditative focus before treating patients. Magoun[12] calls this meditative state a "rapport in the tissues" between practitioners and patients. Empathetic, meditative, centered states produce strong entrainment.[53,54] Practitioners then impose their strongest entrained rhythms onto patients. The patients' CRI then assumes characteristics considered normal in clinical studies.[11,16]

Tiller et al[54] explored the connection between centering and entrainment. Centering is emphasized in Ayurvedic, Tibetan, and Chinese medicine[5] and by many Western methods of energy-field therapeutics, for example, body-mind centering, esoteric healing, Kofutu touch, MaríEL, network chiropractic, polarity therapy, Reiki, SHEN therapy, therapeutic touch, Tragering,[67] and orgonomy.[68] Using centering to harness the powers of entrainment may be a widespread therapeutic technique, albeit unrecognized. Different practitioners use a variety of centering visualizations. Chinese practitioners center on *tan tien,* the "one point," focusing about 5 cm above the pubic bone.[67] Tibetan practitioners meditate on *sMan-gyi-rgyal-po* ("the medicine Buddha"), centered at *sahar chakr* ("the crown of the head").[5] The Western "freeze-frame" technique focuses on the heart to achieve entrainment.[54] As pointed out by Tiller et al,[54] all these techniques focus attention on areas of the body that are known to contain biological oscillators (the intestines, brain, and heart).

Frequency-pulling entrainment may also explain how practitioners induce the "CRI still point."[14] Practitioners may be able to modulate their own entrained rhythms. Pulling their own frequency to a phase 180° opposite that of the patient's frequency (eg, mechanically described as cranial flexion opposed to cranial extension) and then imposing this rhythm on the patient would induce a still point. Whether this therapeutic imposition is achieved by conscious intention or by an unconscious, universal healing force has long been argued about in osteopathic circles.[69] Becker noted that it takes an average of 7 minutes to bring rhythms to a CRI still point but may take up to 30 minutes in patients with systemic diseases such as rheumatoid arthritis.[61] At the CRI still point, slower rhythms continue to be perceived.[63]

Modulating one's rhythms is not difficult. Athletes, for instance, entrain their respiratory rhythms to their exercise rhythms.[70] Respiratory rhythms, in turn, synchronize the autonomic nervous system[71] and many other entrained rhythms.[72] Tiller et al[54] stated that feelings of love lead to strong entrainment. Dossey[73] dedicated a whole issue of *Alternative Therapies in Health and Medicine* to the role of love in healing. Several of the contributing authors described love, empathy, and sympathy with energetic, vibratory qualities:

> All manner of physical systems, whether mechanical, electromagnetic, fluid dynamical, quantum mechanical, or nuclear, display capacities for synergistically interactive vibrations with similar systems.... Coupled harmonic oscillators, all common music instruments, radio and television circuitry, atomic components of molecules, all involve this "sympathetic" resonance, from which strikingly different properties emerge than those that characterize their isolated components.[74]

Jahn[75] described the resonant bond between "agent and percipient" as a form of love. The resonant bond transmits "beneficial information" from agent to percipient, introducing order into random or chaotic physiological processes. Wirkus and Wirkus[76] emphasized that the healer "must feel and be the heart chakra.... It is not thinking the word 'love,' it is not a visualization process, it is the real sensation of pure love which brings warmth, delicate vibrations in your heart area."

CST practitioners also emphasize love as a requirement for successful treatment. Robert Fulford, DO, who worked with Randolph Stone in the 1950s and has recently been the focus of much unwanted media attention,[77] concluded:

> You the [practitioner] stand neutral, acting as a conduit for the flow of divine love. As you learn to use love properly in healing work, your body vibrations increase and it becomes easier to handle the potency of the love energy. The unconditional love and the intention to serve can correct defects in the patient's bioenergetic fields.[78]

CONCLUSION

We hope our hypothesis and discussion direct others to further clinical insights and laboratory studies. We understand that entrainment, based on multiple pulse-coupled oscillators, will be difficult to demonstrate in the laboratory, even with a computer model. Pulse coupling is difficult to reproduce mathematically because it introduces discontinuous behavior into an otherwise continuous model and therefore stymies most standard mathematical techniques.[64] It is also complicated by the fact that many body rhythms oscillate with left and right sides in different phases.[34] For a deeper understanding of biological oscillators, read Arthur T Winfree.[79,80]

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References

1. Sutherland WG. *The Cranial Bowl.* Mankato, Minn: Free Press Co; 1939.
2. Sutherland AS. *With Thinking Fingers.* Kansas City, Mo: Cranial Academy; 1962.
3. Ligeros KA. *How Ancient Healing Governs Modern Therapeutics.* New York, NY: GP Putnam's Sons; 1937.
4. Gehin A. *Atlas of Manipulative Techniques for the Cranium and Face.* Seattle, Wash: Eastland Press; 1985.
5. McPartland JM. Manual medicine at the Nepali interface. *J Manual Med.* 1989;4:25-27.
6. Cottam C, MacGillivray-Smith E. The roots of cranial manipulation: Nephi Cottam and craniopathy. *Chiropractic Hist.* 1981;1:31-35.
7. Hesse N. Major Betrand DeJarnette: six decades of sacro-occipital research, 1924-1984. *Chiropractic Hist.* 1991;11:13-15.
8. Kuchera W, Jones JM, McPartland JM, et al. Glossary of osteopathic terminology. In: *AOA Yearbook and Directory.* Chicago, Ill: American Osteopathic Association; 1994:684-695.
9. Sutherland WG; Sutherland AS, Wales A, eds. *Contributions of Thought, the Collected Writings of William Garner Sutherland.* Kansas City, Mo: Sutherland Cranial Teaching Foundation; 1967.
10. Sutherland WG; Wales A,ed. *Teachings in the Science of Osteopathy.* Portland, Ore: Rudra Press; 1990.
11. Woods RH, Woods JM. A physical finding related to psychiatric disorders. *J Am Osteopath Assoc.* 1961;60:988-993.
12. Magoun HI. *Osteopathy in the Cranial Field.* 3rd ed. Kirksville, Mo: Journal Printing Co; 1976.
13. Koren T. An exclusive interview with John Upledger. *Am Chiropractor.* 1995;17:10-13.
14. Upledger JE, Vredevoogd JD. *Craniosacral Therapy.* Chicago, Ill: Eastland Press; 1983.
15. Moore LA, Hood HE. A method of measuring cranial rhythmic impulse. *Cranial Acad Newslett.* September 1966:2, 5-6.
16. Frymann VM. A study of the rhythmic motions of the living cranium. *J Am Osteopath Assoc.* 1971;70:928-945.
17. Tettamble M, Cicora RA, Lay EM. Recording of the cranial rhythmic impulse. *J Am Osteopath Assoc.* 1978;78:142. Abstract.
18. Kovich VG. Age changes in the human frontozygomatic suture from 20-95 years. *Am J Orthodont.* 1976;75:607-608.
19. Retzlaff EW, Upledger JE, Mitchell FL Jr, Walsh J. Aging of cranial sutures in humans. *Anat Rec.* 1979;193:663. Abstract.
20. Retzlaff EW, Mitchell FL Jr, eds. *The Cranium and its Sutures.* New York, NY: Springer-Verlag; 1987.
21. Adams T, Heisey RS, Smith MC, Briner BJ. Parietal bone mobility in the anesthetized cat. *J Am Osteopath Assoc.* 1992;92:599-622.
22. Heisey SR, Adams T. Role of cranial bone mobility in cranial compliance. *Neurosurgery.* 1993;33:869-877.
23. Lumsden CE, Pomerat CM. Normal oligodendrocytes in tissue culture. *Exp Cell Res.* 1951;2:103-114.
24. Moskalenko YE. On cerebral pulsation in the closed cranial cavity. *Akad Nauk SSR Izv Ser Biol.* 1961;2:620-629.
25. Cardoso ER, Rowan JO, Galbraith S. Analysis of the cerebrospinal fluid pulse wave in intracranial pressure. *J Neurosurg.* 1983;59:817-821.
26. Feinberg DH, Mark AS. Human brain motion and cerebrospinal fluid circulation demonstrated with MRI imaging. *Radiology.* 1987;163:793-799.
27. Ferguson A. Cranial osteopathy: a new perspective. *Am Acad Osteopath J.* 1991;1:12-16.
28. Becker RF. Cranial therapy revisited. *Osteopath Ann.* 1977;5:316-334.
29. Norton JM. A tissue pressure model for palpatory perception of the cranial rhythmic impulse. *J Am Osteopath Assoc.* 1991;91:975-994.
30. Kappler RE. Osteopathy in the cranial field. *Osteopath Physician.* 1979;46:13-18.
31. Greenman PE, McPartland JM. Cranial findings and iatrogenesis from craniosacral manipulation in patients with traumatic brain syndrome. *J Am Osteopath Assoc.* 1995;95:182-192.

32. Frymann V. Relation of disturbances of craniosacral mechanisms to symptomatology of the newborn: study of 1,250 infants. *J Am Osteopath Assoc.* 1966;65:1059-1075.
33. Frymann VM, Carney RE, Springall P. Effect of osteopathic management on neurologic development in children. *J Am Osteopath Assoc.* 1992;92:729-744.
34. Shannahoff-Khalsa D. Lateralized rhythms of the central and autonomic nervous systems. *Int J Psychophysiol.* 1991;11:225-251.
35. Lippincott RC, Lippincott HA. *A Manual of Cranial Technique.* 3rd ed. Ann Arbor, Mich: Edwards Brothers Printing; 1948.
36. McPartland JM. Side effects from cranial-sacral treatment: case reports and commentary. *J Bodywork Movement Ther.* 1996:1:2-5.
37. Carpenter WB. On the influence of suggestion in modifying the directing muscular movement, independently of volition. *Proc R Inst Gr Brit.* 1852;1:147-153.
38. Covina G. *The Ouija Book.* New York, NY: Simon & Schuster; 1979.
39. Vogt EZ, Hyman R. *Water Witching USA.* 2nd ed. Chicago, Ill: University of Chicago Press; 1979.
40. Mühl AM. *Automatic Writing.* 2nd ed. New York, NY: Helix Press; 1963.
41. McPartland JM. Allopathic medical research echoes earlier findings in osteopathic medicine. *J Am Osteopath Assoc.* 1993;93:428-439.
42. Pomeranz B, Macaulay JB, Caudill MA. Assessment of autonomic function in humans by heart rate spectral analysis. *Am J Physiol.* 1985;248:H151-H153.
43. Öri Z, Monir G, Weiss J, Sayhouni X, Singer DH. Heart rate variability. *Ambulatory Electrocardiograph.* 1992;10:499-537.
44. Comi G, Sora MGN, Bianchi A. Spectral analysis of short term heart rate variability in diabetic patients. *J Auton Nerv Syst.* 1990;30:S45-S50.
45. Kleiger RE, Miller JP. Decreased heart rate variability and its association with increased mortality after acute myocardial infarction. *Am J Cardiol.* 1978;59:256-262.
46. Singer DH, Martin GJ, Magid N, et al. Low heart rate variability and sudden cardiac death. *J Electrocardiol.* 1988;21(suppl):S46-S55.
47. Yeragani VK, Pohl R, Berger R, et al. Decreased HRV in panic disorder patients: a study of power-spectral analysis of heart rate. *Psychiat Res.* 1993;46:89-93.
48. Jenkins CO, Campbell JK, White DN. Modulation resembling Traube-Hering waves recorded in the human brain. *Eur Neurol.* 1971;5:1-6.
49. Diehl RR, Biehl B, Sitzer M, Hennerici M. Spontaneous oscillations in cerebral blood flow velocity in normal humans and in patients with carotid artery disease. *Neurosci Lett.* 1991;127:5-8.
50. Vern BA, Schuette WH, Leheta B, Juel VC, Radulovacki M. Low-frequency oscillations of cortical oxidative metabolism in waking and sleep. *J Cereb Blood Flow Metab.* 1988;8:215-226.
51. Olszewski WL, Engeset A. Intrinsic contractility of leg lymphatics in man: preliminary communication. *Lymphology.* 1979;12:81-84.
52. Duffin J, Hung S. Respiratory rhythm generation. *Can Anaesth Soc J.* 1985;32:124-137.
53. McCraty R, Atkinson M, Tiller WA. New electrophysiological correlates associated with intentional heart focus. *Subtle Energies.* 1995;4:251-268.
54. Tiller WA, McCraty R, Atkinson M. Cardiac coherence: a new, noninvasive measure of autonomic nervous system order. *Altern Ther Health Med.* January 1996;2:52-65.
55. Barman SM, Gebber GL. Basis for synchronization of sympathetic and phrenic nerve discharges. *Am J Physiol.* 1976;231:1601-1607.
56. Green E. Foreword. In: Upledger JE, Vredevoogd JD. *Craniosacral Therapy.* Chicago, Ill: Eastland Press; 1983:xi-xiv.
57. Norton JM. Failure of a tissue pressure model to predict cranial rhythmic impulse frequency. *J Am Osteopath Assoc.* 1992;92:1285. Abstract.
58. Retzlaff EW, Michael DK, Roppel RM. Cranial bone mobility. *J Am Osteopath Assoc.* 1975;74:869-873.
59. Upledger JE. The reproducibility of craniosacral examination findings: a statistical analysis. *J Am Osteopath Assoc.* 1977;76:890-899.
60. Wirth-Pattullo V, Hayes KW. Interrater reliability of craniosacral rate measurements and their relationship with subjects' and examiner's heart and respiratory rate measurements. *Physical Ther.* 1994;74:908-920.
61. Becker RE. Time, tissues and tide(s). Presented at the annual convocation of the American Academy of Osteopathy; March 1983; Colorado Springs, Colo.
62. Becker RE. The cerebrospinal fluid as a mechanism. *Cranial Lett.* 1994;47:6-7.
63. Jealous JS. *The Long Tide and the Breath of Life* [self-published course syllabus]. 1995. Available from JS Jealous, RR 2, Box 1120, Fairfax, VT 05454-9405.
64. Strogatz SH, Stewart I. Coupled oscillators and biological synchronization. *Sci Am.* December 1993:102-109.
65. Llinás R. Is dyslexia a dyschronia? *Ann N Y Acad Sci.* 1993;682:48-56.
66. Langhorst P, Schultz G, Lambertz M. Integrative control mechanisms for cardiorespiratory and somatomotor functions in the reticular formation of the lower brain stem. In: Grossman P, Janssen KHL, Vaitl D, eds. *Cardiorespiratory and Cardiosomatic Psychophysiology.* New York, NY: Plenum Press; 1983:9-39.
67. McPartland JM, ed. *Vermont Holistic Health Directory.* Middlebury, Vt: AMRITA Press; 1996.
68. McPartland JM. Osteopathy and orgonomy. *Am Acad Osteopath J.* 1993;3:4. Letter to the Editor.
69. Woodall PH. Concentration of mind while treating. *J Am Osteopath Assoc.* 1906;5:339.
70. Bechbache RR, Duffin J. The entrainment of breathing frequency by exercise rhythm. *J Physiol.* 1977;272:553-561.
71. Eckberg DL, Nerhed C, Gunnar Wallin B. Respiratory modulation of muscle sympathetic and vagal cardiac outflow in man. *J Physiol.* 1985;365:181-196.
72. Pietroni PC, Pietroni M. Respiratory mechanisms and clinical syndromes. *Holistic Med.* 1989;4:67-79.
73. Dossey L. What's love got to do with it? *Altern Ther Health Med.* May 1996;2:8-15.
74. Jahn RG. Report on the Academy of Consciousness studies. *J Sci Exploration.* 1995;9:393-403. Appendix.
75. Jahn RG. Information, consciousness, and health. *Altern Ther Health Med.* May 1996;2:32-38.
76. Wirkus M, Wirkus M. *Bioenergy: A Healing Art.* Bethesda, Md: Bio-Relax; 1992.
77. Weil A. *Spontaneous Healing.* New York, NY: Alfred A Knopf; 1995.
78. Fulford R. Integration of love with the cranial concept. *Cranial Lett.* 1988;41:2-3.
79. Winfree AT. *The Timing of Biological Clocks.* New York, NY: Scientific American Books; 1987.
80. Winfree AT. *The Geometry of Biological Time.* New York, NY: Springer-Verlag; 1980.