

Ch'i: A Neural Hologram? Microtubules, Bioholography, and Acupuncture

Stuart Roy Hameroff

Tucson Medical Center, Tucson, Arizona

Abstract: Structure, occurrence, and functions of microtubules are reviewed. The theoretical principles of bioholography are outlined and the neuronal microtubular system is offered as an anatomical substrate for such a mechanism. This entails microtubules acting as coherency inducing, dielectric waveguides and resonators for atmospheric ultraviolet radiation which is refracted by the stratum corneum and other tissues. The proposed corporeal energy and its pathways are correlated with Ch'i, the ancient Chinese life energy and medium of acupuncture.

MICROTUBULES ARE CYLINDRICAL cytoplasmic inhabitants whose existence was unknown prior to the advent of the electron microscope. Even then they were only occasionally observed until 1963, when glutaraldehyde gained prominence as a fixative. Osmium tetroxide, the previously used agent is now known to commonly dissolve microtubules. Since then their presence has been noted in so many plant and animal cells that they are now considered universal cytoplasmic components(1,2).

Microtubules (MT's) are hollow cylinders and seem to be a uniform size although their diameters are variously listed from 200 to 270 angstroms (A). This range is thought to be due to variations among investigators since the measurement is usually constant from each laboratory over a wide range of cells and MT's studied. The walls of the cylinders are 50 to 70 A thick and they may be as long as a neuron. The walls seem to be composed of about 13 subfilaments which are either arrayed parallel or in a mild helix. These subfilaments appear to be strands of globular protein units, roughly 50 A x 60 A x 55 A. This molecular length coincides with observed striations at 80 A intervals in negatively stained samples, the slight pitch to the striations suggesting a helical arrangement of the subfilaments(3). The globular protein units ("tubulin") are a labile pool which may polymerize and dissolve repeatedly, even in vitro(4). Hemoglobin (A,S, or C) will form MT's under gel condi-

tions(5,6) so the labile pool may vary among tissues. MT's are dissolved by low temperature, increased hydrostatic pressure, and certain drugs, and may re-form upon return to prior conditions(7,8). Their origins and terminations are rarely seen but have been described as being embedded in a dendritic cortex or, if loose in the cytoplasm, capped by a dense blob(9). A second set of MT's, the neurofilaments, similar in structure but only 100 A in diameter is prevalent among MT's in neurons, and a third, smaller set, the "microfibrils" resides in astrocytes(10).

MT's may occur in several patterns. In cilia, flagella, and centrioles they are in couplets and arranged in a circle in the 9&2 or 9&0 formations that are familiar to all biologists. In mitosis, microtubular spindle fibers form between the centrioles and guide the chromosomes to their proper poles. They then dissolve, their constituent protein becoming available for subsequent MT formation(11). This may be to establish or support any cell asymmetry or to direct (in conjunction with a sol-gel transformation) a transient cytoplasmic rearrangement such as cyclosis or pseudopod formation(12). In permanently asymmetric cells, MT's seem to direct cytoplasmic flow and then to act as a cytoskeleton to maintain cell shape. This can occur longitudinally, as in axons, dendrites, glial cells, and spermatazoa, or circumferentially, as in platelets and discoidal nucleated erythrocytes. Muscular sarco-tubules are morphologically indistinguishable from MT's.

How MT's function remains a mystery. It seems they give direction and guidance to cytoplasmic flow and they may participate in a propulsion mechanism. An associated contractile protein or ATPase substance has been found on several occasions(13, 14,15). In axons, peristaltic contractions of the overlying Schwann cells, or activity of extra-microtubular finger like projections have been credited with propelling axoplasm parallel to and among MT's(16). This flow achieves great velocity relative to the size of the organelles carried and the diameter of the axon. In this instance MT's may only be passive guides but they undoubtedly play a role in the development and orientation of the axon along distances up to meters. In megakaryocytes, MT's align to form cytoplasmic projections which break off, creating platelets. They then arrange circumferentially and participate in a spiral contraction during the second phase of platelet aggregation or clot retraction(17.) MT's have been observed outlining and establishing the cleavage furrow following mitosis, thus effecting daughter cell shape before cell division has concluded(18,19). Regardless of the motile force, MT's may be seen to orient, shape, and direct cytoplasmic movement and cell polarity, and subsequently to serve a cytoskeletal role. MT's are known to be strong and rigid enough to provide such support(20), but how they can function in a guidance capacity is as yet unanswered.

Perhaps MT's work like radar? Klystron tubes which are used in radar and other electronic devices utilize cavity resonators(21). These are geometric waveguides in which a specific electromagnetic wave may resonate and dwell, not unlike air in a tuned organ pipe. Cylinders are a particularly good shape for this purpose, and the radius of a cylindrical cavity resonator is related to the frequency of the resonant energy by the equation: $\gamma = 1.19 c / 2 \pi a$

where c is the speed of light, a is the cavity radius, and γ the resonant frequency(22). The function is independent of cylindrical length. In the radio-wave and micro-wave regions, a is in millimeters and cavity resonators (i.e., Klystron tubes)

are a convenient size. If a is set equal to the radius of microtubules, γ is on the order of 10^{16} cycles per second. This energy is in the far ultra-violet (UV) range, beyond the visible spectrum and the upper limit of the narrow window of solar and celestial nonionizing radiation that our atmosphere admits. The equation is given for a vacuum and an intra-microtubular dielectric (as well as skin and other intervening tissue) would alter the propagative properties according to the refractive index of that dielectric. The stratum corneum of the skin is known to have powerful refractile properties due to the abundance of birefringent keratin polymers(23). Thus the velocity and wave length of refracted penetrating radiation are decreased (24,25). Longer wave length energy readily available in our atmosphere (mid to near UV), upon attenuation and refraction, would be available to MT's, tuned to the new refracted wave length, in neurons and other cells. It would be difficult to measure the attenuation of light which is refracted subcutaneously to the specific resonant wave length of MT's (i.e., without constructing resonators the size of MT's). Permeating, or ambient light in the visible and UV ranges has been measured however, and there is some evidence of a physiological role for such energy.

Ganong and co-workers(26) measured extra ocular sunlight penetration into the mammalian brain. Stereotactically placed photoreceptors recorded intensities of 10^{-3} lumens in a sheep's hypothalamus when surface intensity was 0.4 lumens, with a logarithmic diminution. The most light permeable areas were lateral to the orbits, the temporal poles and hippocampus receiving maximum intensity. Light penetration remained constant for about 30 minutes after the animal's demise, at which time tissue opacity rose sharply. To the pineal gland has been attributed regulation of circadian rhythms, although no optic-pineal pathway has been demonstrated(27). (The pineal gland, along with retinal rod cells and hair cells of the inner ear are rich in "sensory" cilia, nine MT couplets with no central pair(28,29,30)). Cyclical, light dependent functions independent of the visual apparatus have been demonstrated in new born rats(31), and continuous photic stimulation by hypothalamic fiber optic implants have been shown to elicit neuroendocrine responses(32). Whether MT's act as inherent fiber optic waveguides remains to be seen.

Apparently analogous and homologous tubular dielectric waveguide structures have been well studied in the antenna sensillae of certain moths and provide a theoretical basis for electromagnetic communication among them, particularly between mating pairs(33). The waveguides are of a diameter considerably greater than MT's and the energy received and transmitted is consequently in the longer wave length infra-red and micro-wave regions. Similarly, EEG evoked responses have been obtained from a boa constrictor following infra-red and micro-wave stimulations, and potentially dangerous, internal human micro-wave sensors have been postulated(34).

The fate of the proposed intra-microtubular wave energy at synaptic junctions throughout the nervous system might include components of: transmission to post synaptic MT's (refracted to fit 100 A MT's ?), reflection to promote standing waves, and dissipation into surrounding tissue. Dissipation at MT terminals near synapses and along MT lengths would seem to be a physiological condition in surrounding tissue. A metabolic role might be surmised, and indeed, mitochondria have been observed aggregating at nodes of Ranvier(35). The physical properties of wave-

guides and resonators include absorption of kinetic energy in linear and angular fashions(36). MT orientation, and hence cell orientation can then theoretically be viewed as reflecting the flux in the resonant wave length (phototropism ?). Colchicine induced dissolution of MT mitotic spindles has reportedly been reversed with low intensity UV light(37). Aberration of endogenous resonant wave fields could retard spindle formation and could conceivably play a role in teratogenic or malignant change.

The observed striations at 80 Å intervals along MT's correspond to one half of the resonant wave length. This could serve to foster coherent waves within MT's by diffraction. Assuming the 80 Å intervals represent the globular protein units (as they are known to in hemoglobin gels) the waves which strike the dense protein would be reflected and remain in the tubule while those striking the gap areas would be dissipated into the cytoplasm. The intra-tubular wave energy, including reflection from MT endings would be "in phase" or coherent. (A well known technological source of coherent photic energy is the laser.) The dissipated cytoplasmic energy would also be coherent due to diffraction by the MT wall. Dissipated coherent energy from among various MT's would interfere in the cytoplasm. An interference pattern from among two or more coherent sources is, by definition, a hologram.

The 1971 Nobel prize in Physics was awarded to Dennis Gabor for his invention (in 1947) and development of holography. A laboratory curiosity at first, holography became important with the advent of the laser in the 1950's. Briefly, holography employs coherent light to record a three dimensional image of an object. One method utilizes a partially transmitting mirror by which a laser simultaneously illuminates a photographic plate directly, and an object which reflects the light onto the plate secondarily. The plate records an interference pattern between the two impinging wave trains. This pattern, the hologram looks like a garbled mess, but it contains all the information in three dimensions of the object expressed as the phase differences between the two impinging, originally coherent, wave trains. If the hologram is reilluminated by the laser source, the object appears due to cancellation of "non object"(38). A detailed treatment of holography is beyond the scope of this paper, but several properties of holograms are particularly interesting and may prove pertinent. One is that holograms have an enormous capacity to store information in a small area, although it is necessary to reilluminate that area to translate that information. A second property is that all the information in a given hologram is contained in any one, small discreet portion of it, although not as sharp or well focused as the entire hologram. These properties have prompted certain analogies:

"Indeed it has been suggested that the human brain may store information in this way. It has always been a great puzzle how the vast amount of information stored in the human memory can be contained in the volume of the brain and the holographic method might well be the way it is done."

Ronald Brown

"Lasers: Tools of Modern Technology"(39)

"For some years now this property of holograms has attracted the interest of neurophysiologists who were puzzled by the difficulty in locating the 'engram'

in the human or animal memory. As is well known, especially since the famous experiments of Lashley, large parts of the brain can be destroyed without wiping out a learned pattern of behavior. This has led to speculation that the brain may contain a holographic mechanism."

Dennis Gabor, 1969(40)

It has been suggested that bats, dolphins, and whales employ an ultra-sonic holographic system of information processing(41). Several scientists, including Dr. Gabor have created mathematical expressions for theoretical holographic systems of temporal recall(42,43,44,45). A psychiatrist, Dr. H.C. Tien has devised a holographic cybernetic model which relates consciousness, personality, time, memory, and acupuncture(46,47). Dr. Karl H. Pribram has proposed a model of brain function with two basic processes: spatially organized states and operations on that state by pulsed neural transmissions(48). He as well as Dr. Philip R. Westlake(49), suggest holography, expressed in Fourier transforms, to be the stratum of that spatially organized state.

But as yet this is all conjecture, for as Dr. Gabor has remarked:

"I am inclined to believe that there exists an abstract mathematical similarity but I am rather skeptical regarding the existence of waves or even of tuned resonators in the brain(50).

But we now know the neurons of the brain and nervous system are packed with MT's which are at least the right size, shape, and configuration to be tuned resonators. If such electromagnetic waves do exist within neuronal MT's, they would seem to be in equilibrium with, or at least affected by the state of surface membrane polarization and ionic flow. Neuronal transmission might then result in an increased dissipation of wave energy by a transient ionic effect upon MT structure (vice versa ?). This interaction fits well with the holographic models, the net coherent wave fields providing a spatially organized state within neuronal groups. Recent evidence has shown MT structure and function to be sensitive to lidocaine and the volatile anesthetics(51) and MT's "may be involved in impulse propagation in ways as yet completely unsuspected"(52).

Subtle magnetic fields have been detected outside the human head which fluctuate directly with alpha rhythms(53), and neuronal generated magnetic fields (cat sciatic nerve) have been measured and analyzed(54). The heart possess a magnetic vector (55,56) and electric fields (i.e., EEG, EKG) are well recognized. These are presently ascribed solely to ionic dipoles. Completely unexplained however, is the phenomenon of Kirlian photography(57,58). This technique utilizes high frequency (radio wave region) oscillating electric fields to visualize on film emanations from living organisms, as well as certain metals and crystals. Lensless photography may suggest a holographic mechanism and coherent interference may be the nature of these emanations. In human subjects, densest emanations of energy originate from acupuncture points(59).

The ancient Chinese described empirically a flow of energy through the body(60,61). The nature of the energy and the anatomical pathways through which

it flows have been unexplained, and consequently denied, by Western science. It is suggested here that Ch'i, the Chinese life energy is in fact interfering, coherent photic energy from the sun and stars which is refracted by the stratum corneum and resonant within microtubules. Tissue pathways of least resistivity to this energy have been described by the Chinese in terms of meridians. These appear to reflect embryological axes of development and, like the axes of cleavage and gastrulation(62) may be determined by MT's in the forms of neurons and non-neuronal cytoskeletal architecture. These seem to manifest primarily in the small, unmyelinated fibers mediating pain and autonomic function, both afferent and efferent. They may be embraced in a peripheral nerve, autonomic innervation of a blood vessel, or a tissue axis with no obvious neuronal axis. The relationship between the meridians and the organ systems they represent by the Chinese categorization lies presumably in the autonomic ganglia. Acupuncture therapy may be viewed as correcting an energy excess or deficiency in a given meridian system, perhaps by allowing equilibrium to be reached among the meridians or across the stratum corneum.

By holographic theory any arbitrary neuronal group, a spatially organized state, should contain the "engram" of the whole body, as measured by modulation of a pulsed function. This might hold diagnostic value and indeed, Chinese acupuncturists have claimed to do just this for thousands of years. Carefully palpating three fingerbreadths of the radial artery, subtle modulation of the pulse character by the neuronal group of autonomic innervation of this segment of the vessel is said to be diagnostic(63,54). What may be the fetal engram can be construed in the human outer ear (inverted) in which ectoderm, mesoderm, and endoderm analogues have distinct innervations(65). The many acupuncture points on the outer ear correspond to their respective body sites by this analogy(66).

Neuronal dissipation of the postulated energy might be dampened by myelin, a recognized insulator (i.e., saltatory conduction). Accordingly small unmyelinated fibers and unmyelinated ganglia would provide most efficient absorption and dissipation of energy and would be the mediators of acupuncture therapy. Myelin itself, however, might be of great significance. Myelin lamella formation, which seems to correlate with learning and development in any given fiber tract(67), consists of concentric spiral wrappings around a neuronal fiber of a lipoprotein blanket. The spacing between the lamellae is constant and corresponds to the intramicrotubular diameter. The insulating effect of myelin might include absorption and resonance into the spiral. A possible analogy is the conch shell, in which sound waves that were present during lamella formation may be reproduced later by a non specific wave. Memory, learning, and development may lie in the resonance of myelin lamellae.

Is there a microtubular forest in the neuronal tree? Did Gabor invent holography, or discover it? Physiology may follow engineering. It is reported that Casper and Klug derived their model of viral structure after studying Buckminster Fuller's geodesic domes(68). Is it that unlikely that we may holographically utilize the energy of the universe so directly, that we may, in fact be part and parcel of that energy? One need only study Eastern philosophy and Maxwell's equations to appreciate that man may have described electromagnetism no less than electromagnetism described man.

References

1. Porter, K.R., Cytoplasmic Microtubules and Their Function in "Principles of Biomolecular Organization" pp. 308-345. (Churchill, London 1966)
2. Bucher, N.L., Microtubules, *New Eng J Med* 287:195, July 27, 1972
3. Ibid Porter
4. Weisenberg, R.C., Microtubule Formation in Vitro in Solutions Containing Low Calcium Concentrations, *Science*, 177:1104, Sept. 22, 1972
5. White, J.G., Heagan, B., Tubular Polymers of Human Hemoglobin, *Amer J Path* 59:101, 1970
6. White, J.G., Heagan, B., Gels of Normal and Sickled Hemoglobin, *J. Exp Med* 131:1079, 1970
7. Peters, A., Palay, S.L., Webster, H.F., "The Fine Structure of the Nervous System" pp. 250-258, (Harper, N.Y. 1970)
8. Ibid Porter
9. Ibid Porter
10. Ibid Peters et al
11. Inoue, S., Motility of Cilia and Mechanism of Mitosis in "Biophysical Science—A Study Journal", p402, (Wiley, N.Y. 1959)
12. Ibid Bucher
13. Johnson, S.A., "The Circulating Platelet", pp. 57-59, (Academic Press, N.Y., 1971)
14. Ibid Porter
15. Ibid Bucher
16. Weiss, P.A., Panta' Rhei—And So Flow Our Nerves, *Amer Scientist*, 57:287, 1969
17. Ibid Johnson
18. Johnson, U.G., Porter, K.R., Fine Structure of Cell Division in *Chlamydomonas reinhardi*—Basal Bodies and Microtubules, *J Cell Bio*, 38:403, 1968
19. Gibbins, J.R., Tilney, L.G., Porter, K.R., Microtubules in the Formation and Development of the Primary Mesenchyme in *Arbacia punctulata*, *J Cell Bio*, 41:201 1969
20. Ibid Porter
21. Terman, F.E., "Electrical and Electronic Engineering", pp. 671-678 (McGraw Hill, N.Y. 1971)
22. Halliday, D., Resnick, R., "Physics Vol. II", p 957, (Wiley, N.Y. 1971)
23. Daniels, F., Optics of the Skin as Related to Ultraviolet Radiation in "The Biologic Effects of Ultraviolet Radiation" Urbach, F., Pergamon Press, Oxford 1969
24. Condon, E.U., Odishaw, H., "Handbook of Physics", 4:109 (McGraw Hill, N.Y. 1958)
25. Ibid Terman
26. Van Brunt, E.E., Shepherd, M.D., Wall, J.R., Ganong, W.F., Clegg, M.T., Penetration of Light into the Brain of Mammals, in "Photo-Neuro-Endocrine Effects in Circadian Systems with Particular Reference to the Eye", *Ann NY Acad Sci*, pp. 217-227 vol. 117 Sept. 10, 1964
27. Kitay, V.I., Altschule, M.D., "The Pineal Gland", p. 194, (Harvard Univ. Press)
28. Eakins, R.M., Westfall, J.A., Further Observations on the Fine Structure of the Parietal Eye in Lizards, *J Bioph Bioch Cyt* 8:483, 1960
29. DeRobertis, E., Electron Microscope Observations on the Sub Microscopic Organization of the Retinal Rods, *J Bioph Bioch Cyt* 2:319 1956
30. Ibid Kitay
31. Baker, Jr., Ransom, R.M., Factors Affecting the Breeding of the Field Mouse (*Microtus azristis*) Part I: Light, *Proc Roy Soc B* 110:313, 1932
32. Benoit, J., The Role of the Eye and of the Hypothalamus in the Photostimulation of Gonads in the Duck in "Photo-Neuro-Endocrine Effects in Circadian Systems, with Particular Reference to the Eye", *Ann NY Acad Sci*, pp. 208 vol. 117, Sept. 10, 1964
33. Hsiao, H.S., Susskind C., Infrared and Microwave Communications by Moths *IEEE Spectrum* p. 69, March 1970
34. Gamow, R.I., Harris, J.F., What Engineers Can Learn From Nature, *IEEE Spectrum* pp. 36-42, August, 1972
35. Truex, R.C., Carpenter, M.B., "Human Neuroanatomy", p. 122 (Williams & Wilkins, Baltimore 1969)
36. Ibid Terman
37. Gordon, L.M., Reversal by Light of the Action of Colchicine On the Organization of the Mitotic Spindle, Univ. of Penna., Thesis M.S. Philadelphia 1971
38. Gabor, D., Holography, *Science*, Vol 177, No. 4046 pp. 299-313
39. Brown, R., "Lasers: Tools of Modern Technology" p. 171 (Doubleday, N.Y., 1968)
40. Gabor, D., Associative Holographic Memories, *J Res & Dev*, 13:2 1969
41. Greguss, P., Biolography—A New Mode of Information Processing, *Nature*, 219:482, 1958

STUART ROY HAMEROFF

42. Longuet-Higgins, H.E., Holographic System of Temporal Recall, *Nature*, 217:584, 1968
43. Gabor, D., Holographic System of Temporal Recall, *Nature*, 217:584, 1968
44. Gabor, D., Improved Holographic System of Temporal Recall, *Nature*, 217:1288 1968
45. Ibid Greguss
46. Tien, H.C., Psychosynthesis: A TV Cybernetic Model in "*The Nervous System and Electric Currents Vol II*", pp. 61-65 Plenum Press, N.Y., 1971
47. Tien, H.C., Neurogenic Interference Theory of Acupuncture Anesthesia, *American Journal of Chinese Medicine*, pp. 105-122, Vol I, No. 1, January 1973
48. Pribram, K.H., "*Languages of the Brain*", pp. 140-166 (Prentice Hall, Englewood Cliffs, N.Y. 1971)
49. Westlake, P.R., The Possibilities of Neural Holographic Mechanisms Within the Brain, *Kybernetik* 7, pp. 229-253, 1970
50. Ibid Gabor (44)
51. Samson, F.E., Hinkley, C., Neuronal Microtubules, *Anesthesiology*, p. 417, 35:5 May 1972
52. Allison, A.C., Nunn, J.F., Effects of General Anesthesia on Microtubules, A Possible Mechanism of Anesthesia, *Lancet II*, 1326, 1969
53. Cohen, D., Magnetic Fields Outside the Human Head Fluctuating with Alpha Rhythms, *EEG Clin Neurophys*, 28: 102, 1970
54. Kitzmann, G.A., Droll, P.W., Iufer, E.J., A Theoretical Analysis of Neuronal Generated Magnetic Fields, in "*The Nervous System and Electric Currents*" Vol II, pp. 87-91 Plenum Press, N.Y. 1971
55. Baule, G.M., McFee, R., Detection of Magnetic Field of the Heart, *Am Heart J*, 66:95, 1960
56. Cohen, D., Magnetic Fields Around Torso, *Science* 156:652 1967
57. Ostrander, S., Schroeder, L., "*Psychic Discoveries Behind the Iron Curtain*", pp. 200-213 Prentice Hall, Englewood Cliffs, N.J., 1970
58. Canavor, N., Wiesenfeld, C., Kirlian Imagery: Photographing the Glow of Life, *Popular Photography*, pp. 90-93, 118-123 February 1973
59. Ibid Ostrander, Ibid Canavor
60. Mann, F., *The Ancient Chinese Art of Healing Acupuncture*, Vintage Books, N.Y., 1972
61. Van Nghi, N., Fisch, G., *Introduction to Acupuncture* I.I.M.B. Press, Lausanne 1973
62. Arey, L.B., *Developmental Anatomy*, pp. 62-83, W.B. Saunders, Philadelphia 1965
63. Veith, I., *The Yellow Emperor's Classic of Internal Medicine (Huang Ti Nei Ching Su Wen)*, Univ. of California Press, Berkeley 1972
64. Ibid Mann
65. Ibid Arey p. 548
66. Nogier, P., *Treatise of Auriculotherapy*, Maisonneuve, Paris
67. Ibid Pribram
68. Ibid Gamow