ELECTROMAGNETIC ENERGY OF VARIOUS TYPES INTERACTS WITH LIVING ORGANISMS TO PRODUCE A VARIETY OF FUNCTIONAL ALTERATIONS

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In the modern literature there are now well authenticated observations indicating that the navigational abilities of migratory animals are guided by the earth's natural electrical and magnetic fields. Major changes in these fields in the geologic past were associated with global extinction of many species, and the normal daily fluctuations in their field strength at the present time are directly related to the phenomenon of biological cycles. Electromagnetic radiation in a wide spectrum of frequencies produces behavioral and morphological changes in experimental animals. Electrical currents, both DC and in a variety of frequencies, directly administered to animals and humans, produces general anesthesia when applied across the brain. Similar currents in conjunction with acupuncture techniques produce local anesthesia. Finally, similar modalities produce acceleration in cellular growth (particularly bone) when applied to wounds or areas of discontinuity.

Unfortunately, none of these effects (except possibly the stimulation of bone growth) are based on any adequate biological theory. In fact, the key proposition—that cells are capable of sensing and responding in specific fashion to these parameters—is hardly universally accepted by science. In searching for some theoretical framework on which to view this entire field of bioelectricity, I believe one should be less concerned over detailing what effects occur or what mechanisms are involved, but rather *why* the effects occur at all. Present physiological concepts of the functions of the nervous system, and growth and healing mechanisms contain no valid reason why electrical currents in the nano-ampere range or electromagnetic fields of strengths little removed from that naturally occurring should have any biological effect.

It seems to me that one is faced with two choices of theoretical framework. The first is that the variety of effects is due to chance constructions on the part of the cells permitting meaningful interaction with these physical parameters; in other words, a fortuitous accident. The second is that the effects are produced by a preexisting biological control system whose functional properties are ones that permit interactions of a meaningful type to occur. It is my contention that the latter concept is correct.

The spectrum of reported effects can be summarized as relating to the biological functions of orientation, cyclic patterns, levels of consciousness and growth processes. The common denominator for all of these is that they are controlled functions. Furthermore, they are controlled functions of a very primitive sort. Our present concepts of how organisms transmit data and effect controls over biological functions are centered primarily on the nervous system. While this system has been shown to be related to these specific functions in a rather indistinct fashion, the mechanism of relationship is obscure and is definitely not mediated by the known method of data

transmission in the nervous system—the action potential. At this point, we may conclude that electromagnetic forces produce functional changes by interacting with some function of the nervous system not presently described or with a separate data transmission and control system that is related to the nervous system. In either event, the mechanism of action, the way messages are transmitted, must be one capable of interacting with all electromagnetic phenomena. Furthermore, this mechanism must be organized to constitute a data transmission system with both input and output characteristics, which can then be perturbed by electromagnetic forces so as to alter the message. Theoretical considerations and experimental evidences indicate that the messages are most probably electronic in nature and solid state; that is, semiconduction, etc. based. In brief, what I am proposing is that all of the effects produced in living organisms by exposure to low level electromagnetic parameters are the result of interaction with a preexisting data transmission and control system with solid state characteristics carrying messages in an analog fashion by electron flow. The system is related to the nervous system in some fashion and deals with such primitive functions as the receipt of injury, the stimulation of growth and repair processes, the phasing of biological cycles to geophysical cycles and the regulation of the general operational level of the central nervous system itself.

Support for this concept is derived from both theory and experiment. In the former case, one of the concepts concerning the origin of life is pertinent. There are presently two such theoretical concepts. The one postulates the origin of life occurring in an aqueous environment, based upon solution biochemistry with the gradual evolution of protein molecules and their subsequent sequestration into proto cells within a semipermeable membrane. The other conceives of the gradual accumulation of complex molecules with electronic properties in a dry state with the slow acquisition of such functions as self-repair and self-organization, and only much later, the sequestration of such units into protocellular structures capable of maintaining their integrity in an aqueous environment. It is not too difficult to conceive of a semiconducting crystalline matrix with self-organizing properties capable of "sensing" injury and effecting appropriate repair. Such a unit would interact with the natural electromagnetic field and would show phase-locked alterations in its behavior with alterations in these environmental parameters. Acquisition of photosensitivity would add light to the list of environmental parameters influencing the unit. Subsequent sequestration into protocells would permit establishment of an aqueous internal environment and acquisition of solution chemistry for energetic requirements. The original material would persist and continue to function as the data transmission and control system. With the development of multi-cellularity, such control functions would be concentrated in specialized cells. Such specialized cells would subsequently be the origin of the sophisticated high-speed data transmission system of the nerves. Finally, while the two control systems would co-exist and be intimately related morphologically and functionally, the basic system would still function with inputs consisting of electromagnetic forces and organismal trauma and outputs consisting of the stimulation of healing, the regulation of morphological organization and controlling the level of activity of its daughter, the nervous system. Several points of view support this concept of dry state biogenesis with primitive "proto living" organisms of solid-state nature. First, the concept of solution

biochemistry as being the primary foundation of life appears to be doubtful, since its concepts have been unable to furnish mechanisms that regulate the basic types of functions we are discussing. Secondly, the cell is a sophisticated unit and to consider one of the earliest steps in biogenesis as the establishment of the cell leaves out a multitude of earlier steps. Lastly, the nerve cell is a highly sophisticated, obviously late arrival on the biological scene, yet all of the organisms that preceded the development of a nervous system must have had a data transmission and control system that at least maintained the integrity of the organism and dealt with the primitive functions we have been speaking about. From a theoretical point of view, then, if a separate, solid-state analog data transmission system does not exist in living organisms, one certainly should.

The experimental evidence for such a system is as follows:

Slide 1. This is a generalized representation of the central and peripheral nervous system of the salamander—an animal that can be viewed as the basic vertebrate.

Slide 2. Careful determination of the pattern of standing or DC potentials on its surface reveals an obvious relationship to the morphological arrangement of the central nervous system. This is important, for if one postulates the existence of an analog type electronic data transmission system, one should detect standing potentials on the surface of animals with moist skin. Further, as we have shown, these potentials vary with changes in functional state, such as levels of consciousness, the occurrence of trauma and during healing processes. Finally, if these DC potentials are overt representations of an underlying control system, the system is spatially congruent with the nervous system.

Slide 3. Some time ago we reported a difference in the potentials recorded at a site of injury between animals capable of regenerative healing and closely related species capable only of scarification-type healing. Not only are the patterns totally different, but the potentials exist until healing is complete. I interpret this to cast doubt upon the concept that the current of injury results only from “leaky” cell membranes and would suggest that the current of injury is the resultant of several factors. The injury is a stimulus to the analog system which then responds by inducing a local electrical environment that results in the appropriate cellular activities to produce healing. The system functions more efficiently in those animals capable of regeneration and in their case, produces an electrical environment that stimulates the local cell population to produce a blastema. We have shown that artificial simulation of the appropriate electrical environment in non-regenerating animals is capable of inducing some measure of regeneration. The electrical potentials at a site of injury then are a composite of those derived from the residual injured cells and a major component from the input-output loop of an electronic analog system such as illustrated in slide #4.

Slide 4. This is our present concept of the operational components of the injury-repair control system. We postulate that the injury produces local potentials that may result from free radicals and which serve as an input stimulus to the DC system. We propose that this latter is the origin of the pain sensation, a primary sensory modality that is notoriously hard to explain on the basis of the action potential system. The input to the DC system results in an output consisting of the generation of an electrochemical environment at the site of injury. This output signal as well

as the input signals are carried by direct current along pathways related to the nerves. Wound healing in a denervated area is slow and difficult and regeneration will not occur in such an extremity. On the basis of this theory, we propose that the neural element related to regeneration by Singer is the DC system and that the reason why the higher animals lack regenerative ability is their sequestering greater and greater amounts of their total nerve mass into the brain, reducing the tissue-nerve mass ratio in the extremities. This can apparently be overcome, however, by simulating the appropriate electrical environment via external sources. In any case, at the site of injury, the electrical environment, if appropriate, produces stimulation of the cells into either mitotic activity or dedifferentiation and subsequent multiplication. As the wound is repaired, the feedback loop brings the process to a close with the gradual decline in the DC signals at the site.

Slide 5. We have gained some insight into the tissue which is the basis for the DC system through this series of experiments. It is known that denervation by sectioning the peripheral nerve will result in delayed healing or non-union of fractures. In this experiment, we sectioned the sciatic nerve—actually removing a 5 mm segment—and fractured the fibula in a large number of young laboratory rats. We noted that when the denervation was done simultaneously with the fracture, that a noticeable delay in the regenerative portion of the fracture healing process occurred. In an attempt to produce a more obvious delay, the denervation was done at two days and five days before the fracture. We expected that the degenerative processes in the distal portion of the nerve would be more evident when the fracture was incurred, and the corresponding delay would then be more evident. We found exactly the opposite effect; in fact, fractures produced five days after denervation in these animals healed in a perfectly normal manner. We then theorized that the tissue responsible for the regenerative phase of fracture healing had regrown in the five days preceding the fracture. Examination of the nerve section site in these animals showed the nerve to be still disconnected with no evidence of regeneration or restored continuity.

Slides 6 & 7. However, the nerve ends were joined by a thin filmy material which upon histological examination was revealed to be the Schwann cell sheathes. This was not surprising, since Cajal in his investigations demonstrated very nicely that the Schwann cell tubulations that normally surround each nerve axon must regrow first and establish continuity with the distal tubulations before any nerve regrowth can occur. This observation, however, indicated to us that the Schwann cells might be the tissue responsible for carrying the DC analog messages in the periphery. However, the Schwann cells are only part of a cellular system called the perineural cells.

Slide 8. These cells are derived embryologically from the same tissue that produces the nerves. They pervade the entire nervous system, the glia cells being present in the brain, the satellite cells in the ganglia and the Schwann cells in the peripheral nerves. In each instance the perineural cells surround the nerve cells themselves and all elements of the perineural cell system are in direct contact with each other. In fact, the evidence suggests that the Schwann cells that ensheathe the peripheral nerves are a syncytium with the cell walls missing at the points of intercellular contact and with protoplasmic continuity throughout. The perineural cells therefore are present wherever nerve cells are found, and their overall organization is exactly similar to that of

the entire nervous system. In addition, the glia cells have been shown by several investigators to be electrogenic, producing DC potentials and slow electrical waves in the brain. These phenomena have further been shown to exert a biasing control on the level of excitability of the nerves themselves. Shifts of the glial cell population in one area of the brain in a negative direction will produce hyperexcitability of the nerve cells in that area and may produce convulsive seizures. Positive shifts have the opposite effect. In short, the entire complex of perineural cells appeared to be an ideal candidate for the primitive electronic control system. Since they accompany the nerves everywhere, this could easily explain the dependence upon an intact nerve supply for pain sensations in response to injury and for control over subsequent cellular healing processes without anyone being able to show a direct relationship to either the action potential or chemical transmitter substance or to the known interrelationships of the nerves themselves. On this concept, I would like to theorize the development of data transmission and control systems in an evolutionary fashion.

Slide 9. We propose that the original material was solid-state in nature and that it showed self-organizing and repair processes based upon analog DC signals after sequestrating from the environment into protocells. These data transmission properties would be further organized as a network with the appearance of integrating nodal centers which could have been the forerunners of the nucleus. With the development of multicellular organisms, the data channels would have been concentrated in single cell types that would have formed primitive networks.

Further development and increase in size would have required that the high resistance cell membranes between these cells be replaced by syncytial structures or other low resistance junctions to facilitate transmission of the DC signals, leading to more advanced and sophisticated nets with large capacity integrating nodal centers. The resulting need to process information quickly and reliably would have given rise to the nerve cells that function in a digital fashion via the action potential.

In this view, the nerve cells would have developed on the basis of the pre-existing DC system and would follow the anatomical organization of that system. Furthermore, while there would be a simultaneous dichotomy of function evident with the nerve cells handling special sensory data in a digital fashion and the perineural cells handling primitive data in an analog fashion, the functional level of the nerve cells would be set by the operational level of the surrounding parent perineural cells.

Slide 10. While the action potential system of the nerve would permit transmission of digital signals over long distances, the analog signal in the perineural cells would degrade due to cable constants, unless units analogous to operational amplifiers were inserted in series in the transmission lines. Such amplifier sites should be evident as point sources of DC along the peripheral data transmission channels. Evidences for this concept comes from our electrical evaluation of the acupuncture points.

Slide 11. The charts detailing the acupuncture meridians and the acupuncture points along these meridians are now well known. It has also been known that the points could be located by measurement of skin resistance—the points showing a marked minimum in resistance.

However, the usual resistance bridge would also read a minimum if the points were sources of DC and skin resistance actually remained linear. Measurements of DC output from the points using high impedance electrometers readily showed that all points were *sources* of DC with geometry equivalent to the resistance measurements.

Slide 12. In this slide I have attempted to show the perineural system and its relationship to the usual spinal reflex arc. Note that the perineural cells form fully as complete a system as the nerves do, including the transmission to higher centers in the brain via the glial network of the cord. In the lower left the interaction between the acupuncture needle with its small electrical charge and the field around an acupuncture point or amplifier mode is graphically shown. In the lower right I have tried to indicate the variety of effects that could be produced by either an injury, insertion of needle or electrical stimulus of appropriate type stimulating an input channel of the perineural DC system. DC input charges would spread centrally and be transmitted to the brain via the spinal cord network while some DC would be also transmitted peripherally along the simple reflex arcs. In addition, since the functional state of the nerves depends upon the DC environment generated by the perineural cells, one can expect that the nerves in the input pool of the reflex arc would experience an altered state which would also be expressed peripherally. Further, the receipt of the DC message in the glial network of the brain would produce local DC shifts which would alter the functional state of the central neurons in the same area. I have omitted from this slide, for the sake of clarity, the output portions of the perineural DC system which would be derived from the cerebral glial network and which would also produce peripheral DC environmental shifts in different areas.

Slide 13. In short, I have described a primitive data transmission and control system, located within the perineural cells. The system, I believe, antedates the nervous system and transmits its messages and control signals by means of analog type direct currents in a solid-state matrix. Inputs to the system consist of injury to the organism and environmental electromagnetic fields. Outputs from the system consist of the control of cellular growth by inducing specific electrical environment within the organism and a bias control over the functional level of the central nervous system. Both outputs are apparently mediated by means of electrochemical effects. This system presently appears to be capable of explaining several of the problems connected with our understanding of pain mechanisms, biological cycles, control of growth and healing, acupuncture and the phenomenon of the response of living tissues to a variety of electromagnetic parameters. It further appears to relate to a variety of other problem aspects of biology such as the question of the origin of life, and the possibility of data transmission and control systems in plants as well as animals.