

## Electromagnetic fields and life

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The relationship of environmental electromagnetic (EM) fields to living things is a profoundly basic one. There are evidences relating the EM fields to the origin as well as the evolution of life so that present day living things including humans, have primitive mechanisms dependent upon these fields. This review discusses these specific areas and included the possible effects resulting from the introduction of novel frequencies and amplitudes into the earth's normal EM field spectrum resulting from communication and power applications.

Life began, evolved and exists today in a continuum of electromagnetic fields. While modern science has rejected the concept that such force fields have any effect upon living organisms, new evidence suggests that they have played a central role in the origin and evolution of life and that the modern technological use of them for power and communication poses a menace for life itself. The classical scientific view that no effects can occur from electromagnetic (EM) field exposure (other than heating at high frequencies, etc.) is based solely and primarily upon the present concepts of how living things function. These concepts are fundamentally those of solution chemistry and in this case, it is indeed difficult to postulate any coupling effects except at absurdly high field strengths. As has always occurred in the history of science, these concepts have assumed the status of dogma and the present scientific establishment feels they satisfactorily explain the majority of life functions. The defect in this thinking is evident when one constructs a list of life functions that are satisfactorily explained by present concepts and another list of functions not presently explicable (Table I). It is evident that there are a number of important properties of living materials that are inexplicable by the concepts of solution chemistry. Interestingly enough, these all are primitive functions - those which could be considered to be associated with life forms from their inception. It would seem reasonable to postulate that these functions are based upon principles other than those encompassed by solution chemistry and, in view of the very basic nature of these functions, a single, common, primitive mechanism may be responsible for all.

It is important at this juncture to note that, when the basic present day

TABLE I  
Present limits of biological knowledge

Known	Unknown
1. Heredity	1. Growth control
2. Metabolism	2. Energy conversion
3. Muscle coordination	3. Consciousness
4. Special senses	4. Memory
5. Infectious disease	5. Pain
	6. Biological cycles
	7. Origin of life
	8. Parapsychological phenomena

physiological concepts were being formulated, the only mechanism provided by chemistry and physics were those of solution chemistry. Since then, advances have occurred in these sciences and there are a number of new mechanisms (such as solid state physics) which have yet to be enthusiastically applied to the problems of biology. The identification of mechanisms involving aspects of solid state physics, such as semiconductivity, within living organism would provide a rational mechanism for coupling between living organisms and environmental EM fields. It is this writer's position that the identification and study of such a mechanism is much more important in securing agreement within the scientific community on the biological effects of EM fields, than are any number of phenomenological studies. Working over the past twenty years, initially on the mechanisms stimulating and controlling growth and healing, we believe we have described a previously undetected biological data transmission and control system based upon such solid state electronic mechanisms.<sup>1-8</sup>

The system's signals are analog in type and electrical in nature. They are associated with the central nervous system, not with the neural, action potential portion, but with the perineural tissues. The system is characteristically a primitive one and we have advanced the postulate that it represents the original data transmission system in the earliest life forms. Most recently we have been able to relate this system with a majority of the unknown functions listed in Table I. The regulation of such basic life functions by an electronic solid state control system provides a direct sensitive link with EM force fields external to the organism.

With this concept in hand, one can predict that EM field effects upon living organisms would be found in subtle changes in basic mechanisms and not in any gross functional or anatomical alterations. This concept also permits the prediction that such force fields played a role in the origin of life and subsequent evolutionary development as well.

In reviewing the literature in this field, I shall not attempt an exhaustive survey of all available documentation since such a paper is currently in press.<sup>21</sup> I believe that a much more useful purpose will be served by discussing in some small detail key papers dealing with each specific area of interest.

Cole and Graf in a series of papers<sup>10,14</sup> have examined theoretically the electro-dynamics existent on the Pre-Cambrian earth. They have developed a model based upon the dimensions and interactions between the Van-Allen belts, the earth's rotational frequency and magnetic field that predicts the release of enormous amounts of electromagnetic energy in the extra low frequency (ELF) region, particularly at the eigen-frequency of 10 Hz. This disturbance would exist within the earth-ionosphere cavity, in the primitive reducing gas atmosphere and would result in extremely large continuous electrical discharges. A similar circumstance is believed to be currently present in the Great Red Spot area of Jupiter. The magnitude of the disturbance would decline with the condensation of water vapor and the escape of atmospheric hydrogen. During the period of electrical discharge, the generation of large amounts of complex organic molecules such as proteins would occur. These molecules would subsequently provide the raw materials for the development of living organisms. Most importantly the structure of the complex molecules thus formed would have to reflect the 10 Hz frequency that dominated the original field. Subsequent development of more complex structures built upon these molecular units would still perform reflect the same 10 Hz resonance. This intriguing concept correlates well with a number of other well known facts; for example, the natural frequency range of the electroencephalogram and its great similarity in widely divergent life forms. The structure of the organic molecules formed in this Pre-Cambrian period may well have permitted the development of solid state electronic processes such as semi-conductivity as is present in today's protein structures.<sup>11</sup> Further development of life as complex molecular structures may well have occurred in accordance with the dry-state biogenesis concept as developed by Hinton<sup>16</sup> in which pre-formed complex molecules in the dry crystalline state interact with electrical forces and produce even more complex, sophisticated structures with interesting properties. In fact, the concepts of Cole and Graf dovetail very well with those of Hinton. Thus the very basic beginnings of life would have been intimately tied to EM forces. Their structures would reflect this and would exhibit sensitivities of function to the specific frequencies of the ELF region.

It is pertinent at this time to consider what functional properties could be assumed to be demonstrated by this earliest living material that would distinguish it from the non-living and would be necessary for its survival. It is obvious that at that time in the development of life, such sophisticated



mechanisms as nerve conduction, sense organs or organs of locomotion would not have developed; indeed it is not even necessary to postulate a capacity for self-replication. Organisms, such as they were then, must, however, have had the capacities of sensing injury to themselves (pain), subsequent self-healing and self-organization, some rudimentary information storage mechanism (memory) and they must have demonstrated biological cyclic patterns of variation in some function. It is most interesting to note that these are some of the basic life processes that have eluded explanation on the solution chemistry basis (Table I). It therefore appears quite reasonable to conclude that these mechanisms are based upon properties inherent in the original solid state living material and that their persistence in present day life forms is similarly based. Most importantly, the basic materials from which all living things are fashioned, must be responsive to the EM environment.

The unfolding of life in great diversity followed the initial step of the origin of life. While our knowledge of this process is perforce based upon the fossil record and cogitation (such as that resulting in Darwin's theory of natural selection), certain well established observations now indicate that again the EM environment played a very important role. These observations, chiefly by Hays<sup>15</sup> at the LaMont Geophysical Laboratory, clearly established a relationship between the survival of species, involving great numbers of organisms and disturbances in the EM field characterized as magnetic reversals. Studies of this type require an accurate, undisturbed record of both magnetic field and organisms over long periods in the geologic past. The deep oceanic sediments provide such a record, since in the deposition of magnetic particles, they will become oriented to the existent magnetic field. Knowing the time and rate of deposition, the sediments accurately reflect the overall status of the earth's field over long periods in the past. The record shows that on a number of occasions the poles reversed themselves. Each reversal took about 1000 years, with gradual onset and without the field dropping below half-normal strength, even at the peak of the cycle. Unfortunately the sensitivity of the record is not adequate to record anything other than the gross changes in field direction and magnitude. We know nothing about fine structure, such as the appearance or magnitude of any frequencies that would have been present. The earth's field at present includes such fine structures, known as micropulsations. Their frequencies lie in the ELF range with a maximum in the 10 Hz region and their origin is unknown. It is reasonable to postulate that disturbances in such characteristics would accompany field reversals. The sediments also are composed of the skeletal remains of a microscopic oceanic animal, the foraminifera. These organisms are present in uncountable numbers and exhibit a wide diversity of species identifiable in the exoskeleton. Paleontologists interested in the develop-



ment and time course of species changes have used this record extensively in the past and it was known that it was marked by occasional catastrophic changes in which species would become extinct over short periods of time. Hays correlated these two types of occurrences – the magnetic reversals and species extinction and found a correlation far beyond chance. Unfortunately this type of correlation is possible only with the deep ocean sediments and we can only speculate as to whether similar events and correlations occurred with more highly developed species. The extinction of the dinosaur still remains inexplicable today. It may be of interest to indicate that the courses for and the mechanisms involved in magnetic reversals are completely unknown. Nonetheless, such changes occurring in the earth's magnetic field were accompanied by far reaching and important changes in the pattern of life forms on the earth. The last recorded magnetic reversal occurred approximately 25,000 years ago and it is currently impossible to predict the time of the next reversal.

Life on the earth at present is influenced by the electromagnetic environment in a number of fashions. The conditions at present are, however, unique, never having existed before, while life in some form has been present in the natural EM field since Cambrian time, at least three billion years ago; within the past fifty years, human activities have produced a marked alteration in the characteristics of this field. Today, everywhere on the Earth's surface, frequencies and magnitudes of EM fields exist that are totally unnatural and in many instances never existed before (Figure 1).

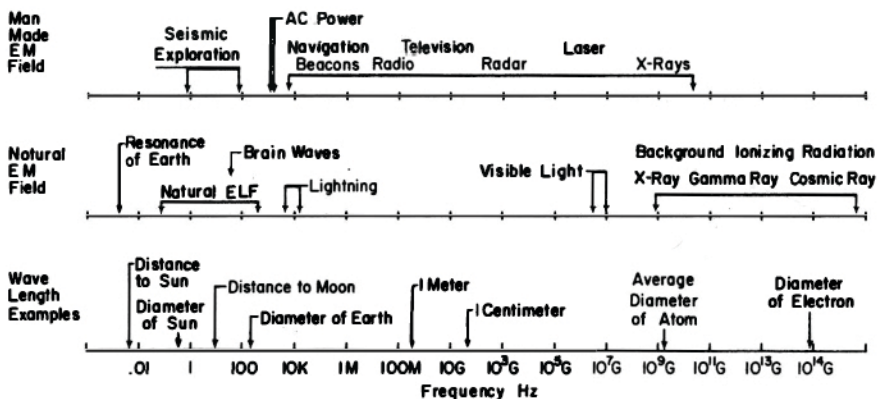


FIGURE 1 A comparison between the earth's normal EM field and that produced artificially. The lower portion of the chart summarizes the relationships between frequency and wavelength across the known EM spectrum. The center portion illustrates those portions of the spectrum that antedated man's usage of this energy. Those portions of the spectrum without specific notation were basically devoid of EM energy. The upper portion of the chart summarizes very briefly man's use of the spectrum. It should be noted that this has resulted in the appearance of novel frequencies and the injection of very large amounts of power at specific frequencies, far above that pre-existing in the normal field.

Therefore field effects observable today fall into two broad categories; those in which the organism is responding to the natural EM fields and those produced by artificially generated fields.

In view of the preceding correlations between EM fields and the origin and evolution of life, it is hardly surprising that certain basic life functions are linked to the natural fields. All living things display the phenomena of biological cycles or Circadian rhythms in which not only activity, but also many physiological functions display cyclic changes with periods of approximately 24 hours, 28 days and 11 years. These are obviously related to solar, lunar and earth's rotational cycles; the major question of course, has been that of the linkage mechanism. It has been known for some time that the earth's EM field has the same cyclic periodicity obviously resulting from the geophysical ones. In a long series of observations it has been shown chiefly by Brown<sup>9</sup> that it is this cyclic variation in the EM field that furnishes the time base for the ubiquitous biological cycles. More recently, Wever<sup>29</sup> has demonstrated a similar mechanism in man. In his experiments he completely isolated human subjects from all variations in the earth's field. This resulted in a major perturbation in their biological cycles which could be corrected by introducing a 10 Hz field into the experimental chamber. While all living organisms possess this necessary mechanism to "perceive" the natural EM field and derive their cyclic pattern from it, the evolutionary development of some animals has resulted in an increased capacity to sense the fields. In these life forms this ability has become a mechanism of enhanced survival value and has resulted in important physiological-behavioral patterns. It has been demonstrated that the migratory pattern of the Atlantic eel is the resultant of its ability to use the minute variations of the earth's electric field as a directional cue.<sup>27</sup> The same authors have also shown in experiments that the Atlantic salmon is capable of perceiving electrical fields of 0.0007 V/cm in magnitude.<sup>24</sup> Keeton<sup>17</sup> has investigated the navigational systems employed by the homing pigeon and has determined that one system used is a magnetic compass of extreme sensitivity. The mechanisms employed by these animals to sense the earth's EM field and extract information from it far exceed our technological capabilities. Over the past few years, however, our ability to measure magnetic fields has been somewhat increased by the development of the super-cooled Josephson junction. This device has been employed to demonstrate the existence of magnetic fields surrounding the human body produced by the activity of the heart and brain.<sup>30</sup> This field can only be produced by organized electronic currents flowing within these structures and the observation lends major support to our postulate of the existence of such systems. This also demonstrates that the acceptance of such postulates frequently must await technological breakthroughs in measurement capabilities. It is apparent that biological organisms possess



field sensing mechanisms several orders of magnitude more sensitive than the Josephson junction and as yet undiscovered by man.

Considering these observations, linking all life forms to the earth's natural EM field, the question of the effects of man's technological pollution of this field with abnormal frequencies and field strengths becomes of prime importance. These alterations in the field began in the closing years of the 19th century with the first feeble beginnings of AC power systems. Since then, growth has been exponential until at present the entire EM spectrum is crowded, large frequency bands which were devoid of EM energy before now have high signal densities and the 50 or 60 Hz power frequencies are inescapable in the developed nations (Figure 1). Most of this development has occurred within the past 15 years – barely one generation has been conceived, gestated, born and grown to adulthood under these circumstances. By analogy with one of our experiments in which three generations of mice were raised in an elevated 60 cycle field;<sup>19</sup> this is insufficient for gross effects to become apparent. The present literature reports on a wide variety of controlled experiments on field effects in the ELF range above.<sup>21</sup> These fall into two general categories: physiological alterations resulting from activation of the neural stress response system and growth effects at all levels from cellular to organismal.

While the clinical concept of stress requires that it be consciously perceived, there is no question that the physiological alterations that are produced are neural in origin.<sup>28</sup> We have reported on a number of controlled experiments at 60 Hz in which such physiological alterations have been produced<sup>20</sup> and our present postulate is that the field action is directly upon the responsible central nervous system structures. This is substantiated by the work of Noval who not only found the same physiological alterations as we did with less 60 Hz exposure, but also detected alterations in the neuroenzymes in the brain.<sup>26</sup> Working at the same field strength and frequency Gann noted disturbances in cardiovascular compensatory reflexes that were also neural in origin.<sup>12</sup>

The slowing of normal growth in young animals exposed to 60 Hz fields has been reported by several investigators.<sup>18,20,26</sup> While such an effect may be associated with the stress response syndrome, there are other reports dealing with direct growth responses. McElhaney and Stalnaker reported the production of bone tumors in rats by exposure to an ELF field of 70 volts/cm<sup>25</sup> and Marsh noted abnormal morphology in regenerating flat worms exposed to a 60 Hz field.<sup>23</sup> Finally, mitotic activity disturbances have been reported in slime molds at 60 and 75 Hz.<sup>13,22</sup>

It is obvious that much more work needs to be done to characterize the full spectrum of biological interactions with ELF fields. In particular, a complete assessment of the hazards associated with our present use of EM urgently

needs doing. In my own opinion, the highest priority should be given to an investigation of the biological electronic systems, their design and function, for it is in this area that techniques of major clinical import can be expected. In any event, the concept that living things are totally unresponsive to EM fields, particularly in the ELF region, now appears untenable.

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## REFEREE'S COMMENTS ON R. O. BECKER'S PAPER

R. O. Becker has written a comprehensive review paper on the effect of electromagnetic fields on living systems.

Becker makes a very good point when indicating that techniques such as those of solid state physics can be applied to biological and surely this will bring about ways of solving some theoretical problems.

Becker then claims that he and his co-workers have detected a data transmission and control system in the human body which is based on an analog-type solid state mechanism. Furthermore, he claims that they have related this mechanism to most of the unknown functions listed in Table I; if this is so, it is only unfortunate that he does not give details of this since the importance of a theory which could give a satisfactory model for any of the unknown functions would be a tremendous leap in our knowledge and understanding of human functioning. Instead, Becker goes on to give a historical-evolutionary picture of life and the way it relates to the EM

environment. He divides these effects into two categories: (i) the organism's response to natural EM fields and (ii) its response to artificially generated EM fields.

He gives a good discussion on biological rhythms and sensing of EM fields.

Finally, we are again left with just a few details of ELF effects on man, which Becker claims can go from physiological alterations resulting from activation of the neural stress response system to growth effects at cellular or organismal level.

It seems to me that the author did not rightly balance the importance of the topics discussed in his paper. It is disappointing that Becker has not provided more details on the topics which involved his own work on a new mechanism of data transmission in the human body; clearly, this would have been a most valuable contribution.

#### REPLY

I have received the referee's comments on my paper entitled "Electromagnetic Fields and Life." I agree with the referee that a more comprehensive discussion of our own work would have been desirable. However, since full details have previously been published and are available in the scientific literature (Refs. 7 and 8), it did appear redundant to present them in this manuscript. I should like to indicate that our postulated data transmission and control system serves merely as a vehicle for the understanding and coordination of the scientific data pertaining to electromagnetic field effects in living organisms. Obviously the data stand by themselves; the control system serving merely to produce a coherent overall field. Perhaps the most important contribution of the control system concept was in its providing a rational mechanism for the interaction between living organisms and electromagnetic fields. Without such a concept, there does not exist in the body of scientific knowledge an adequate mechanism for such interaction.

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