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Electromagnetism and Psi Phenomena¹

ROBERT O. BECKER²

ABSTRACT: Certain psi phenomena, such as extrasensory perception, may be viewed as actions at a distance, a concept that requires the passage of coded information across a distance by some force that does not elicit a response from any of the five senses. Electromagnetic fields have been long postulated to serve this function. However, firm evidence has been lacking, and this, combined with the frequent nonreproducibility of these phenomena, has essentially excluded them from scientific examination. New evidence has indicated that various aspects of such extrasensory perceptions are associated with the condition of the geomagnetic field. A "quiet" field enhances the chances of such phenomena occurring, whereas a "disturbed" field reduces them. This evidence has provided at least a clue to the nonreproducibility, and it has indicated that some aspect of the geomagnetic field may be involved with this action at a distance. A major problem with this thesis is that neural function is not influenced by magnetic fields of much greater magnitude. However, there is good evidence that information processing in the brain is not solely a neuronal function and that a much more primitive system exists in the brain that operates on the basis of electromagnetic fields. This paper is an attempt to review the new data on the relationship between psi phenomena and the geomagnetic field as well as on the electromagnetic system of information processing and to combine them in a testable hypothesis for the mechanisms involved in producing such psi phenomena.

HISTORICAL BACKGROUND

Certain psi phenomena, such as extrasensory perception and remote viewing, may be defined as the detection of external information directly at the level of consciousness without any preceding sensory stimulus, by-passing completely the sensory organs. Phenomena of this type will be

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² I am grateful to Dr. Stanley Krippner for many discussions and for providing a number of bibliographic citations. I also am grateful to Rhea White for checking references and attending to many details.

considered in this paper. Although the data presented may be applicable to other psi phenomena, any such application at present would be speculative.

Present neurophysiology is based solely on the "neurone doctrine" that holds that all operations of the brain are the result of nerve impulses and their associated process. This requires that the only entry into consciousness is through the special senses; therefore, validation of psi phenomena would require a drastic revision of present understanding not only of the mind/brain relationship but of the total neurophysiological structure. Unfortunately, although unusual events of a startling nature do occasionally occur, parapsychological phenomena are characterized primarily by a lack of reproducibility and apparent randomness in their occurrence. As a result, these phenomena have been considered to be mystical and imaginary, not fit subjects for scientific study.

Concurrent with the early development of radio communications in the first few decades of this century, it was postulated that extrasensory perception (ESP) functioned in a similar manner, one consciousness communicating with another via some electromagnetic (EM) field that traveled through space from the transmitter to the receiver. In fact, this idea was the stimulus behind Hans Berger's discovery of human brain waves by means of the electroencephalogram or EEG. Berger himself was involved in a vivid ESP event as the transmitter, and he was convinced of the validity of the phenomenon (Bender, 1963; Berger, 1940). However, the strength of the EEG found by Berger was far too weak to provide a basis for such extrasensory communication, and all subsequent attempts to relate EM fields to psi and parapsychological phenomena were without success (Vasiliev, 1963).

Furthermore, it was believed in the early days of the 20th century that the powerful humanmade radio waves that could be detected by appropriate receivers thousands of miles away had no apparent effect upon any living organism. This observation was in keeping with theoretical physical considerations that indicated that the energy contained in such an EM field was far lower than the naturally occurring random atomic oscillations produced by thermal energy in the human body. Therefore, such EM waves impinging on the body would be lower in energy than this thermal "noise," and they would be not only detected but without biological effects. Finally, the nervous system and brain had been shown to operate not by electricity but by a traveling wave of depolarization in the nerve membrane produced by the movement of charged ions of sodium or potassium across a portion of the nerve membrane itself. The known principles of physics indicated that this movement could not be influenced by even a strong EM field. Although a "nerve impulse" could be detected electrically, electricity per se, as an actual electrical current, was not involved. Berger's strange electrical waves from the brain were theorized to be simple by-products of the simultaneous discharge of a large number of nerve cells. Therefore, science totally excluded any effect of electrical currents or EM fields on living organisms other than the production of

shock or heat by high energy EM forces. By the early 1940s, this concept became the accepted scientific paradigm, and electromagnetic fields were used for power and communications purposes in an unrestricted fashion, with scientists secure in the knowledge that these fields, which had never before been present on the earth, were totally safe.

THE DEVELOPMENT OF A NEW SCIENTIFIC PARADIGM: BIOELECTROMAGNETICS

However, over the past 30 years, a new scientific discipline has come into being, one that has slowly but effectively challenged this dogma. It has shown that, despite all the theoretical objections, minute electrical currents and very low-strength electromagnetic fields do indeed have profound biological effects. In the 1950s, this discipline, now termed "bioelectromagnetics," was founded on two lines of inquiry into very basic life functions, biological cycles and regeneration. Initially, Frank Brown (1963) of Northwestern University investigated the phenomena of biological cycles that are not only universally present in all living things but that have also been shown to be essential for life. He unequivocally demonstrated that steady magnetic fields lower in strength than the earth's geomagnetic field altered biological cyclic behavior in a significant and reproducible fashion. Brown postulated that the timing signal for biological cycles was derived from the same rhythm of cyclic changes in strength as the earth's geomagnetic field. Despite the validity of his experiments, his observations were not accepted by science because there was no conceivable mechanism by which such low-strength magnetic fields could have any biological effect.

A few years later, because of my interest in the mechanisms of wound healing, I began experiments on the remarkable healing phenomenon of regeneration in many animals, particularly in salamanders. Salamanders are capable of regrowing an entire extremity comparable in complexity to a human arm or leg following its amputation. Although this process had been shown to be related to the nerve supply, it had also been shown that it was not related to nerve impulses. I postulated that it might be related to the "current of injury" first described by Galvani, and I observed a very low-strength steady (or direct) electrical current (DC) at the site of injury in animals capable of regeneration that was unmistakably different from that in nonregenerating animals (Becker, 1961a). Because the regenerated limb was completely functional and anatomically appropriate to the rest of the organism, I reasoned that this could not be simply a local phenomenon but must be an expression of some similar electrical system that reflected the organization of the entire body. Looking back through the neurophysiological literature, I found that, beginning in the 1930s, several eminent neurophysiologists had reported convincing evidence for an organized, extraneural, direct current system in the brain that appeared to control the level of activity of the brain cells themselves (Aladzhilova & Kashtants,

1960; Caspers, 1961; Gerard & Libet, 1940; Goldring & O'Leary, 1954; O'Leary & Goldring, 1964). I repeated this work and then extended it into the peripheral nervous system. I concluded that the current of injury was the local expression of a larger total-body DC data transmission and control system (Becker, 1972, 1974). The evidence indicated that this system was located, not in the nerve cells proper, but in the perineural cells. The perineural cells actually constitute more than half of the bulk of the brain and accompany even the smallest nerve fibers throughout the body. Additional studies showed that this perineural DC current was semiconducting in nature (Becker, 1961b) and that it controlled not only growth and healing but also regulated the ability of the nerve cells of the brain to generate and transmit a nerve impulse (Becker, 1965).

Because such semiconducting electrical currents would be sensitive to low-strength magnetic fields, Brown and I collaborated and theorized that the internal control system of all present-day living organisms is a dual system. One portion is the primitive DC electrical system that transmits information in an analog fashion by means of electrical currents and magnetic fields. The other is the much more complex nerve impulse system that transmits information in a digital fashion. The analog system is involved with relating the organism to external electromagnetic fields and controlling the basic functions of growth, healing, and biological cyclic behavior. The digital system provides all senses, and it controls movement and other motor functions.

Interest in bioelectromagnetics grew and expanded significantly when it was demonstrated that human bone fractures that had failed to heal could be stimulated to do so by the application of a small DC electrical current (Friedenberg, Harlow, & Brighton, 1971). Later, it was shown that the same result could be obtained by the application of a low-strength, slowly pulsing EM field (Bassett, Pawluk, & Pilla, 1973). While a valid mechanism of action at the cellular level was never really demonstrated, these applications were accepted by clinical medicine, and eventually their use became widespread. This, in turn, led to further experimentation on the effects of EM fields on living organisms. Despite the fact that physicists and engineers insisted that this was all nonsense, biologists continued to produce evidence for a wide variety of bioeffects from DC currents and EM fields, all with strengths far below those required for shock or heating effects (Adey & Bawin, 1979).

Work in bioelectromagnetics was stimulated even more when evidence was obtained indicating that exposure to artificially generated EM fields could have serious health consequences. In the early 1970s, the U.S. Navy proposed building an enormous antenna system in mid-continent to communicate with submerged submarines anywhere on the globe, using frequencies just above and below the electrical power frequency of 60 cycles per second (60 Hz). These frequencies, which are within the extra low frequency (ELF) region of the EM spectrum, were chosen because of their ability to propagate through the earth and oceans. This proposal resulted in

a public outcry over its possible bioeffects, and the Navy was forced to fund an ambitious research program to "prove" its safety. The results were totally unexpected. The oscillating fields, with a strength below that of the average high voltage electrical power transmission line, had substantial impact on the blood chemistry of human subjects (Ad Hoc Committee, 1973). The significance of this observation was not only in the potential hazards it revealed but also in the fact that the strength of this ELF field was many orders of magnitude below the thermal (heat-producing) level. If the effect was real, it not only required a complete rethinking of the established "thermal effects only" paradigm, but it cast serious doubt on the safety of our entire electrical power system. The controversy finally resulted in a major 5-year research program conducted by the New York State Department of Health on the safety of the electrical power system. The final report, issued in 1987, confirmed the Navy's observations and extended them to include effects on embryonic growth, cell division, the incidence of cancer, and the behavior and functioning of the central nervous system ("Biological Effects of Power Line Fields," 1987). The health effects of our unrestricted use of artificial electromagnetic fields now appear well on the way to becoming the environmental problem of the next decade (Becker, 1990; Becker & Selden, 1985; Brodeur, 1989; Marino, 1988; O'Conner & Lovely, 1988).

During the last 20 years, a major advancement was made in the ability to detect and measure extremely low-strength magnetic fields. The discovery of the SQUID (superconducting quantum interference detector) magnetometer revealed that, in addition to the EEG, the brain also produces a magnetic field measurable in space around the head, now called the magnetoencephalogram, or MEG (Cohen, 1968, 1975; Morris, 1989; Romani, Williamson, & Kaufman, 1982). The production of such a magnetic field requires that actual electrical currents be flowing within the brain, confirming the initial reports of Gerard & Libet (1940). Thus, to a certain extent, the functional state of the brain is represented in the external magnetic field surrounding the head. However, the strength of the MEG is far too low for it to serve as a vehicle for extrasensory communication. The SQUID magnetometer is also capable of detecting the presence of submicroscopic deposits of magnetic mineral, and it has revealed that a very wide range of living organisms, from bacteria to humans, have a specific deposit of such material associated with the brain (Baker, 1988; Blake-more, 1975; Kalmijn, 1988; Walker, 1984). This is now termed the *magnetic organ*, and it has been shown to be able to detect the strength and direction of the earth's magnetic field and to serve as a navigational system in animal migratory behavior. The widespread occurrence of the magnetic organ over such a diverse range of living animals would seem to indicate that it is an evolutionarily ancient structure.

All of this work led to a reevaluation of Brown's research on the relationship between biological cycles and the same cyclic pattern in the strength of the earth's magnetic field. This resulted in the discovery that

the pineal gland (a small structure buried deep in the brain that is the remnant of the "third eye") is another organ that is capable of detecting the tidal variations in strength of the geomagnetic field (Semm, 1988; Semm, Schneider, & Vollrath, 1980). These variations, in turn, regulate the output of a large number of neuroactive substances, such as melatonin, by the pineal gland (Preslock, 1984). The level of melatonin produced by the pineal is directly related to the level of excitability of the brain, resulting in the sleep-wakefulness cycle and probably most of the remainder of biocyclic phenomena. Normal cycles of alternate rest and activity are an absolute requirement for living organisms, and alterations in the normal cycle have been associated with physiological stress and neurobehavioral dysfunction (Preslock, 1984; Wilson & Anderson, 1990). Brown's (1963) observations were thus validated.

These scientific discoveries of the past three decades have gradually resulted in a new paradigm of the nature of life. Living things now may be viewed as basically electromagnetic in nature, possessing an internal, organized, analog-type DC electrical system that regulates the basic functions of growth and healing, provides the basic operational level for brain activity, and produces magnetic fields of a specific nature that are detectable outside the body. The operations of this electrical control system are regulated in part by the magnetic organ and the pineal gland, which detect the status of the geomagnetic field and directly relate the organism to its electromagnetic environment. In this fashion, all living things are intimately tied to the natural geomagnetic fields of the earth. This paradigm, however, does not replace the nerve-impulse digital communication system. Rather, it supplements it with a more basic operational system.

Although the validity of these observations is now becoming accepted, the exact mechanisms by which electromagnetic fields and electrical currents of miniscule strength operate at the cellular level are not known. However, in recent years, a number of theories for the mechanism of action have been proposed that are capable of obviating the thermal "signal to noise" problem by concentrating the small amount of energy in the field on specific structures rather than total body mass (Blackman, Benane, Rabinowitz, House, & Joines, 1985; Liboff, 1985; Weaver & Astumian, 1990). This subtle relationship between living organisms and electromagnetic energies is a revolutionary concept that has expanded our understanding of the capabilities of living organisms, with far-reaching implications.

APPLICATION OF BIOELECTROMAGNETICS TO PSI PHENOMENA

The intimate relationship between the earth's geomagnetic field and living organisms stimulated a reevaluation of the relationship between electromagnetic fields and psi phenomena. Several resulting studies were first reported at the 94th annual meeting of the American Psychological Association meeting in 1986 in Washington, D.C. by four individuals

representing four different laboratories.³ Each group reported a statistically significant relationship between the status of the geomagnetic field and various ESP phenomena such as remote viewing and dream ESP content. When the geomagnetic field was quiescent, such events were far more likely to occur than when the field was disturbed by magnetic storm conditions. These correlational studies indicate that all prior experimentation in ESP most likely contained a hidden variable, the status of the earth's geomagnetic field. This may well account for the lack of reproducibility that plagues psi research.

Three conclusions of great importance can be drawn from these studies. First, they support the scientific validity of ESP phenomena. Second, they indicate that this class of psi phenomena is directly related to electromagnetic forces in some fashion. Finally, by showing that one can introduce information directly into consciousness without involving sensory inputs, these studies have important implications for our understanding of the mind/brain relationship.

Although a strong link has been established between psi phenomena and electromagnetic forces, the nature of the link remains unknown. Using radio communication technology as a model, ESP must consist of a transmitter, a signal that extends across distance, and a receiver. At this time we can only speculate as to which of these elements is adversely influenced by geomagnetic storms. However, radio technology can serve only as the broadest frame of reference in this regard. Although it is now evident that brain function results in the production of an external magnetic field, the MEG, the strength of this field is totally insufficient to serve as a transmitted signal over any distance. The extremely faint MEG signal is lost in the general electromagnetic background radiation, both natural and artificial, unless SQUID technology is used. Even if one postulates a receiving capability in the human brain akin to that of the SQUID, transmissions would be limited to a few feet at best. It is therefore necessary to postulate some as yet undiscovered property of magnetic fields accompanied by a biological capability to utilize this property for both transmission and reception of the informational signal.

Nonetheless, the findings of these electromagnetism/ESP studies cannot be dismissed simply because they do not conform to the present scientific paradigm. It appears that an electromagnetic signal of some sort is generated, transmitted over distances, and received directly at the level of human consciousness by an electromagnetic mechanism the exact nature of which is presently unknown.

However, the data provide a singularly significant insight into the nature of consciousness. It is well known that magnetic fields, even those of great

³ The individual researchers and their institutional affiliations were as follows: Marsha H. Adams, Time Research Institute; Erlundur Haraldsson, University of Iceland; Stanley Krippner, Saybrook Institute; and Michael A. Persinger, Laurentian University.

strength, have little or no effect upon nerve impulses. Therefore, if consciousness is solely the province of the nervous system, such a magnetic signal could not be received at the conscious level. However, recent evidence indicates that this is exactly what happens. Therefore, regardless of the mechanism involved, such signals must be received by the primitive analog system, and we may reasonably postulate that this system has a control or integrating center where such signals are received. This indicates the possibility that consciousness, rather than being the sole province of the nerve impulse system, may reside in the primitive electromagnetic data transmission and control system. The concept of the dual nervous system may therefore provide us with explanations for some forms of psi phenomena and also with insight into the very basic questions raised by the mind/brain relationship.

THE MIND/BRAIN RELATIONSHIP AND BIOELECTROMAGNETICS

To explore the concept of the dual nervous system theoretically, we must go back to the Precambrian era in the history of the earth, when the first signs of life appeared, and ask what was the nature of the communication system present in the existing organisms. Classical neurophysiology assumes that such a communication system was based on cells with the ability to generate, transmit, and receive action potentials, cells essentially equivalent to present-day neurons. This would require such a degree of sophistication and specialization appearing *de novo* as to be highly unlikely. Yet the most primitive organisms must have possessed the most basic attributes of life, such as the ability for self-repair and the alternating biological cycles of rest and activity. An analog type of control system based upon electron flow in a semiconducting matrix and the transmission of information by variations in the DC electrical current flow is, however, not inconceivable. Such a system would not depend upon a high degree of sophistication and could actually reside in the structure of the original "living" material itself. It would be capable of sensing injury, directing self-repair, and sensing the cyclic patterns in the geomagnetic field. Furthermore, the electrical current flow within the organism would produce an external magnetic field of very low strength that would reflect the operations of the internal analog system.

This concept of the basic elements of living material is compatible with the "dry state" biogenesis theory in which quasi-crystalline, self-organizing structures with semiconducting abilities formed on dry materials (Hinton & Blum, 1968). Due to the sun being some two billion years younger and to the specific composition of the earth's atmosphere then existing, the environment of the Precambrian period would have been characterized by much stronger fluctuations and disturbances in the geomagnetic field than is the case today. Despite its energetic nature, the geomagnetic field still would have reflected the rotational period of the earth and provided the one quasi-static element of the environment re-

quired for the timing of biological cycles. The geomagnetic field, therefore, would have constituted the most important environmental factor for these organisms, and its high energy content and strong oscillations at the 8-to-12 Hz Schumann frequency may have left their imprint on the operating control system. In this light, it is interesting to consider that those animals existing today that have well-developed electrosensing ability are maximally sensitive to the same range of frequency (Kalmijn, 1988). It has been proposed that the common ancestor of all vertebrates was electrosensitive (Bodznick & Northcutt, 1981). It is not currently known if the Precambrian organisms possessed collections of magnetite akin to the present-day magnetic organ. However, the evidence indicating its evolutionarily ancient status appears to make this likely. Therefore, this slightly higher degree of sophistication in magnetic field detection could have added to the innate ability of the semiconducting system.

What I have described is an organism capable of the most basic life processes, possessing an internal DC electronic control system, and directly tied to the geomagnetic field. It is reasonable to postulate that with further evolutionary development and the acquisition of multicellularity, this system would have been organized on the basis of specific cells, either as a syncytium or as single cells with intervening tight junctions, both of which would be capable of transmitting DC electrical currents. Anatomically, one would expect there to be a central mass of cells for integration of data. This mass would constitute a rudimentary "brain," which operates on the basis of the magnetic encoding of information with inflow tracts for sensing of damage and outflow tracts for repair signals. The magnetic organ would have had the same intimate relationship to this "brain" as it does today. Communications between organisms would have been possible on the basis of the generation and reception of electromagnetic fields, even in the absence of the special senses that now dominate human communication inputs. This rudimentary communication system operating on the basis of magnetically encoded information would have been located in the precursors of the present-day perineural cell system.

With evolutionary development, this analog system could have given rise to the more complex digital system with the acquisition of the special senses and effective motor control that then permitted the explosion of life forms that characterized the early Cambrian period (Morris, 1989). The primitive analog system, however, was not discarded but was retained in the perineural cell system as the basic substratum for all internal control and communications and the primary system relating all living organisms to the external electromagnetic fields of the environment. There is some evidence that glial cells are the precursors of neurons and that they are capable of information transfer processes (Cornell-Bell, Finkbeiner, Cooper, & Smith, 1990). More recently, Balaban and his colleagues have reported specific functional changes in neurons resulting from exposure to steady-state magnetic fields (Balaban, Bravarenko, & Kuznetsov, 1990). Most importantly for this thesis, they demonstrated that this effect is me-

diated by the glial cells surrounding the neurons; removal of the glial cells causes the disappearance of the functional changes.

Somewhere in the evolutionary process what we call consciousness appeared. If consciousness is defined as an awareness of the internal and external environment and the ability to respond to changes in these parameters, then consciousness was present in the "magnetic brain" of the earliest organisms. The development of the special senses required that somewhere and somehow the information they carried had to be inserted into this "electromagnetic consciousness" as magnetic information. This concept is supported by some recent studies that have shown that in the auditory system at least, incoming messages in the digital system are converted into specific magnetic fields deep within the auditory cortex of the brain (Hari, Aittoniemi, Järvinen, Katila, & Varpula, 1980; Papanicolaou, Baumann, Rogers, Saydjari, Amparo, & Eisenberg, 1990). It may therefore be feasible to postulate that all special sensory inputs enter consciousness in the same fashion. The flood of information from these sources is so great that it appears to relegate the more primitive direct messages to the analog system to the lowest level of consciousness. Hence, we presently attribute all consciousness solely to the digital neural system. However, this new paradigm of the dual communication and control system provides a new frame of reference for the mind/brain relationship.

I believe that all of the data I have discussed indicate that consciousness probably resides in the primitive analog magnetic system and that there are two distinct "sensory" inputs to consciousness. The first consists of the electromagnetic sensory system, which directly enters the magnetic consciousness with magnetically encoded external information. The second is the digital neuronal inputs from the sensory nerves and organs of the special senses, which are converted into appropriate magnetic fields within the structure of the brain. It appears feasible also to postulate that the state we call "consciousness" is not only located in the electromagnetic portion of the brain, but that it is "delocalized," that is, present throughout the entire perineural portion of the brain and not localized to discrete structures or areas such as the various "centers" of the digital neuronal system. This requires that some mechanism for integrating this information be present throughout the entire structure. One such mechanism would be a "scanning" signal common to all parts of the "magnetic brain." Theoretically, the frequency of this signal should reflect the major frequency range thought to have been present in the geomagnetic field at the time of the origin of life, 8 to 10 Hz. It is interesting to consider that this is exactly the frequency range known as *alpha*, which is revealed when the eyes are closed. However, this does not necessarily exclude other frequencies such as *theta* (4 to 7 Hz), which is dominant during periods of total sensory deprivation. In any event, it is possible to postulate that information is encoded at even higher frequencies on the basic "scanning" frequency. Recent reports (Gray, König, Engel, & Singer, 1989) indicate the presence of slightly higher scanning frequencies of about 40 Hz in the visual cortex.

Gray, König, Engel, and Singer (1989) suggest that this frequency may be involved in integrating the multitude of individual visual signals from the retina into the perception of the total object.

The present evidence suggests that psi and parapsychological information may be encoded in the universal magnetic field arising from the environment and other living organisms, and it may enter consciousness directly when the inflow of information from the digital system is reduced and the geomagnetic field is quiescent. This concept not only accommodates the existence of such phenomena but also provides a mechanism by which they may be studied in a scientific manner. It also raises a number of interesting questions and indicates directions for further research in neurophysiology and basic physics that may greatly increase our comprehension of the nature of life and its place in the universe.

SPECIFIC QUESTIONS AND SUGGESTIONS FOR FURTHER RESEARCH

First, let us consider the possibility of other presently unknown properties or phenomena associated with magnetic fields that may account for the long-distance communication involved in ESP and similar occurrences. A major problem with science has been its tendency to believe at any given time, the present not excepted, that everything is known and nothing of significance remains to be learned. The defect in this mindset is easily revealed by the history of the development of the present knowledge of electromagnetics.

The north-pointing magnetic compass was undoubtedly known to many peoples in prehistory. Lacking knowledge of the earth's magnetic field, it was attributed to such things as rays emanating from the North Star. The fact that the earth was a giant magnet and that electricity and magnetism were two different forces was first described by William Gilbert, physician to Queen Elizabeth I, in his book *The Magnet*, which was published in 1600. In Gilbert's time, the only kind of electricity known was static electricity generated by friction in certain materials that could cause a spark.

In 1791, almost 200 years after Gilbert, another physician, Luigi Galvani, described a new type of electricity that was a continuously flowing, or direct current, generated by living organisms. Shortly thereafter, Alessandro Volta discovered that two dissimilar metals in a conducting solution also generated direct current. This discovery led to the invention of the storage battery and later to the explosion of electrical technology.

Fifteen years later, Hans Christian Oersted accidentally made the completely unexpected discovery that when an electrical current flows in a wire, a magnetic field is produced in space around the wire. In 1845, Michael Faraday proposed that these magnetic fields carried energy and were related to visible light. In 1864, James Clerk Maxwell published his equations indicating that an entire spectrum of electromagnetic waves could be produced, extending in frequency from zero oscillations per sec-

ond to frequencies in the billions of oscillations per second, simply by varying the electrical current flow at the desired frequency. Twenty years later, Heinrich Hertz proved that Maxwell was correct by producing "Hertzian" waves from a spark gap and detecting them at a distance by causing a spark to jump across another gap many feet away. Less than 20 years later, Marconi used the same technique to transmit the letter "S" across the Atlantic Ocean.

None of these discoveries could have been predicted in advance, and each expanded our knowledge in totally unexpected ways. Are there no further discoveries still to be made in electromagnetism? Certainly there are. Although we know how to generate, transmit, and detect electromagnetic fields and even how to encode information on them with a variety of techniques, we still do not know the real nature of these fields. It is quite possible that, as in Galvani's case, new and unexpected physical knowledge can come from scientific studies of the relationships between the magnetic consciousness and electromagnetism. We simply need the courage to look.

The broader implications of this concept of a link between magnetic fields and living things reveals other significant possibilities. It is now known that even from a physical point of view, the geomagnetic field is a strange and complex beast. For example, many times in the geological past the earth's field has reversed itself, the North and South poles changing places. These "magnetic reversals" have been related to the simultaneous extinctions of many species of animals of the time—the "great dyings" of the highest developed types of life, which may have determined the course of evolution (Watkins & Goodell, 1967). The factors that caused these mysterious reversals and the other alterations in the normal magnetic field that were associated with them are simply unknown. In addition, there is theoretical evidence suggesting that the unique electromagnetic environment at the time of the origin of life may have played an energetic role in that very event (Cole & Graf, 1974). Even today, there is evidence that naturally occurring perturbations in the geomagnetic field have important biological effects. The sun is subjected to cyclic variations in its activity, the solar cycle, which peaks every 11 years. Magnetic storms occur with greater frequency during the peak periods than during the quiet periods. Some years ago, my colleagues and I found a statistically significant relationship between magnetic storms and abnormal human behavior (Friedman, Becker, & Bachman, 1963, 1965). Most recently, Hoyle and Wickramasinghe (1990) reported that influenza pandemics caused by genetic shifts in the influenza virus are temporally related to the peaks in the solar cycle over the past century. Although Hoyle and Wickramasinghe (1990) attribute the correlation to another theoretical mechanism, the evidence linking magnetic fields and genetic alterations makes that a more likely one (see Goodman & Henderson, 1988). The possibility that even today the magnetic field within which we exist plays an important role in our health

and destiny is a perfectly testable theory and easily subject to scientific inquiry.

The linkage between consciousness and the geomagnetic field is not a simple one. What we call the geomagnetic field is not just what is produced by the magnetic core of the earth, but it is that field as it is perturbed by such local factors as energetic events occurring on the sun, the solar cycle, and even the position of the moon in relationship to the spatial relationship between the earth and the sun. The magnetic field of the solar system is, in turn, influenced by the magnetic field of the galaxy, which is part of the total field continuum of the universe. Cosmology is at present as much a theoretical science as is quantum physics. We know that the universe is awash in gravitational and magnetic fields, yet we cannot account for more than half of the matter that should be present in "empty" space. More and more evidence suggests that the organization of the universe is nonrandom, and perfectly respectable theories have proposed that the energy of this organization is magnetic (Lerner, 1988; Peratt, 1990). Even without postulating some undiscovered aspect of magnetic fields, all living things on earth are influenced to some extent by the magnetic structure of the universe. Although these concepts are speculative at present, they can also be subjected to scientific examination, the results of which might have profound implications for the nature of life, its origins, and humanity's place in the universe.

Many different techniques, such as meditation, yoga, and primitive rituals claim to provide access to some "other reality" that is not accessed by our five senses. Most of these techniques involve reducing the digital special sensory input, which may make possible the conscious reception of magnetic system inputs that would otherwise be obscured by the flood of information from the special senses. Our concept of "reality" is presently limited to the information provided by our digital special senses. It is possible that our magnetic sense provides our consciousness access to the information encoded in the universal magnetic field, and is this the speculative "other reality"? In any event, in this fashion one may be able to explain the mechanism involved in gaining access to this magnetic consciousness as well as the nature of the "sensations" that are received in these exceptional states. At present, no objective method has been employed to determine if the practitioner of such techniques is actually more sensitive to magnetic field inputs. However, such a study would not be difficult to perform and might yield very valuable information. Apparently not all individuals who try these techniques experience the same result. There is some evidence that electrically "driving" the "brain waves" at the theta frequency of 3 to 6 Hz assists in the depression of sensory input and possibly in a greater receptivity to ESP phenomena (E. Green, personal communication, 1990). This may be significant in that it might reveal something about the operating mechanism involved in magnetic consciousness. Again, scientific exploration of these possibilities would

yield information of basic importance to our knowledge of psi phenomena and brain mechanisms in general.

Finally, although this concept provides a new frame of reference for viewing the operations of the brain that is experimentally verifiable, such experimentation carries with it more than a modicum of danger. Knowledge of the operating magnetic frequencies and the mechanisms of encoding information on them would enable those who possessed the knowledge to insert information directly into the consciousness of others without their being aware of it. The "psychocivilized society" envisaged by Delgado (1969) then would be possible, and the likelihood of misuse of this ability would be great. It is an open secret that military and intelligence services of a number of governments have been investigating parapsychological phenomena for the past 20 years. The results of these studies have, for the most part, not been made public, and neither science nor the public has any idea of the knowledge gained thus far. It is my firm belief that this type of study, more so than any other scientific investigation, must be conducted in a completely open fashion with full and continuous disclosure and under the control of parties not connected to agencies capable of misusing the information. We are on the verge of profoundly important discoveries, possibly the most important that we have ever obtained; this is simply too important to be left to agencies that would suppress or misuse the findings.

REFERENCES

- AD HOC COMMITTEE. (1973). Review of Biomedical and Ecological Effects of ELF Radiation. *Proceedings*. Washington, DC: U.S. Navy, Bureau of Medicine and Surgery.
- ADEY, W. R., & BAWIN, S. M. (1979). Brain interactions with weak electromagnetic fields. *Neurosciences Research Program Bulletin*, 15, 1-129.
- ALADZHALOVA, N. A., & KASHTOIAN, C. K. (1960). Ultra-slow rhythmic potentials in isolated strip of cortex. *Fiziologicheskii Zhurnal SSSR*, 46, 1-8.
- BAKER, R. R. (1988). Human magnetoreception for navigation. In M. E. O'Conner and R. H. Lovely (Eds.), *Electromagnetic Fields and Neurobehavioral Functions* (pp. 63-80). New York: Wiley.
- BALABAN, P. M., BRAVARENKO, N. I., & KUZNETZOV, A. N. (1990). Influence of stationary magnetic field on bioelectric properties of snail neurones. *Bioelectromagnetics*, 11, 13-25.
- BASSETT, C. A. L., PAWLUK, R. J., & PILLAI, A. A. (1973). Augmentation of bone repair by inductively coupled electromagnetic fields. *Science*, 184, 575-577.
- BECKER, R. O. (1961a). Bioelectric factors in amphibian limb regeneration. *Journal of Bone and Joint Surgery*, 43-A, 643-656.
- BECKER, R. O. (1961b). Search for evidence of axial current flow in peripheral nerves of salamander. *Science*, 134, 101-102.

- BECKER, R. O. (1965). The neural semiconduction control system and its interaction with applied electrical currents and magnetic fields. *Proceedings of the XI International Congress of Radiology, Rome, 1965*, 1753-1759 (Excerpta Medica International Congress Series, # 105).
- BECKER, R. O. (1972, December). Electromagnetic forces and life processes. *Technology Review (MIT)*, 75, 32-38.
- BECKER, R. O. (1974). The basic biological data transmission and control system influenced by electrical forces. *New York Academy of Sciences, Annals*, 236, 236-241.
- BECKER, R. O. (1990). *Cross Currents: The Promise of Electromedicine, the Perils of Electropollution*. Los Angeles, CA: Jeremy Tarcher.
- BECKER, R. O., & SELDEN, G. (1985). *The Body Electric: Electromagnetism and the Foundation of Life*. New York: William Morrow.
- BENDER, H. (1963). Hans Berger und die energetische Theorie der Telepathie [Hans Berger and an energetic theory of telepathy]. *Zeitschrift für Parapsychologie und Grenzgebiete der Psychologie*, 6, 182-191.
- BERGER, H. (1940). *Psyche*. Jena, Germany: Gustav Fischer.
- BERGER, H. (1987). *Biological Effects of Power Line Fields*. Albany, NY: New York State Department of Health.
- BLACKMAN, C. F., BENANE, S. G., RABINOWITZ, J. R., HOUSE, D. E., & JOINES, W. T. (1985). A role for the magnetic field in the radiation induced efflux of calcium ions from brain tissue in vitro. *Bioelectromagnetics*, 6, 327-337.
- BLAKEMORE, R. (1975). Magnetotactic bacteria. *Science*, 190, 377-379.
- BODZNICK, D., & NORTHCUTT, R. G. (1981). Electoreception in lampreys: Evidence that the earliest vertebrates were electoreceptive. *Science*, 212, 465.
- BRODEUR, P. (1989). *Currents of Death: Power Lines, Computer Terminals and the Attempt to Cover Up Their Threat to Your Health*. New York: Simon & Schuster.
- BROWN, F. (1963). How animals respond to magnetism. *Discovery*, 24, 18-22.
- CASPERS, H. (1961). The cortical DC potential and its relation with the EEG. *Electroencephalography and Clinical Neurophysiology*, 13, 651.
- COHEN, D. (1968). Magnetoencephalography: Evidence of magnetic fields produced by alpha rhythm currents. *Science*, 161, 784-786.
- COHEN, D. (1975). Magnetic fields of the human body. *Physics Today*, 28, 34-43.
- COLE, F. E., & GRAF, E. R. (1974). Pre-Cambrian ELT and abiogenesis. In M. A. Persinger (Ed.), *ELF and VLF Electromagnetic Field Effects* (pp. 243-274). New York: Plenum Press.
- CORNELL-BELL, A. F., FINKBEINER, S. M., COOPER, M. S., & SMITH, S. J. (1990). Glutamate induces calcium waves in cultured astrocytes: Long range glial signaling. *Science*, 247, 470-473.
- DELGADO, J. M. R. (1969). *Physical Control of the Mind: Toward a Psychocivilized Society*. New York: Harper & Row.

- FRIEDENBERG, Z. B., HARLOW, M. C., & BRIGHTON, C. T. (1971). Healing of non-union of the medial malleolus by means of direct current: A case report. *Journal of Trauma*, 11, 883-885.
- FRIEDMAN, H., BECKER, R. O., & BACHMAN, C. H. (1963). Geomagnetic parameters and psychiatric hospital admissions. *Nature*, 200, 626-628.
- FRIEDMAN, H., BECKER, R. O., & BACHMAN, C. H. (1965). Psychiatric ward behavior and geomagnetic parameters. *Nature*, 205, 1050.
- GERARD, R. W., & LIBET, B. (1940). The control of normal and "convulsive" brain potentials. *American Journal of Psychiatry*, 96, 1125-1152.
- GOLDRING, S., & O'LEARY, J. L. (1954). Correlation between steady transcortical potential and evoked response. *Electroencephalography and Clinical Neurophysiology*, 6, 164-200.
- GOODMAN, R., & HENDERSON, A. S. (1988). Exposure of salivary gland cells to low-frequency electromagnetic fields alters polypeptide synthesis. *National Academy of Science. Proceedings. USA*, 85, 3928-3932.
- GRAY, C. M., KONIG, P., ENGEL, A. K., & SINGER, W. (1989). Oscillatory repose in cat visual cortex exhibit inter-columnar synchronitization which reflects global stimulus properties. *Nature*, 338, 334.
- HARI, R., AITTONIEMI, K., JARYINEN, M. L., KATILA, T., & VARPULA, T. (1980). Auditory evoked transient and sustained magnetic fields of the human brain. *Experimental Brain Research*, 40, 237-240.
- HINTON, H. E., & BLUM, M. S. (1968). Reversible suspension of metabolism and origin of life. *Proceedings of the Royal Society*, 171, 43-57.
- HOYLE, F., & WICKRAMASINGHE, N. C. (1990). Sunspots and influenza. *Nature*, 343, 304.
- KALMUN, A. J. (1988). Electromagnetic orientation: A relativistic approach. In M. E. O'Connor and R. H. Lovely (Eds.), *Electromagnetic Fields and Neurobehavioral Functions* (pp. 23-45). New York: Wiley.
- LERNER, E. J. (1988, June). The big bang never happened. *Discover*, 9, 70-79.
- LIBOFF, A. R. (1985). Cyclotron resonance in membrane transport. In A. Chiabrera, C. Nicolini, and H. P. Schwann (Eds.), *Interactions Between Electromagnetic Fields and Cells* (pp. 281-296). London: Plenum Press.
- MARINO, A. A. (Ed.). (1988). *Modern Bioelectricity*. New York: Dekker.
- MORRIS, S. C. (1989). Burgess shale faunas and the cambrian explosion. *Science*, 246, 339.
- O'CONNER, M. E., & LOVELY, R. H. (Eds.). (1988). *Electromagnetic Fields and Neurobehavioral Functions*. New York: Wiley.
- O'LEARY, J. L., & GOLDRING, S. (1964). DC potentials of the brain. *Physiological Review*, 44, 91-125.
- PAPANICOLAOU, A. G., BAUMANN, S., ROGERS, R. L., SAYDIARI, C., AMPARO, E. G., & EISENBERG, H. M. (1990). Localization of auditory response sources using magnetoencephalography and magnetic resonance imaging. *Archives of Neurology*, 47, 33-37.

- PERATT, A. L. (1990). Not with a bang: The universe may have evolved from a vast sea of plasma. *The Sciences*, 30, 24-32.
- PRESLOCK, J. P. (1984). The pineal gland: Basic implications and clinical correlations. *Endocrine Review*, 5, 282-308.
- ROMANI, G. L., WILLIAMSON, S. J., & KAUFMAN, L. (1982). Tonotopic organization of the human auditory cortex. *Science*, 216, 1339-1340.
- SEMM, P. (1988). The magnetic detection system of the pigeon: Involvement of pineal and retinal photoreceptors and the vestibular system. In M. E. O'Connor & R. H. Lovely (Eds.), *Electromagnetic Fields and Neurobehavioral Functions* (pp. 47-61). New York: Wiley.
- SEMM, P., SCHNEIDER, T., & VOLLRATH, L. (1980). Effects of an earth-strength magnetic field on electrical activity of pineal cells. *Nature*, 288, 607-608.
- VASILIEV, L. L. (1963). *Experiments in Mental Suggestion*. Church Crookham, Hampshire, England: Institute for the Study of Mental Images.
- WALKER, M. A. (1984). A candidate magnetic sense organ in the yellowfin tuna, *Thunnus albacares*. *Science*, 224, 751-753.
- WATKINS, N. D., & GOODELL, H. G. (1967). Geomagnetic polarity change and faunal extinction in the southern ocean. *Science*, 156, 1083-1087.
- WEAVER, J. C., & ASTUMIAN, R. D. (1990). The response of living cells to very weak electric fields: The thermal noise limit. *Science*, 247, 459-462.
- WILSON, B. W., & ANDERSON, L. E. (1990). ELF electromagnetic-field effects on the pineal gland. In B. W. Wilson, R. G. Stevens, & L. E. Anderson (Eds.), *Extremely Low Frequency Electromagnetic Fields: The Question of Cancer* (pp. 159-186). Columbus, OH: Battelle Press.
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