MAGNETOBIOLOGY AND POSSIBLE IMPLICATIONS FOR AWARENESS RESEARCH

by

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Magnetobiology refers to the effects of magnetic fields on living systems. The magnetic stimulus can be either static or alternating. In the case of the static stimulus, there are predominantly weak inhibitory effects on the organism, tissue, and cellular levels. Current research has found that electrophysical changes on the nervous system from a static field are primarily registered as deactivations. Of the brain structures, the diencephalon is the most sensitive to a static field, and it is hypothesized that the static field acts indirectly on the glial cells of the nervous system. The mechanism of magnetic field interactions with living matter is unknown, but several plausible theories of interference with key enzymatic reactions have been advanced. Psychologic changes from static fields have not been adequately studied. It remains an open question whether humans or other animals can perceive static magnetic fields; but there is sufficient evidence to conclude that a static field is not a suitable tool for the alteration of awareness. In the case of alternating fields, research has been very scant. Magneto-phosphenes (bright dots of light covering the entire visual field) are the only established reaction of humans to alternating fields. However, a careful investigation of previous work indicates that insufficient knowledge of experimental parameters
probably accounts for the negative findings. It is suggested that a suitable alternating field can produce a magnetic driving effect analogous to photic driving of brainwaves. Such a phenomenon would provide the basis for an excellent tool for awareness research when used in conjunction with brain-stimulus feedback techniques. Several experimental designs are suggested to determine the existence of a magnetic driving effect, and its possible properties.
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INTRODUCTION

A number of months ago out of curiosity, I placed a small 60 cycle electromagnet near my throat and moved it back and forth in a small elliptical orbit. I closed my eyes and relaxed my mind. Much to my surprise I soon heard and felt a clicking sound, like a record stuck in a groove, somewhere in the back of my throat. I continued to move the magnet around, and was soon aware of a subtle change in my being, an elusive stillness that was subjectively similar to some of the experiences of meditation I had had. After five or six minutes, I turned off the magnet, and lay back, closing my eyes. I felt magnetised! A high frequency buzzing sound continued to ring in my ears and I felt very calm and still, but not at all sleepy. The sound went away after eight or nine minutes and I felt much as I had before I turned on the magnet.

I obtained a few other such small electromagnets (tape-head demagnetisers) with different field intensities and shapes. The smallest was about a hundred oersteds with a 2mm gap and the largest about three-hundred oersteds with a plate over the poles to produce a very diffuse field area. In the next few months, I put everyone I knew under the magnet, with varying positions of
stimulation, times of exposure, and movements of the magnet. It was variously placed on the top of the head, between the eyes, on the left and right temples, at the base of the neck and spine, and over the heart. The exposure was usually about a minute and a half per position, but varied between 30 seconds and about four minutes. At times the magnet was held stationary over a position; at others it was held stationary, but the current was switched on and off as rapidly as was possible with a simple push button; and at still others the magnet was oscillated, either slowly or rapidly in a rough ellipse around the point of stimulation. Very soon, I devised the procedure of blindfolding the subjects and using a small clock, (which produced the same sound as the magnet, but had no appreciable magnetic field) instead of the magnet on one out of three passes. Each pass had several positions of stimulation and lasted about ten minutes.

In the later work, when I began to keep records, there were fifteen "subjects" all of whom had some prior experience with awareness alteration. They were instructed to relax and put themselves in a state of meditation. Eleven reported definite changes in the state of their awareness due to the fields. The most vivid reports included: the perception of white waves of energy, tingling sensations in the frontal lobes, greatly reduced thought activity with no effort, feelings of calm and relaxation, and the sensation of currents running through their heads. All generally agreed that the experience was different and earth going region...
was pleasant and worth doing again. Nine of the subjects could distinguish clearly between the magnetic field and the "dummy" magnet, although they had not seen either of the instruments prior to exposure. Since the work was informal, with no accurate recording of data and no great uniformity in procedure from subject to subject, we can draw no conclusions, except perhaps, the subjects who reported positive effects, were very suggestible, or that they were of a real physiological effect of the field, most likely both. In any case, I considered it worthwhile to investigate the literature on the biological and physiological effects of the magnetic field.

When one thinks about the possible effects of an alternating magnetic field on the nervous system, it seems simple enough. The primary effect is not magnetic, but rather due to the induced electrical currents resulting from the repeated interruption of the magnetic field. Nerves have spikes, as well as smaller generator potentials travelling through them, and the effect might be some sort of interference with electrical activity in a whole area of the cortex. Unfortunately, there are dozens of unanswered questions and uncertainties left by our initial simplistic experiments and models. In the first place, it is quite difficult to influence nerve potential from an external source. Are we certain that there was any real effect of the induced currents? Might the reported results not simply have been artifacts of the imagination? We don't know, since there was no quantitative control over experimental parameters, and no objective measures of possible changes.
It is not obvious what physiologic changes to look for when dealing with such small fields and such subtle subjective or behavioral changes. It is not likely that any gross changes could be found in the urine or blood analysis; GSR, EKG, ENG, or EEG of a human subject, following exposure of ten to fifteen minutes. Current research has not dealt such measures following exposure to magnetic fields in humans. It is even possible that sitting in a chair with eyes covered, could account for the subjective changes in the particular subjects used, and that possible physiologic changes would reflect the experimental conditions, rather than effects of the magnets. There are even more basic questions we can ask. Was the field sufficiently strong to penetrate the scalp, skull, and layers of matter covering the brain to influence neural populations? Would the currents, if they did penetrate to nervous material, produce any non-random, orderly interference with electrical activity? Would they not simply raise the background noise of CNS? How would an induced current interact with an individual neuron? At the present time, only some of the answers are known. Further serious research is needed between the subjective effects and the known effects of magnetic fields on the CNS.

With this brief introduction, we have indirectly stated our purpose, which is to investigate the effects of magnetic fields on biologic systems, especially with the view of developing a new tool for awareness research. In the following chapters, we will concern ourselves with previous investigations
of magnetic interactions with living systems and the various
difficulties of both biomagnetic and awareness research. The
question of magnetic effects on living systems is once again
being actively investigated because of the possible use of
strong magnetic fields as radiation shields on future space-
craft, and the important part such effects play in many theor-
ies of animal guidance. Our discussion and suggested research
should provide important information for both these areas by
elucidating possible psychologic effects of alternating mag-
netic fields and determining whether a human subject can be
trained to consciously discriminate low order alternating
magnetic fields (Appendix A). But most important, we hope to
be able to decide after the experimental work is carried out;
whether alternating magnetic fields are suitable stimuli for
awareness research.

We might say a few words about awareness research. It
is an interdisciplinary branch of psychology that is fast
becoming a field of study in its own right. It draws upon
the findings of all branches of psychology, as well as the
subjective disciplines, such as yoga. It is absolutely neces-
sary in awareness research, that close contact be maintained
between subjective, behavioral, and physiologic data. Its
goals, ultimately are to explain, predict, and control the
subjective states of human awareness, including many of the
unusual ones that occur naturally in psychosis, as well as
those induced through the use of chemicals, and those achieved
by means of the practices of yoga. However, unlike current
physiologic research, it is not constrained by a primitive model of awareness, and recognizes that a sophisticated theoretical and practical knowledge of the various states of awareness is a necessary precursor to a study of the mind-body problem.

The sections to follow are divided into three groups: magnetobiology, awareness research, and practical proposals. The section on magnetobiology deals with the three trends of magnetic research on living systems: magnetotherapy, biomagnetism, and psychomagnetism. The use of magnetic fields to cure mental and physical illnesses, magnetotherapy, has a long and controversial history. The work of serious clinicians is mixed in with miracle cures by quacks, charlatans, and practitioners of the occult. It is a problem to separate the effects of magnetic fields from those due to suggestion. Psychomagnetism is a term coined in the U.S.S.R. by L.I. Vasilev. Its use reflects the difference between American and Russian research, the latter having accepted for a long time the possibility of psychological changes from exposure to magnetic fields; the former dwelling on physiological effects mostly in lower organisms and at the cellular and tissue levels. The acceptable research in this area consists of a total of three or four sets of experiments, since suitable techniques for human subjects have only recently emerged, and most researchers have previously been unwilling to deal with the complications of suggestion. The section on biomagnetism will establish the reality of some of the effects of magnetic fields on living
systems by showing that many of the previously reported findings were based on an incomplete understanding of the magnetic stimulus. It will also point to the neglect of alternating magnetic fields as a stimulus and discuss the substantial evidence of effects of static fields on the nervous system. Finally, a review will be made of current theories of the magnetic interaction with living systems.

In the second major section considered will be the young field of awareness research in the laboratory. Electroencephalographic studies of practitioners of the awareness disciplines will be discussed; and we shall seek to put together a tool for awareness research through an investigation of the phenomenon of photic driving, and the techniques of brain-stimulus feedback. Finally, we will discuss the subjective aspects associated with the conscious production of alpha-wave activity in experimental subjects.

In the final section, the two areas of magnetism and awareness research will be drawn together by a proposal for experimental research and a heuristic program that controls the brain-stimulus feedback.
Some of the first records, as early as 337-330 B.C., that mention the properties of natural lodestone record its use for curative and magical purposes. There are records from the temples of Hercules in which rituals for healing the sick were described that consisted of priests chanting incantations and waving Herculean and magnesian stones around various parts of the patient's body. Magnesian stones were also used in an unknown manner to determine when the deities had successfully been invoked in oracular sessions.

By the fourth century A.D., several well-known Romans were beginning to associate magnetic stones with the cure of nervous disorders. Theodore Pirscianus is the first to record consistent cures of headaches with applications of the loadstone to the painful area. Maruilus the Empric also used magnets at about the same time to treat stiff necks and backs. Thales, Aristotle, Anaxagoras of Clazomenae and the Greek sophist Hippias, associate the remarkable properties of magnets to attract other substances and cure various ailments to a soul embodied in all magnets. This soul is identified with the universal astral light drawn to the Earth from the pure celestial fires by the first inhabitants of the planet. Its ability to act on humans is a property of the natural attraction of souls and the continuity of the astral substance. In 450 A.D. Aetius (Amidenus) mentions
that "those who are troubled with the gout in their hands or in their feet, or with convulsions, find relief when they hold a magnet in their hand." In the seventh century L’Aegieta cryptically remarks that magnets can cure diseases because the hematite ore that composes them has special properties; the forerunner of the many later theories that postulated direct magnetic effects on the iron containing hemoglobin of the blood.

In 1200 Albert Magnus was the first to state that magnetic fields have the power of affecting the healthy as well as the sick. His experiments, as might be expected, would not stand up to critical twentieth century evaluation.

From 1490 to 1541 Parcelsus (Aureolus Theophrastus; pseudonym of Philppus Aureolus Theophrastus Bombast von Hoheim of Switzerland) exactlying studied the properties of magnetic lodestone, rediscovering many of its properties that were lost to scientific knowledge since the time of the Greeks and early Romans. He was one of the great chemists of his day, and in his well-known work, Archidoxorum, discussed many of the uses of the magnet in medicine. His studies laid the foundations for the discoveries of Electromagnetism by Oersted, and provided the insights and research for the entire school of animal-magnetism popularized by Mesmer some three centuries later. Of special interest to us was his work on the occult properties of the magnet, forming a historical continuation of the use of the bone of Horus (shaped pieces of lodestone) in the Theurgic mysteries to summon the gods and supernatural forces and persuade them to fulfill the wishes of man. Parcelsus was directly
responsible for the first great wave of popularity that magneto-therapy enjoyed during the Renaissance, providing the first recorded magnetic cures of nervous disorders including hysteria and epilepsy, as well as putting the earlier treatments of hemorrhages and fluxes on firm ground once again.\(^{13}\)

We quote a few extracts from Paracelsus cited by Mottelay and taken from the Hermetic writings of A.E. Waite in which is described a medicine made from the magnet:

The adamant. A black crystal called... is dissolved in the blood of a goat...
The magnet. Is an iron stone, and so attracts iron to itself. Fortified by experience... I affirm that the magnet... not only attracts steel and iron, but also has the same power over the matter of all diseases in the whole body of man.\(^{14}\)

We note the curious mixture of Greek notions of Spirit with the beginnings of a scientific approach to magnetic properties. In the following cryptic abstracts, we find this mixture as well as a possible statement about the dependence of magnetic effects on the functional state of the human subject.

The life of the magnet is the spirit of iron which can be taken away by rectified vinum ardens itself or by spirit of wine.\(^{15}\)

The pseudo-scientific confusion that forms the majority of Paracelsus' hypothesis are sufficiently unacceptable by modern standards, that we need say nothing more about them, except
perhaps that they form the historical setting upon which modern research began.

At about the same time, another trend in magnetotherapy, the curing of toothaches and diseases of the gums, was developed by Marcellus and Camilus Leonardus. Since then, repeated claims have been made along these lines, the most modern being the work of Hansen in Sweden in 1938 which we shall discuss later. Because of the clinical nature of the work (and since no one during these times thought of it), controls could not be made in the same subject, and since the effects are said to vary from subject to subject, all findings must be considered unsubstantiated. A few typical quotations should sum up the attitude towards magnetic effects on humans during the Early Period, 337 B.C. to 1600 A.D..

The magnet...gives comfort and grace, and is a cure for many complaints; it is of great value in disputes. When pulverised, it cures many burns. It is a remedy for dropsy... The magnet reconciles husbands to their wives. It is principally of use to the wounded. It is a remedy against spleen, the dropsy and alopecian.

During this Early Period, we see the emergence of distinct procedures of magnetotherapy from its beginnings in shamanistic rites and acts of divination. By 1600, magnetotherapy had branched to treat three distinct types of ailments: wounds and hemmorhages, for which it was reputed to have speeded healing and reduced pain; muscular and physiologic nervous disorders such as headaches and epilepsy; and quasi-physiologic nervous complaints such as headaches and hysteric, which have occupied...
such as backaches and epilepsy; and quasi-physiologic nervous complaints such as headaches and hysteria, which have occupied much of our attention since 1900 with questions of psychologic, rather than purely physiological causes.

In 1600 a new era in the science of magnetism and electricity began with the publication of Gilbert's *De Magnete*. Magnetism with its properties properly classified was now on firm scientific ground. *De Magnete* is divided into six books, the first of which describes the effects of lodestone on the human body. However, this section is merely an historical survey and adds nothing new to the biologic questions raised by previous medical use of the magnet.¹⁸

During the last third of the seventeenth century, magnetic cures of diseases suffered from neglect. It is one of the strange features of biomagnetic research that it comes in waves, alternately enjoying great popularity, and then being carelessly tossed aside and forgotten. This is probably so because the research seems very promising at the outset and is surrounded by the occult aura that always has, and still continues to some extent, to surround magnetism. It is also a subject in which earlier research can be "uncovered" after many years of seemingly unexplainable neglect. But serious research has inevitably become snared in questions of other artifacts, especially the spurious stimulus of suggestion, which might have been responsible for the reported results. In the late eighteenth century Franz Mesmer developed a course of treatment based upon suggestion alone. When the magnetic effects and
the artifacts can not be separated, serious research halts, unable to draw any conclusions, and the popularizers, magicians, quacks, and charlatans take over. This is a sorry state of affairs, but it was not possible to do anything about it until modern times, when sophisticated experimental procedures could weed out the artifacts, and modern techniques and equipment could settle the question of physiologic basis for magnetic interactions with living systems.

We can take advantage of this lull to discuss some of the theories of universal magnetism, which form the basis for the work of the Mesmer school (and even of ESP researchers today). Since Greek and Roman times, and all through the Middle Ages, one group whom we may refer to as the esotericists identified magnetic properties with souls, subtle ethers, and invisible radiances, all imperceptible to the external sense organs. The other group has its purest early representative in the figure of Gilbert, previously mentioned as being the Galileo of magnetism. We may refer to this group as the materialists. Of course, up until fairly recent times, at least well into the nineteenth century, most scientists of the materialist school, still retained some of the ideas of the esotericists. From 1660-1680 Athanasius Kircher, a German writer on physics and mathematics, expounded the distinction that should be made between mineral magnetism and zoomagnetism, or animal magnetism. He concurred with Gilbert's conclusions about the physical properties of iron and lodestone, but disagreed on the definition of a magnet. Gilbert had maintained the earth is a great
magnet; Kircher contradicted him, asserting that all particles of matter (as well as the unseen spiritual entities) have magnetic properties, but were not therefore to be considered magnets. He believed that there is only one magnet in the universe, called God, or the central Spiritual Sun, and that physical properties of all lodestone and iron magnets are special classes of effects of matter in general all manifested by the One Universal Magnet. Of course, part of the statement is in agreement with modern thought. The differences between mineral and animal magnetism, Kircher maintained, were from the Soul which has intimate contact with the Universal Magnet, and gives man the ability to consciously control his animal magnetism.

This finding was the cornerstone for Mesmer's work, and the "discovery" of hypnotism some eighty years later. It does not suggest the possible "conscious" control of sensitivity to a magnetic stimulus.

The discoveries of distinct electrical phenomena were taking attention away from magnetism, and it is not until the 1770's that interest was resumed. At that time, we encounter the tremendous confusion that can come when desire for personal fame interferes with scientific inquiry. In the great controversy that surrounded the career of Franz Mesmer, it is difficult to separate those seeking fame from those interested in legitimate discovery. The principal parties involved were Father Maximillian Hell, a Viennese astronomer and priest; Franz Anton Mesmer, the well-known publicizer of hypnotism, and Mr. Ingenhousze, member of the Royal Academy of London and experimenter with the use of electricity in medicine. In the public controversy, the distinction between genuine biodynamic effects and
with the uses of electricity in medicine. In the public contro-
versy, the distinction between genuine biomagnetic effects and 
results accomplished by way of suggestion was clearly demon-
strated for the first time. The issues raised are still relevant 
to our understanding of biologic effects of magnetic fields, and 
in some aspects continue to remain unanswered.

Mesmer, upon receiving his medical degree, undertook the 
investigation of magnetotherapy as a continuation of his diser-
tation entitled "The Influence of the Planets on the Human 
Body". His main contention was that just as the cosmological 
forces produce the tides and other natural phenomenon involving 
intensification and remission, so in the animal body, subject 
to the same forces, there are what we would call today "nat-
ural rythms". These rythms are controlled by way of an invis-
ible "substance" with properties analogous to light and mineral 
magnetism, which Mesmer called animal magnetism. 22 According 
to Mesmer's diary, he was looking for an artificial stimulus 
to simulate the natural ebb, flow, and equilibrium of the heav-
enly bodies upon the human being; when he heard about the use of magnetotherapy in Germany, France, and England. He approached 
a friend of his, Father Hell, to make a number of magnets of 
various shapes to try on a patient, whom we would probably 
characterize as psychoneurotic (she had convulsions, toothaches, 
and earaches, followed by delirium, rage, vomiting, and swoon-
ing). By application of three magnets, one to the pelvis, and 
one to each leg, for a number of hours, a cure was affected.

Father Hell, according to Mesmer and the majority of writers
on the area, subsequently went to the press claiming that his unusual shapes was the key to effecting the cures of nervous disorders by means of a magnet. Although the point and area of application is a probable important parameter in producing psychomagnetic effects, it is most likely that the initial cures effected by Hell (if indeed there were any) were effects of suggestion. As Mesmer discovered, the basis of the startling cures he managed to effect, were not magnetic but rather were produced by post-hypnotic suggestion.

The public controversy raged: Mesmer repeatedly producing cures without the use of the magnet, although he admitted it was a very good conductor of his animal magnetic influence, while Father Hell made use of his reputation as an astronomer and academician to denounce Mesmer as a fraud. Mesmer put on a demonstration with patients secured by others and even convinced the dubious Mr. Ingerhouse, who published a paper denying what he had seen, claiming his magnets and not Mesmer's principle had produced the cure. Events became more entangled with further demonstrations, refutations, investigations, and counter-refutations. Its value to us is entirely as a paradigm of professional rivalry. Mesmer's importance can not be denied; he could easily be spoken of as the father of modern psychotherapy. His importance as a biomagnetic researcher is in the sharp line he drew between the effects of suggestion (animal magnetism) and those of the magnet. He says:

I have always stressed in my writings that the use of the magnet, however
convenient, was always imperfect without the assistance of the theory of animal magnetism... The physicians... have taken upon themselves to spread about either that the magnet was the only means I employed or else that I used electricity as well... Most of them have been undeceived by their own experience, but instead of realizing the truth I was expounding, they have concluded from the fact that they obtained no success from the use of these two agents that the cures announced by myself were imaginary and that my theory was nothing but an illusion... The desire to refute such errors once and for all... determined me to make no further use of electricity or of the magnet from 1776 onwards. 28

We might perhaps conclude that most of the previous and subsequent cures by magnet of nervous diseases were mostly artifacts of suggestion and that the possible influence of the magnet must be much less dramatic and limited to more subtle changes, especially when working with such low magnitude fields (probably less than 300 gauss). However, the possibility still remains of magnetic effects underlying or mixed with those of suggestion.

Mesmer's followers grew very large in number and established numerous journals, societies, and clinics. They achieved remarkable cures of "nervous" disorders, and temporary cures of the symptoms of some "physical" ailments. 29 The art of hypnotic suggestion so developed that Esdaile 30 could report in
1852 the use of Mesmerism as the sole anesthetic agent in surgical operations, including the extraction of teeth; amputations of the penis, arms, and breasts; and the removal of tumors weighing from 8 to 80 pounds. In the same report he cites eighteen cures of nervous disorders with a single trance or general local trance: including lumbago, sciatica, convulsions, rheumatism, and hallucinations. The practitioners of Mesmerism evolved elaborate theories, based upon analogies to mineral magnetism to explain their results. There are a number of relevant experiments from Mesmer's time until the present day, in which the magnetic stimulus was retained and proved to be of some significance in clinical treatment. These works, although for the most part empirical, indicate that there are two distinct effects, one due to suggestion, and the other directly biomagnetic.

While the non-mineral magnetists captured scientific attention, a small number of researchers continued to experiment with cures derived from the magnet alone. At the turn of the eighteenth century Audry and Chouret at the Academy of Medicine in Paris attempted to demonstrate the influence of magnetic fields on the nervous system by substituting a piece of wood in place of a magnet, in several subjects. Results were negative, but we would have to disregard their work because of the lack of a double blind control. Since effects by suggestion, without any verbal cues had been demonstrated by Mesmer, the negative results could be attributed to a negative attitude on the operator's part. Audry and Chouret found that the magnetic field produced
aggravation of symptoms including fever, headache, dizziness, and abdominal pain; and urged caution in its use. In this case, as in the next three, preliminary attempts were made to eliminate the artifacts of suggestion. In 1815 Poli, an Italian physicist, reported magnetic cures of neuralgias and rheumatism, while Doctor Reil of Gottingne, devoted himself to magnetic cures and published his findings in 1835. Their controls for the Mesmer effect were that they did not consciously will anything; they merely applied the magnet and attempted to keep their actions and minds free of any activity that might induce suggestion. This is certainly an admirable aim, but is most difficult to practice. In 1845, a major breakthrough occurred, with the quasi-quantitative experiments of Reinchenbach. He worked with normals, as well as afflicted subjects, and found that three or four out of twenty are noticeably sensitive to magnetic fields. This is not statistically significant, but there remains the possibility that there is variable sensitivity to the perception of the weak magnetic stimulus. We can not be certain what Reinchenbach was measuring, perhaps only suggestibility, since his data are incomplete.

Progress in medical knowledge led to a decline in magneto-therapy by the 1880's, when the more powerful methods of electrotherapy and diathermy appeared. Laboratory investigation of biomagnetic phenomenon took place, however, coincidentally with the appearance of the electromagnet; bringing the possibility of study of the biologic effects of magnetic fields without the complications of spurious effects due to suggestion.
The question of genuine biomagnetic effects underlying those due to suggestion could not be decided by empiric investigation although many attempts were made. However, the magnet remained of some limited clinical use as a method of treatment, throughout the early part of the twentieth century. In Japan today, magnetic bracelets are widely used to normalize blood circulation and cure insomnia, although the company that manufactures them does not claim any scientific basis for their effect. During World War II, research scientists of the Permiicheskii Medical Institute reported that they used alternating magnetic fields for its analgesic effect following amputation of limbs, in nephrites, and cardiovascular diseases. The Bucharest Institute of Balneography and Physiotherapy recently reported that in their use of the magnetic field in the treatment of about 4,000 patients, a favorable effect was evidenced in Parkinson's disease, the paralysis following poliomyelitis, spondylisis, chronic bronchitis, and the after effects of epidemic hepatitis.

Current research reveals a number of possible effects of magnetic fields that could account for the magnetotherapeutic effects on physical ailments. Among them are: the increase in the leucocyte count of animals in magnetic fields which counteracts the reduction of leucocytes in radiation sickness; the inhibition of the growth of tumor cells; and contradictory effects on the healing and immunological processes. There is also an indication that magnetic fields could influence psycho-neurological diseases, from the appearance of slow waves in the
EEG of people who have had extensive magnetotherapeutic treatment and those working in magnetic fields. We will consider one other modern series of investigations of magnetotherapy in a clinical setting by K.M. Hansen. Since these experiments had marginally adequate controls, their conclusions are significant. The poles of a strong D.C. electromagnet (14 Kg holding power) were applied directly to the inflamed or painful area.

To avoid undesirable side-effects the need for flexibility in the application schedule was stressed, and if additional treatment was necessary, an interval was allowed between the series of applications.

In treating ten patients for sciatica, applications of the south pole to the affected side for periods of from one half to three hours, were repeated from four to eleven times. There were two controls, which were identical in average exposure time, average number of treatments, and position of the magnet except that the current was not turned on and there was no magnetic field. There were no signs of relief of symptoms. Of the ten patients, eight incurred no more pain. In the two remaining, there was a mistake in treatment, as both showed strong signs of functional neurosis, reacted only slightly and temporarily to magnetic treatment and should have been treated with psychotherapy. In experiments with lumbago, arthralgia, headache, internal disorders, there were positive, but not as strong results. Hansen's conclusions are as follows: chronic and subacute lesions and affections yield more readily to treatment, in general, than do acute lesions; in some cases relief
was immediate, in others relief was not felt until the next day; in some cases, pain returned in a matter of hours or days after treatment, in others relief of pain was permanent. This work still furnishes no mathematical proof of the effects of the magnet, since the results might have been effected through suggestion, accidental circumstances, or unknown parameters.

The most important result of Hansen's work is her later experiments with acute inflammatory processes. In this area we are dealing with an easily detectable, definite physiologic effect, quite isolated from obvious influences of suggestion. From observations of the facial flush after treatment with a magnet not near the face, and reduced sweating after stroking the axilla with a magnet, Hansen hypothesizes that magnetic effects are exerted on the autonomic nervous system. In order to test this hypothesis, the change induced by a magnet in the skin reaction to puncture with histamine was measured, with rigorous controls and a strict interpretation of data. The site was well determined geographically, the exposure time, was constant (1 minute), the dummy magnet reproduced the physical characteristics of the real one, examination criteria were specific and independently verified, and all results were repeated a number of times. Her results are significant: in at least nineteen out of twenty-five double curves, there is a positive inhibition of inflammation as a result of the magnetic treatment. The effect is cumulative, that is the inhibition is greater with repeated magnetic treatments. This would elucidate similar claims made by much earlier investigators; and raises the possibility that the inhibition is carried by the
parasympathetic system, which is first activated by the magnetic stimulus and then inhibited. The area of magnetotherapy is not closed. When the effects of magnetic fields on bio-systems are well understood, a more sophisticated version of magnetotherapy perhaps will appear as a useful, diagnostic tool, and method of treatment.
The possibility that magnetic fields have psychological effects on the human organism, was suggested in earliest times when pieces of lodestone were used by priest-doctors in divinatory and healing rites. Recently an American physicist, R.O. Becker, presented a paper entitled "The Relation Between Natural Magnetic Field Intensity and the Incidence of Psychotic Disturbances in the Human Population" before an international conference at M.I.T. It is best to make clear our present understanding of the concept "psychologic" before going any further. Originally referring to Soul or Spirit (from the Greek: psyche), it is now used in reference to mental and behavioral phenomena, which in many instances are not physiologically definable; and may or may not be subject to confirmation by an observer who has at his disposal various testing techniques. This makes immediately apparent the problems of psychologic effects of magnetic fields since the only indicator of subtle changes presently available is the subjective report of the individual; which can be tested for honesty and accuracy by a number of different procedural ruses. Psychologists are also currently using objective behavioral measures such as reaction time, but the manner in which these tests are related to subjective is at times unclear. The term psychomagnetism is meant to include
the perception of magnetic fields, as well as the effects on psychological phenomena, and as such is basically different in outlook and method from biomagnetism, which deals largely with laboratory animals. It is not possible to generalize from mice to men, as regards psychologic effects. As we proceed through this section we should keep in mind the concluding advice of Guilleminot, who after investigating this area as a part of magnetotherapy wrote:

These facts are to be retained because in therapeutics one makes use above all of the magnet to act upon certain hysterical manifestations, and one is very inclined to believe that the only action produced is due to suggestion. In many cases suggestion plays a role, but this would begin to expose oneself to great mistakes when not recognizing a physical action often hidden by the suggestive action, and yet very little studied.45

During the later part of the nineteenth century, there was a great deal of investigation of the effects of magnets on people in hypnotic trances and patients with forms of hysteria. Sometimes these were real investigations, but more often they were pseudoscientific. In the 1840’s, when Mesmerism was enjoying another wave of popularity, there was a great deal of confusion about the differences between mineral and animal magnetism. This was the historical setting in which claims about
sensitivity to mineral magnets professed the same symptoms as
descriptions of the hypnotic state. The reverse also took place—
those cataloging the properties of animal magnetism drew upon
analogies to mineral magnetism. It is not difficult, then, to
understand why there were so many dramatic reports of sensitivity
to magnets. Leger,\(^{46}\) writing on animal magnetism in 1846 tried
to delineate the differences between the two types of magnetism,
but still left the air cloudy with his belief in a mystical
substance. He lists the following qualities of the subtle sub-
stance:

There are manifested, particularly in
the human body, certain properties
analogous to those of the magnet;
there may be distinguished certain
poles, equally different and oppo-
site, which may be connected toget-
er, destroyed, and reinforced.

That property of the animal body
which renders it susceptible of the
influence of celestial bodies, and of
a reciprocal action with those which
surround it, manifesting its analogy to
the magnet, was the reason for naming
it animal magnetism.

The action and the virtue of animal
magnetism, thus characterized, may be
communicated to other animate and inam-
inate bodies; the one and the other, how-
ever, being more or less susceptible.

We observe, by experience, the efflux of
a matter, of which the subtility penetrates
all bodies, apparently without loss of
its activity.

\(^{46}\) Leger, R. (1846). Animale magnetism.
all bodies, apparently without loss of its activity.

Animated bodies are not equally susceptible; and there are some, though rare, which have a property so opposite; that their presence destroys all the effects of magnetism in other bodies.

The magnet, whether natural or artificial, is likewise, with other bodies, susceptible of animal magnetism and also of the opposite power; without, in either case, undergoing any alteration in its action upon iron or the needle; which proves that the principle of animal is essentially different from that of mineral magnetism.

It will explain that the magnet and electricity only have, with respect to disease, properties common to many other agents in nature, and if some useful effects have resulted from their employment, these are due to animal magnetism.

With these ideas in mind, we may look at the reports of sensitivity to magnets during the middle of the 19th century. Curiously, there are to be found qualities of the psychologic effects that are being confirmed by current research. But this might simply be due to the weak, non-specific nature of the stimulus. Robert Gibbes, an American physician of the time, reports several instances of unusual sensitivity. In one case a woman with neuralgia of the arm found relief from the pain when the North pole was applied, and an increase when the South pole was applied. In several other cases of rheumatic joints, the
same effects were noticed, but only in people with great sensitivity to the field. The curious opposite influence of polarities is a common finding of psychomagnetic research, although it is not obvious from physical considerations why there should be any difference. There might be some connection with the findings of magnetic theories of animal guidance.

In other cases it was found that all subjects capable of being hypnotized experienced such symptoms as giddiness, headache, and convulsions when the magnet is applied to the head. This work suggests the weakness of the stimulus, and since it has been duplicated in the twentieth century, deserves further investigation. There is one reported instance of an extraordinarily sensitive subject who fell into a trance whenever a magnet was placed over her head. She could not be awakened and her whole body seemed paralysed, she experienced repeated periods of spasms. There are several other reported cases of persons with extreme sensitivity to magnetic fields, and it is of course possible that there might be such people. They would make excellent subjects.

By about 1870 more serious investigations of magnetic sensitivity were taking place throughout the world; using better, though by no means adequate, techniques. In Italy, Charles Maggiorani conducted a series of experiments in the course of which he noted that the symptoms of the magnetic syndrome; including dim vision, trembling, occasional nausea and weakening of the body, and a form of vertigo characterized by movements of the head; showed a strong analogy to the effects of
lesions of the cerebellum. (One wonders at the remarkable suggestibility of patients at that time, but such a study is the subject for a history of disease.) Other Italians, Lombrose and Ottolenghi, working with people who were easily hypnotized, found that suggestibility was highly correlated with the presence of "psychic polarization" in response to the magnet. Bianchi made the same observation, but found that the "psychic polarization" could be produced by other aesthesiogenic agents. The case for biomagnetic effects did not fare very well in Italy.

In France there was a great deal of investigation of the effects of magnets on hysterics. This work was initiated by Charcot and Regurad and subsequently confirmed by many others. In 1880 Charcot, Binet, and Feri hypnotized an hysteric subject, causing visual, auditory, and olfactory hallucinations. The patient reported seeing a butterfly on his hand, hearing music, and smelling a rose. When a magnet was applied three centimeters from his head, the suggested hallucinations were diminished or suspended. This result could not be repeated in all subjects, but subsequent investigations succeeded in duplicating the results. This adds further evidence to the notion that the weak magnetic stimulus is best perceived in a state of heightened sensitivity. Proust and Ballet, in continuing Charcot's work at Salpetiere, found that the magnet must be used cautiously because very often patients would complain of secondary effects and manifest a specific set of symptoms unrelated to the original malady. Too long an application with too strong a magnet would produce digestive disorders, pain in the epigastrium and frontal walls of the
In summarizing one set of work with eleven subjects, eight of whom were women with hysterical symptoms (hystero-epilepsy), and three were men with sensory hemianaesthesia resulting from poisoning and cerebral tumors, Proust and Ballet said that the effect of various applications of varying numbers of magnets from a few minutes to several hours, manifested direct effects on the nervous centers of nine of the eleven subjects. In controls with unmagnetized objects they found the effects to be peripheral ones as would result from pressure.

At about the same time, a parallel set of works was carried on by the French neurologist Babinski. He could use the magnet to produce a transference of symptoms in an individual or from one individual to another. For example, in an hysterical patient with sensorial anesthesia, paralysis, arthralgias, or other functional manifestations on one side of the body, Babinski was able to make these symptoms disappear with the application of a magnet, after which they would manifest themselves on the unaffected side of the body, or appear in a different patient, or in a healthy person.

In the French work we have discussed one could discount most of the overt effects as transference of functional neurosis, but the question of a masked magnetic influence still remains when one considers that the patients used in the studies were likely to be unusually sensitive to a weak order stimulus because of their condition or because of some correlation with the presence of functional neuroses and sensitivity to magnetic stimuli.
At the same time, there was a considerable medical and scientific interest in the magnetic stimulus in America. Current belief then was that a magnet affected living matter through an attraction of opposite electricities near the point of application and also through direct effects from the magnetic lines of force. The production of physiological and behavioral effects was merely a question of the strength of the magnet. Some investigators found startling effects including dramatic differences between applications of the North and South poles to painful areas; the former decreasing pain, the latter increasing it. The areas of the human body that reacted in specific ways to the poles were charted in repeated trials on the same and different subjects. Different areas or organs giving rise to the same symptoms were assumed to be in the same polar state. (A plus magnetic pole applied to a plus part of the body produced increased activity.) It is not likely that these polar states correspond to anything physiological, and are probably meaningless generalizations. However, the conclusion was drawn that there are two kinds of subjective effects from polar applications: one reflecting increased organic activity and the other its opposite.

The results of nineteenth century work seem to indicate that if there is any psychologic sensitivity to magnetic fields, it will not be found in all subjects; manifest itself in a non-specific manner; be more readily found in states of heightened sensitivity associated with hypnosis and the stress from disease; can be confounded with the heightened suggestibility of these states.
In 1919, L.L. Vasilev, a Russian physiologist, tried to verify Binet and Charcot's experiments by inducing hypnotic hallucinations in healthy subjects and observing the effects of a permanent magnet. The results in six sensitive subjects were very positive when a moderately strong permanent horseshoe magnet was used (lifting power of 1.5 Kg.). Vasilev found that the position of stimulation on the head was not important as long as the vertical plane of symmetry went through the two poles of the magnet. In five subjects, the magnet destroyed the induced hallucinations when the north pole was against the left hemisphere. In one of the subjects, the reverse was also found—the north pole could be either on the right or left hemisphere. The possibility of unconscious cues was eliminated, when the experiments were repeated, by means of a double blind technique. The magnet was wrapped in a piece of cloth, but effects were again manifested only with the north pole applied to the left hemisphere. When a similarly wrapped wooden or metal object was placed in position, there were no effects on the hallucinations. After repeated alternations of magnetic and non-magnetic objects, the dummy exerted some effect on the hallucinations, possibly because of pairing with the UCS of the magnetic field. Further experiments, confirmed by the Soviet Commission, showed that when the hypnosis was not deep or the hallucination weak, the magnetic field could strengthen the effect. There are findings very similar to earlier ones as regards polarities and inhibition and excitation. Vasilev theorized that the magnetic field affected sleep inhibition of cortical and sub-cortical
systems. Testing this hypothesis in further work he found that the duration of an artificially induced hypnoid state in frogs increased from 2.045 minutes without a magnet, to 2.733 minutes when the magnet was not selectively positioned, and to 3.163 minutes when the poles were positioned in the same manner as in the human experiments. The result was repeated several times, and suggests that the character of the effect depends on the functional state of the system. In twelve experiments with four graduate students, Vasilev found the consistent inhibition of conditioned reflexes due to electrical stimulation of the hand. He notes that the inhibition resembles the depressing influence of the positive pole of a direct D.C. current. In general, the work of Vasilev points to the magnetic stimulus as a weak inhibiting agent of the CNS, capable of being consciously discriminated in states of increased sensitivity, and having a peculiar vector effect on those states. There is, however, no proof of a direct neural effect.

In 1947, another Russian group under Perikhanyantz, and Terentyev, found that a strong horseshoe magnet could produce phosphene like hallucinations in a woman who had mescaline. In a dark room, and with the subject's eyes closed a quick vertical movement of the magnet, three cm. from the subject's head, produced moving phosphenes that looked like the trace of a shooting star. When the magnet was brought to the occipital lobe and rotated 180° many times, it created a similar rotation of the spontaneous visual image. It was very easy for the subject to distinguish the magnet from a control.
It is very difficult to speak intelligently about these Russian findings, since the results are only for a small number of subjects, and with very little effort one could come up with alternative explanations for the observed effects. However, we should note that the qualities of the stimulus found in these modern investigations are in complete agreement with those hinted at by earlier research: a weak, predominantly inhibitory stimulus that can be detected in cases of naturally occurring or artificially induced heightened sensitivity. Attempts should be made to duplicate these results since they form a consistent picture of the psychologic effects of magnetic fields and explain many of the negative results encountered in recent work with humans in normal waking states.

Recent experiments in the West have not considered the possible need for heightened sensitivity or special training to perceive magnetic stimuli. The feeling here is that possible effects should be made manifest through the use of higher magnetic fields. This is an unwarranted assumption since the mode of action of the magnetic stimulus is not known. We have been quite willing to accept the reports of workers in high magnetic fields, or people who have casually stuck their heads in magnetic fields as conclusive evidence of the lack of psychologic effects of magnetic fields. Under the reported conditions it is very unlikely that the perception of a weak, non-specific stimulus could be felt. We should raise the warning now that prior expectations, repeated habitual motions, intense concentration on mental activity, even an excessive amount of background
thoughts during these exposures would not provide adequate conditions for the perception of such a stimulus. 66

Russian research has studied workers in magnetic fields, 67 and unlike the single result reported by Beischer, 68 has found that in cases where the exposure is from 20-40% of the working time, there are frequent and characteristic variations in EEG patterns, including slow, high-amplitude waves and alpha activity with spindles characteristic of an inhibitory state. Reactions to light stimuli were not as clearly differentiated in a blocking of the alpha activity and spindles as when the system returned to normal, a short time after removal from the field. Since the reported changes are within the limits of "normal" physiological shifts the evidence is only useful as another incomplete corroboration of the previously reported effects. Subjective changes in the workers, were unfortunately, not reported and further research is needed.
BIOMAGNETISM

Current Research—Part One

The majority of current research is involved with functional and behavioral changes of whole laboratory specimens and isolated tissues and cultures in static magnetic fields. There is a similar amount of interest in the effect of static magnetic fields on key biochemical reactions, but strictly speaking, this is not magnetobiology. Serious attempts are being made to understand the experimental parameters that have accounted for the great variability in previous findings, so that biomagnetic effects can be produced with greater reliability and predictability. There has been a great deal of progress and some of the causes of previously reported negative results are now understood. It has been found that many of the observed effects are more dependent on the magnitude of the gradient than the field strength. One example is the mortality of Drosophila in a field with a gradient above 6koe/cm. It has also been found that many of the biomagnetic effects are reversible with a change in field direction. Previous experimental designs often did not take this factor into account by either restricting the motion of the specimen or by using a vertical field in cases where there is motion only in the horizontal plane. There are numerous other causes of the contradictory findings in the past including: failure to allow for the delay between
exposure and physical manifestation of effect in the specimen; failure to shield against spurious stimuli, such as cosmic radiation, lighting, air-currents, and humidity.

In recent years adequately designed and controlled experiments have taken the above factors into account. Among the recent findings of the biological effects of magnetic fields are: the retardation of growth in young mice and drosophila, rejection of transplanted tumors, changes in the number of leukocytes, effects on wound healing and tissue regeneration, effects on the CNS, plant growth, and magnetotropisms, disappearance of the oestrus cycle, resorption of embryos in the uterus, decrease in tissue respiration, and inhibition of bacterial cultures. According to J.M. Barnothy, the above effects can all be considered a stress effect of the magnetic field; similar to other stress factors such as heat, cold, confinement, bleeding, and starvation.

There are also probable effects of the magnetic field on the genetic code such as: the decrease in the incidence of certain tumors, retardation of aging, and pathological change in the adrenals.

Of the numerous reported effects of magnetic fields on function, growth, and development, the most dramatic are those on biological systems that are in a rapid process of change. Experiments on the monolayer culture of chicken embryo cells showed that the magnetic field only effects those cells that are dividing. Chromosomes of the dividing cells displayed a nonuniform distribution about the poles as well as agglu-
tination resulting in asymmetrical mitosis. In some cases the chromosomes were disturbed enough to prevent mitosis and the cells degenerated. It has been found that the tissues of embryos and infant animals are more sensitive to the static magnetic stimulus than adult tissues. An homogenous field of 7300 Oe. decreased the oxygen consumption of an embryo mouse kidney up to 93.5% whereas there were no statistically significant changes in oxygen consumption of an adult mouse kidney. It was also found that there is a regular increase of the percentage of respiratory depression in S-37 cells with increased field strength. At 80 Oe. there was a 38% respiratory stimulation; at 225 Oe. there was neither stimulation or depression; above 225 Oe. the effects showed positive depression reaching a value of approximately 48% at 7300 Oe. A further basis of the conclusion that magnetic fields produce the greatest effects on those cells that are subjected to the greatest functional load is the inhibition of S.aureus growth after the fifteenth hour in an homogenous field of 15,000 Oe. We should note, however, that the biological reaction to magnetic fields shows great inter-species variation. In the case of S.lutea and E.coli there were no significant changes in the growth response curves. There is no adequate explanation for these differences. In another case it was found that S.marcescens undergoes a strong growth inhibition after the seventh hour in an inhomogenous field of 14,000 Oe. with a constant gradient of 2300 Oe.

The authors conclude from a mathematical analysis of the growth rate curves, that the magnetic field very likely exerts
its greatest influence during the period of DNA replication, and further that there are possible alterations in the genetic code since the effects of the field do not show up until the fifth to the eighth generations. This sort of statistical elaboration of biomagnetic findings is a common feature of current research.

The study of the effects of magnetic fields on developing systems has been expanded to plants. R.P. Mericle, et. al. found that a small inhomogeneous field of 1200 Oe. increased the rate of growth of the roots and shoots of barley seedlings. The effect was greatest on the shoots and it is theorized that the responses are mediated by magnetic effects on susceptible microelements, leading to changes in their rates and patterns of translocation and accumulation.

One of the possible conclusions that can be drawn from these works is that the magnetic field retards mitosis. This is further corroborated by other research that indicates that a static magnetic field can inhibit the development of fish from the ova stage, the incubation of chicks from eggs, and the development of mammalian foetuses. Pregnant rats in a 2500 Oe. field gave birth to young who were about 25% smaller than those of previous litters of the same mothers. The progeny of pregnant females exposed to a 3100 Oe. field survived only a few days. Under a 4200 Oe. field the embryos resorbed in the uterus. In females exposed to a 300 Oe. field for a prolonged period of time the menstrual cycle was disrupted; but resumed immediately after their removal from the field. There are especially reliable results indicating retardation of growth in young mice (three
to four weeks old) subjected to an homogeneous field. The effect is established with a probability level of 1:1560 and is strongest on the second day of exposure, probably due to a shock effect of the field. The retardation of growth effects individual mice to a different degree, and retards the growth of males more than it does females. There was no significant effect on the growth rate of adult mice.

Morphological research showed that after 500 hours in a 7000 Oe. field the ovaries, spleen, and lungs of guinea pigs showed a marked disruption of cellular development. Similar experiments in mice showed histological disturbances in the spleen and a decrease in the weight of the liver. Great morphological changes were found in the spinal cord and skeletal muscles of mice previously subjected to a fifteen minute swim before exposure. When the animal could change direction with respect to the field vector the morphological changes reported were reversible. This work further illustrates the substantially greater effect of magnetic fields on those organisms, organs, tissues, or cells subjected to a heavy functional load.

There are many other effects on whole organisms including: a drop of 0.3°C in mice; an increase in the motor activity in fish, birds, and mammals, a decrease of 14% in the food consumption of mice; and the preservation of fur in older animals that have been pre-treated. However, for the most part, these are single reported results and attempts have not yet been made to duplicate them. An exception is the effect on
balding, which has been well documented by M.F. Barnothy.\textsuperscript{102}

It has been reported that magnetic fields can lower the cholinesterase level of the blood and modify the distribution of radioactive isotopes of phosphorous and iodine.\textsuperscript{103} An increase of the membrane permeability of plant and animal cells has also been noted, but this important possible effect needs to be studied in greater detail.\textsuperscript{104} Hackel, et.al.\textsuperscript{105} have made preliminary studies of the effect of magnetic fields on immunochemical reactions. It was found that an overall enhancement of agglutination of erythrocytes of 32\% resulted from exposure to a 2000 Oe. field. There was a regular increase of agglutination with field strength up to 5000 Oe. where the effect flattened out. Further studies of the effect of inhomogeneous fields were inconclusive. Results vary with the type of antibody used and the whole question needs further study because of the complicated technical procedures involved.

In connection with cancer research, the effects of static magnetic fields on transplanted tumors have been carefully studied. In fields of 2400 to 4500 Oe. with a paramagnetic strength of at least 1 M\(\text{Oe}^2\)/cm a rejection of homotransplant tumors in mice was found in from 20 to 80\% of the cases with a probability level of 1:1000.\textsuperscript{106} A rejection of isotransplants only occurred when the paramagnetic strength exceeded 5 M\(\text{Oe}^2\)/cm. There was a significant lengthening of the life span of mice with isotransplants in practically homogeneous fields of 4200 Oe. There is a great variation in effects depending upon the strain of tumor used. Other studies confirm this lengthening of life span of
tumor-bearing hosts that have previously been treated with a magnetic field for thirty days. The effect is probably related to the leukocytosis which occurs following exposure.

We note that current research with large static magnetic fields shows a broad spectrum of magnetic effects on living systems. There is no simple dependence of the effect on field strength and there is considerable variation from species to species. In some instances the effects of magnetic fields are coupled with other variables such as temperature and concentration of constituents in biochemical reactions. The characteristic effect of the magnetic stimulus on biological systems is an inhibition of functional activities through the application of a stress on the system. Further research will help to elucidate the specific underlying biological mechanisms responsible for these effects. In many cases the authors have suggested selective effects of the magnetic field on microelements or on key enzymatic reactions as a possible explanation. (See "Theoretical Considerations"). It is a complicated process by which changes in biological function are produced by the physical reaction of the constituent elements to the magnetic field. We note that in all reported results there is a lapse of time between initial exposure to the field and observable effects, suggesting that the physical effect of the field has to first reach a biological threshold and further, that the biological process initiated has to be amplified by the system in order to produce an observable change.
Current Research—Part two

Another area of biomagnetic research concerned primarily with questions of sensitivity to weak magnetic fields, usually in connection with theories of animal navigation. There have been a number of significant demonstrations that add credence to the notion, that bird migration is guided by the Earth's magnetic field through a Coriolis force. There have also been many counter-refutations, demonstrating negative results, and stating that there is no cogent evolutionary reason for birds to have developed such high sensitivity to magnetic fields. Earlier claims that the semicircular canals or the cochlea were the organs that mediated magnetic sensitivity were disproved when it was demonstrated that the otoliths are not magnetically susceptible. Still other theories found the sensitive organ in the feathers and the orbital zone or the crest of the bird's eye. More likely, the sensitivity is not carried by any specific system. Recently, J.M. Barnothy has suggested several new theories which are sufficiently esoteric to ward off attack. One is based on a continuous modulation of the small polarization currents induced by wing flapping. Barnothy notes that directional changes in flight induce alternating currents with different directions of flow and different rhythmic peaks in each wing. It is possible that birds gain guidance information from the simple patterns of these currents.

Much work has also been done with the possible sensitivity of other organisms to the earth's magnetic field.
notes that ants, beetles, bees, crickets, grasshoppers, and flies all have preferred directions of orientation that could be experimentally changed by a small artificial field of a couple oersteds. Barnwell and Brown, have tested the sensitivity to weak magnetic fields of a great variety of different organisms, including snails, flatworms, fruit flies, and unicellular Paramecia. From their work they unequivocally conclude that living systems are extremely sensitive to magnetic fields. Using very simple, bug-proof experiments; they have demonstrated many thousands of times that the orientation of organisms can be modified by artificial fields of a few Oersteds. They further conclude that there is no one simple system for the perception of magnetic fields, since the responses noted were systematically and regularly related to the intrinsic biologic and cosomologic rhythms such as time of day and sun and moon cycles. More likely, there is a functional interrelation of the magnetic perceptive mechanism to the three-dimensional structure of the organism as a whole, and to its other biologic functions.

Criticisms can be made of the experimental findings. One can say, for example, that the work so far has not demonstrated a cause and effect relationship; it has only indicated that there are certain daily changes in orientation in the presence of a magnetic field. There remains the possibility that the organisms are reacting to certain unknown stimuli such as temperature or humidity. However, these criticisms are cogent in so far as they have relevance in pointing out that this sensitivity has
not been clearly isolated from the complex interactions that
govern the biologic cycles of organisms.

Perhaps there are far-reaching implications of these simple
experiments with lower organisms. One naturally wonders about
the possibilities for the conscious discrimination of such low
fields in humans. On the basis of the bug experiments, it is
possible that with special training such sensitivity could be
demonstrated. The results of Perikhanyantz reveal that in
states of heightened sensitivity, the perception of a field of
a few hundred Oersteds is unmistakable. One also wonders what
effects the geomagnetic field might have on higher nervous func-
tioning. The only relevant work in this area is the reported
by Beisher (1962). After a ten day exposure of humans to a
field of $10^{-5}$ Oe, there was a clear decrease in the threshold
for flicker fusion, indicating an increase in the sensitivity
of the visual analyzers. It can confidently be predicted that
further research will deal with sensitivity of humans to small
magnetic fields.
Effects on the Central Nervous System

Since serious investigation of the physiological effects of static magnetic fields began, many attempts have been made to demonstrate the direct effects of magnetic fields on isolated nervous tissue. Some of these had positive results. For example, M'Kendrick in 1879 found that the sciatic nerve of a frog stretched between the two poles of a direct current electromagnet was less excitable to stimulation by a copper prod. However, the majority of reports were negative. The well known work of Peterson and Kennelly conducted at the Edison laboratory had several demonstrations that there are no appreciable effects of magnetic fields on the nervous system. One was to determine whether a magnetic field of 2000 CGS lines/cm² increases the resistance to conduction in motor nerves. A dog was kept in the field for five hours without any visible effect on behavior, although there was no mention of the criteria for judging changes. From the results of this and other experiments, the authors concluded that neither static nor alternating magnetic fields have any effect upon blood circulation, ciliary motion in protoplasma, sensory or motor nerves, or the brain. We may note that in neither of these early experiments were the broad conclusions warranted by the data, nor was adequate control made for spurious influences.
As time went on, the number of negative reports increased and research interest in the effects of magnetic fields on the nervous system waned. One such negative report was published by Drinker and Thomson in 1921. The isolated sciatic nerve-muscle complex of a frog was exposed to a powerful field of up to 19,000 G lines/cm². It was found that neither the threshold for electrical stimulation, nor the conductivity, nor the contractible power of the muscle nerve units changed during and following exposure. Results were repeated eighteen times. It was noticed that after twenty-one hours exposure the nerve in the magnetic field was in better condition than the control; but this was not held as significant, although current research indicates that this secondary effect of the field characterizes magnetobiologic effects in general. Subsequent attempts to demonstrate a direct inhibitory or excitatory effect of a static magnetic field on an isolated neuro-muscular system failed to reveal any significant changes. However, it has been reported that the magnetic field can remove the state of parabrosis following strong stimulation. The effects of an alternating field which can produce a wiggle in a neuro-muscular element, will not be discussed here, since the primary effect is not magnetic, but results from the induction of a comparatively large EMF. Later research realized the stimulus was weak and looked for more subtle effects that would be reflected in changes in the functioning of the nervous system of the organism as an entity.

The effects of static magnetic fields on the CNS is distinct in many respects from the question of the biophysical mechanism
of magnetic action. The problem is to decide how the observed behavioral effects, are mediated by changes in the nervous system. The difficulty is in relating data at all possible levels. If one begins with data about the effects of magnetic fields on behavior, these must be correlated with changes in the functioning of the entire system, as might be revealed in the EEG.

From there the specific parts of the nervous system that might be mediating these changes must be isolated and then one must understand how the effects on the areas involved result from the action of the field on individual nervous units. The problem is now expressed at the lowest possible neural level; and is a question of the physical effects of magnetic fields on such things as membrane permeability, ionic concentrations, small gradient potentials, axonal and dendritic conductivity and synaptic transmission. It is optional which end one starts from, but there is a possible source of difficulty if one begins with the smallest units and attempts to work up since most investigators found that it is easier to demonstrate effects on whole organisms with smaller fields. Still, it is not at all obvious how these changes are registered at the lowest levels of neural functioning. Some interesting possibilities are raised by the recent finding that the spike in a frog's nerve is preceded by a very minute magnetic field.\textsuperscript{121}

Several researches have again suggested direct effects of magnetic fields on the nervous system from theoretical considerations of the sensitivity of living systems to very small electric currents. In particular the work of Lissman and Machin\textsuperscript{122}
has often been cited as demonstrating delicate sensitivity to electric fields in living systems. However, Barnothy \(^{123}\) notes that while the induced potentials from the motion of laboratory animals in a moderately high 5000 Oe. field are of an order large enough to interact with neural potentials, their duration and likelihood of occurrence is not great enough to account for the observed effects. An induced EMF from the internal motion of charge carriers is not likely to produce the observed changes either, since the velocity is great enough only in the case of the blood flow in the human aorta during the ejection period of the start of the systole.\(^{124}\) Another suggestion at the neural level might be a paramagnetic influence of the magnetic field on axonal charge carriers. But this is not likely since the impulse is not a continuous flow of current and the disturbance is only in one place for a very short time.

The fact remains that current research shows definite effects of static magnetic fields on the CNS. It is particularly worthwhile to consider the methods and conclusions of the Soviet researcher Y.A. Kholodov.\(^{125}\) Out of his extensive research emerges a theory which takes into account empirical findings about the magnetic stimulus and the nervous system. He reports that attempts to develop positive food-seeking and defensive conditioned reflexes with fields of 200 Oe. in rabbits and pigeons were unsuccessful.\(^{126}\) In fish, a 200 Oe. field could develop an unstable conditioned reflex of 60% stability with food-seeking and 39% stability with electrodefensive methods.\(^{127}\) Threshold action was produced with a field of from 10 to 30 Oe.\(^{128}\)
The magnetic field inhibited previously established conditioned reflexes. In fish, inhibitory food-seeking reflexes appeared after an average of only three trials, and were established with 84% stability after fifteen trials. Electrodefensive inhibitory conditioned reflexes appeared in one group after three trials, and were established with an 84% stability after 15 trials. The inhibitory effect of the magnetic field persisted for several minutes after the stimulus was removed.

In pigeons, the magnetic field exerted an inhibitory effect on conditioned alimentary reflexes to light and sound stimuli, with complete consistency from the first trial. In fish, the inhibition of the conditioned reflexes occurred in 85% of the reactions to light and 70% to sound, and was accompanied by an increase in the number of intertrial reactions. The inhibitory character of the stimulus was further illustrated in experiments in which the irritability of fish by electric currents decreased by 45% in a field of 100-200 Oe., and the reactions of amphibians to stimulation by acid decreased 70% in similar fields. Kholodov concludes that the static magnetic field is a weak correcting irritant, which changes the reaction to other irritants and causes a predominantly inhibitory state of the CNS.

Various operations were carried out to determine the mechanism by which fish perceived the magnetic field. A denervation of the lateral line did not affect the production of magnetic inhibitory reflexes. Nor did blinding, disproving the theory that the retina is sensitive to magnetic stimuli. After
a complete bilateral enucleation of fish, the reflexes were formed in a greater percentage of cases. The removal of the forebrain, cerebellum, or the optical tegmenta did not disturb conditioned reflexes to magnets, although those conditioned to light and sound were, of course, affected. Removal of the diencephalon did eliminate the magnetic conditioned reflexes. On the basis of this strong evidence, it was possible to suggest that in fish, the magnetic field acts directly on these brain structures, without mediation through sensory pathways.

Other standard methods were used to corroborate the results. EEG recordings of salamanders exposed to fields of 200-800 Oe. displayed a high incidence of slow, high amplitude waves in the occipital and motor cortex; and spindles in the frontal regions, following exposure to an 800 Oe. static field. These results indicated a deactivated, inhibitory state. An encephale isole preparation of a rabbit with additional bilateral sections of the optical and olfactory nerves was exposed to an 800 Oe. field and evoked potentials were recorded. The isolated forebrain and diencephalon showed a stronger reaction than an intact brain. However, the results were not as regular as with a fifteen minute exposure, with an exposure of only three minutes, even when the field was 1000 Oe., further indicating the weakness of the stimulus and possibly indicating that it is a stress effect. There is a latency of over ten seconds to all reactions to the magnetic stimulus.

When the magnet is de-activated there is a second increase in the number of spindles and slow waves. This off-reaction
does not occur as often and is not as strong as the original reaction, suggesting either that the on-reaction and off-reaction are mediated by different mechanisms,\textsuperscript{143} or that the off-reaction is an artifact of the change in flux. The amount of slow waves and spindles could be increased in a regular manner with a stronger field.\textsuperscript{144} The EEG reaction could also be intensified through the injection of stimulants (adrenalin) and weakened through the administration of depressants (nembutal).\textsuperscript{145} When other parts of the body were stimulated by the magnet, there was no effect on the EEG.\textsuperscript{146} The conclusion is well-established that the magnetic field acts directly on the brain. Recordings made from electrodes introduced into several brain structures showed that the hypothalamus, cortex, and reticular formation of a rabbit react most strongly, while the reticular formation of the midbrain reacts the least intensively to a static magnetic field.\textsuperscript{147} Later research aimed at the lower levels of nervous structure, and tried to determine which of the neural elements is sensitive to the magnetic field. It was found that evoked potentials to the magnetic stimulus in the cerebral cortex of a rabbit increased in some neurons, decreased in others, and remained unchanged in a third group.\textsuperscript{148} In the instances in which inhibition or stimulation occurred, the latency was over ten seconds, indicating that the neuronal reaction was secondary to another reaction on a different nervous element. Subsequent morphological analysis of the brains of rats, rabbits, and cats, which had been in magnetic fields from 1-10 hours reveals an increase in the number of glial cells. After 50-70
hours exposure to a magnetic field, the nerve cells themselves showed a morphological reaction. One could hypothesize that primary effects of a static magnetic field are on the glial cells. This would explain the weakness of the reaction, its long latency, predominantly inhibiting character, and the prolonged effects following removal from the field. However, the mechanism of interaction between the glial cells and whole systems of neurons is not clear. A great deal of further investigation must take place before there will be an integral understanding of the effects of magnetic fields on all levels of neuronal activity. The work of Kholodov on the nervous system is fine preliminary research. One hopes that American researchers will take a greater interest in the question of magnetic effects on the nervous system and attempt to further Kholodov's findings.

Recently Beischer has begun work on the effects of very powerful magnetic fields of up to 91,258 Oe. on the EEG of laboratory animals. With total exposures of up to 90 minutes, it was found that the EEG of a squirrel monkey reveals a steady increase in amplitude with field strength and an increase in frequency that shows no field dependence. The peak to peak amplitude in the preliminary of 25-50 microvolts increased to 50-400 microvolts during the exposure period. The prevailing frequencies in the resting EEG were in the 8-12 c.p.s. range. During exposure, they were between 14-50 c.p.s. No differences were recorded between homogeneous and gradient fields, nor was there any influence of polarity. The results support the conclusion that a field of this intensity exerts a strong synchronizing
effect on brain activity, and produces a wave pattern characteristic of extreme wakefulness accompanied by tension. One may also conclude that squirrel monkeys, when constrained in a small cylinder under the action of 90,000 Oe. field will not perform a visual discrimination test. There is no disparity in this case between the activated state of the EEG and the decreasing ability to perform behavioral tests. It should be noted that some findings of this research are valid only for very powerful fields; since at these strengths, we may expect qualitatively different physical effects of the magnetic field to predominate. It is possible that the primary effect in a field of 90,000 Oe. is due to a direct induction of an EMF in the moving charged particles of the system. Another source of the results might be large induced currents from the rapidly changing field strength during the activation period of the magnet. At the Naval Research Magnet, the increase is 500-1000 Oe/sec and at the National Magnet Laboratory the increase is 6,000 Oe/sec. These large changes in flux could indeed be responsible for the primary effect on the EEG.
BIOMAGNETISM

Theoretical Considerations

We have seen that there are now well-documented effects of magnetic fields on a great variety of basic biological processes like growth and nervous activity, often leading to overt behavioral changes. Unfortunately, the work to date, especially in the areas of effects on growth and respiration, is highly specific to this or that organism, and is largely disconnected. Until there is a basic understanding of the underlying mechanism or mechanisms by which the magnetic field interacts with living systems, it will be difficult to fit the data into a unified picture, and make use of the magnetic stimulus as a research tool. This is especially so in experiments with humans, where it would be best to have numeric values for parameters in mind before hand, rather than drawing upon the results of empirical investigation.

The underlying mechanism we will consider must involve one of the primary physical effects of magnetism on matter. It is best to have these clearly in mind when considering the various theories that have been offered to account for magnetobiological interactions: When a living system is in motion with respect to a magnetic field, a current is induced in the conducting parts according to Lenz' Law. In an homogeneous field there will be a rearrangement of the electric charges of the conductor, caus-
ing polarization currents; while in an inhomogeneous field the various parts of the system will be affected by different field strengths, leading to conduction currents. There is the possibility that these currents would be large enough to cause significant changes in the temperature, electrolytic dissociations, or nervous potentials of the system and consequently the observed changes in behavior. This would be the simplest explanation of magneto-biological effects and has often been proposed in the past. In fact, refutations of this theory have frequently been used to deny the possibility of physiological effects of magnetic fields. This was the commonly held position as late as the 1950's. It resulted from the criticisms of early attempts at an adequate explanation of the effects of magnetism on living tissue, and can be found in the work of Hermann. However, recent theoretical investigations reveal that the voltage induced by motion in a magnetic field are within the range of sensitivity of certain neurons. In the case of gradient fields, an induced voltage gradient of 0.14 mV/cm results from the motion of a theoretical biologic specimen or components of its bloodstream, at 100 cm/sec in a field of 500 Oe/cm gradient. In the case of a uniform field, the induced polarizing voltages will be of the order of 5mV/cm with comparable constant velocity and 0.1 mV/cm with a reasonable acceleration of this theoretical system in a field of 5000 Oe. perpendicular to the plane of motion. These theoretically computed values for polarization and conduction currents in a magnetic field, while less than the membrane depolarizing value, could perhaps have a sig-
significant effect in producing measurable changes in neuronal systems. However, J.A. Barnothy maintains that a laboratory mouse, traveling seldom above 10 cm/sec with an acceleration below 20 cm/sec² in an homogeneous field of 10k Oe. and gradient field of 1000 Oe/cm would experience polarization and conduction currents of $10^{-8}$ and $10^{-6}$ A/cm² respectively, only for a very short duration while the animal is in motion. In this case, the induced voltages would not produce a significant change in the Joule heat of the system consonant with the observed effects. The case for an effect of induced currents through internal or external motion of the system of conductors is by no means closed, especially when one is dealing with the possibilities for sensitivity to magnetic fields rather than the gross effects they produce through stress on the system. In the latter case, larger values are undoubtedly necessary and it is more productive to look at magnetochemical effects of the type charted by Valentinuzzi but in the case of sensitivity, the results of Barnwell and Brown and Beischer with magnetic fields of less than a few Oersteds suggest that none of the possible physical effects of magnetic fields on matter, no matter how small the numeric value might seem, should be completely disregarded until further research has clarified the exact nature of organism, system, or tissue "awareness" to magnetic stimuli. Of possible relevance, is the finding that the spike in a frog's nerve is preceded by a very small magnetic field.

A charged particle in motion in a magnetic field, experiences a force perpendicular to the direction of motion and
the applied field by the Hall effects. There can result an unequal distribution of the ions in one of the biological fluids, or a change in the path of the charge carriers in the nervous system; leading to a transverse potential difference and a consequent temperature gradient. In MKS units, the force of displacement is given by \( F = e' (\mathbf{v} \times \mathbf{B}) \) where \( F \) is in Newtons, \( e' \) in Coulombs, \( \mathbf{v} \) in m/sec, and \( \mathbf{B} \) in Webers/m². The current density in amps/m² is given by: \( J' = N_e' \mathbf{v} \), where \( N_e' \) is the number of free charges/m³. The Hall force involts is given by: \( \mathbf{E}_{H} = -\frac{e}{N_e'} (\mathbf{v} \times \mathbf{B}) \)

At present, there is insufficient knowledge to calculate \( N_e' \) and \( J' \) for all charge carriers in a biological conductor. Some researchers have stated that it is unlikely that there is a significant Hall effect in axonal conductors, while others have demonstrated the appearance of the Hall effect in the nervous system of a salamander.

There is another consequence of the Hall effects on the atomic and molecular levels, called diamagnetism. An external field interacting with orbital electrons produces a precession of the orbital axes around the field vector, analogous to the motion of a gyroscope, in the presence of an external force. This precession gives rise to a weak internal magnetic field that decreases the magnetic induction of all substances. The observed diamagnetic moment is a result of the orbital and spin components of electron motion. When there are no unpaired electrons, as in most compounds, the vector magnetic moment due to electron spin is cancelled by the various opposing spin directions. There remains, however, the effect of the magnetic field
on the orbital motion of the paired electrons. By application
of the Larmor theorem\textsuperscript{166} it is found that the net effect of the
force is not a change in the motion of the electrons or the shape
of the orbits, but a common precession of the orbits about the
direction of the applied field. When a magnetic field is ap-
plied to a compound, a weak repulsion is established, independent
of temperature changes, except when they are large enough to
alter the state of the system. This effect is found in almost
all compounds with the exception of free radicals and the com-
pounds of the transition elements, where it is masked by the
stronger paramagnetic effect, due to the presence of unpaired
electrons. The magnitude of diamagnetic susceptibility is neg-
ative and very small; at 20^\circ C it is of the order of 10^{-6}. There
is an appreciable difference in considering the diamagnetism of
single atoms and of large molecular systems. In the latter
case, the internal electric field of electrons is not sphereically
symmetrical except in the case of linear molecules in the
S state;\textsuperscript{167} when the charge distribution is not symmetrical with
respect to the magnetic field vector, the amount of diamagnetic
susceptibility will be reduced due to an alteration in the motion
of orbital electrons. Unfortunately, for research, a theoretic
Calculation of diamagnetic susceptibilities is extremely
difficult and a practical application limited by a dependence
of the equations on knowing the value of the molecular radii.\textsuperscript{168}
According to Mulay,\textsuperscript{169} the approximations usually used for correlat-
ing diamagnetic susceptibilities of compounds is without real
significance. Biomagnetic theories have not focused exclusively
upon diamagnetic effects, because of the smallness of experimentally determined values, and the lack of certainty in the theoretical approximations. However, diamagnetism could be responsible for biologic effects in non-paramagnetic substances through interactions of pi electrons in large organic molecules. 170

A third group of physical effects of magnetic fields on matter occurs only in a special class of atoms and molecules having either unpaired electrons, or an odd number of electrons in their orbits,(paramagnetic substances ). The attractive force exerted by an external field on non-spherical particles also belongs to this class of phenomena.171 In both instances a torque is exerted on the particles by the field. The implications of this effect for biomagnetism are very great since susceptibility values for paramagnetic substances are generally at least one order of magnitude higher than those for diamagnetics172. Paramagnetism occurs as an attraction between the substance and applied field and is prominent in complexes of the transition elements; and in molecules with an odd number of electrons, such as NO2 and oxygen; and in free radicals. Considerable theoretical research and speculation has gone into establishing paramagnetic effects in basic biologic reactions;173 and it is therefore worthwhile to understand their physical basis. The molecular paramagnetic effect is of greatest interest from the point of view of biomagnetics. At the atomic level, there are restrictions on the orientation of the angular momenta of individual orbital electrons resulting in a quantization of their magnetic potential energy. An external magnetic field will change differentially
the energy state of the quantized particles. This shows up in spectral analysis in a magnetic field as the normal Zeeman effect.\textsuperscript{174} There are also similar considerations for the electron spin magnetic moment, which has two possible orientations and two different energy states (the anomalous Zeeman effect). In the case of sodium, the orbital motion of the single valence electron interacting with the spin moment produces an internal magnetic field of 200 kOe strength.\textsuperscript{175} If an external field were to interact directly with this spin-orbit coupling, it would have to be markedly stronger than this value. However, for other elements, the value is considerably lower, and it can reasonably be expected that, with proper conditions, a change in the atomic and molecular energy levels could result from the application of a powerful external field. The manner in which such an effect could alter biologic processes will be discussed below.

In molecules with an unpaired electron, there is a magnetic moment dependent in magnitude upon the electron spin.\textsuperscript{176} An external magnetic field will cause the alignment of the components of these magnetic moments roughly one half in the direction of the field, and one half in the opposite direction. This is a consequence of the quantization of electron angular moments (values of odd integral multiples of $\hbar/4$) in an applied field. When thermal equilibrium is reached, there will be a predominance of molecules in the lower energy state, with their moments aligned with the field; and consequently the internal induction will be greater than the applied field. Paramagnetic effects are temperature dependent since thermal agitation disaligns the estab-
lished arrangement of movements. They are mostly reversible, depending on the vector of the applied field.

There is another physical effect in which a force is exerted upon the unpaired or odd electrons, rather than a torque. This can result, especially in the case of free radicals, in an alternation of the Brownian motion and will be discussed as one of the possible causes of biomagnetic effects in connection with diffusion inhibition. The discussion of the physical basis of magnetic susceptibility has here been rather superficial, and is meant to serve only as a logical structure upon which current theories of the biomagnetic mechanism could be discussed. Those interested in a fuller quantitative treatment of the principles of magnetic susceptibility are referred to other sources.

The various physical effects we have enumerated have all been examined theoretically and experimentally to determine their part in the observed biomagnetic changes. In all cases the physical effects are so small in magnitude, that any direct action at the higher biologic levels of integration is unlikely. The observed changes are either produced by a biologic amplification through a slight change in one of the positive feedback factors in the growth processes, or the production of a small number of new catalytic, growth promoting enzymes through a molecular change; or a change in the DNA code itself. At this point, evidence is incomplete and no further conclusions can be drawn. Most current ideas about the mechanism of biomagnetic reactions involve some elaboration of the last two paramagnetic effects.
Gerencer, Barnothy, and Barnothy\textsuperscript{182} noted that a highly inhomogeneous field was required to inhibit the growth of bacterial cultures, and concluded that the mechanism would, because of its vector character, involve a purely paramagnetic effect. Several theories draw upon the finding of Commoner who used electron spin resonance techniques to demonstrate the presence of unpaired electrons in enzymatic reactions.\textsuperscript{183} The concentration of the intermediary free radicals containing these unpaired electrons is of the order of $10^{-7}$ moles per gram, which is significant when considering enzymatic processes. In a magnetic field it is theorized that there will be a significant decrease in the freedom of motion of these paramagnetic free radicals resulting in an influence on the reaction rate of biologic reactions and leading cummulatively to the observed effects.\textsuperscript{184} However, effects on specific molecules are still unclear. Valentinuzzi\textsuperscript{185} and Gross\textsuperscript{186} have developed preliminary mathematical and chemical models to explain the mode of interaction in greater detail. According to Valentinuzzi, the mechanism will operate through changes induced by the magnetic field in the concentration of constituent substances, the free energy of activation, and ultimately in the rate constants of the chemical reactions which take place in the system. His particular thesis is the mathematical demonstration of the manner in which a magnetic field could significantly alter the Brownian rotation or rotational diffusion of a system of paramagnetic molecules composed of free radicals. In molecules with specific reactive sites, it has been demonstrated by Setlow and Pollard\textsuperscript{187} that rotational diffusion can increase the rate
constant by a full order of magnitude. If these molecules were also free radicals in an excited state, then by paramagnetic attraction from an external field, the rotation could be significantly reduced to a point of retarding effective collisions and inhibiting the biologic reaction. Through a consideration of the quantum levels of molecules in a magnetic field, Valentinuzzi hypothesizes that the ratio of the magnitude of the population with lower energy over the higher energy will determine the amount of decrease in the reaction constant. By working through the equations, he obtains a value of $4.5 \times 10^6$ Oe. to stop a reaction containing a free radical with one unpaired electron at $300^\circ$K. However, it would only take a field value of $5000$ Oe. to reduce the reaction rate by 12%. If instead of considering the distribution of magnetic moments as quantized orientations, one considers them in a continuous way, the field necessary to stop the reaction completely in the example of ferrihemoglobin with a molecular magnetic moment of $5.3 \times 10^{-20}$ erg/Oe at $300^\circ$K, is $8 \times 10^5$ Oe. It is concluded that the derived equations show that an inhibitory effect can be maximized by decreasing the temperature, increasing the field intensity, and the value of the molecular magnetic moment. It remains to practically apply the derived inhibition factor to well-known enzymatic reactions and the differential equations of biologic growth. Valentinuzzi points out that this is a very difficult task.

Gross has suggested from his observations of the general inhibition of biologic processes in magnetic fields and specif-
ically the delay of antibody production in high gradient fields, that the effects might be mediated by a distortion of the bond angle of key paramagnetic enzymes necessary for the synthesis of macromolecules. In the case of free radical intermediaries, the unpaired electron will assume a preferred direction, as we previously mentioned, causing an inhibition of the rate of reaction. When the unpaired electron is in a transient state and is localized in the form of an sp$^3$ hybrid to form a covalent bond, it is hypothesized the electron will have its orbital changed by the external field, and the reaction of which it is a precursor might be prevented from occurring for a short period of time. If the energy removed is great enough to affect the level of activation it is possible that the reaction will not take place. The change in the orientation factor for bonding of .03$^{192}$ calculated by Gross' mechanism would be sufficient to produce the observed biological change. He further noted that the effects would be greatest on the large molecules where disturbances due to agitations would be at a minimum. At last report Gross' laboratory was numerically investigating the strong possibility of an indirect biologic action of the magnetic field involving redistribution of these chemical components of biologic systems having permanent and even transient paramagnetic susceptibilities. It is generally agreed that although these forced are small, they may be able to upset the chemical equilibria of living systems.$^{193}$ A great deal of current research is concerned with investigation of the effects of magnetic fields on the reactions of the enzyme trypsin in high magnetic fields.$^{194}$
The Barnothys in particular have suggested another possible mechanism of magnetic interaction involving quantum mechanical effects on proton tunneling. This is particularly relevant to the question of a magnetic influence upon chromosome structure. It is postulated that the magnetic field can change or split the energy levels of the nucleotide bases of DNA helixes in a manner analogous to the Zeeman effect discussed earlier. A change could take place in the depth of the potential wells formed by attractive forces exerted by the two lone electron pairs on a common shared proton forming the hydrogen bond between complementary nucleotide bases. The probability of proton tunneling between base pairs could be changed causing an unequal number of reversed tunnels, and leaving many of the reduplicated bases in a tautomeric form. In this manner errors might be introduced in the DNA code when the normal complementary bases are not attached to the tautomeric bases. These errors multiply exponentially and the genetic code could be influenced. It is suggested that these possible effects could be investigated experimentally by activating the magnetic field only during the time of DNA replication in synchronized bacteria. However, mathematical treatment of these hypothesis has yet to be performed.

It has been found that the magnitude of the biomagnetic effect is roughly proportional to the field strength rather than to the square of the field strength, following Maxwell's equations. This supports the notion that the magnetic field acts on those molecules that have permanent magnetic moments (or through a quantitization of the magnetic moments of the electron pairs). Evidence is still in conclusive.
By considering some of the proposed theories we have seen that in the case of the indirect paramagnetic action on basic biochemical processes that current research is approaching with a more precise understanding of the basic magnetobiologic mechanisms. However, it in all probability is more likely that the various physical effects all exert their separate influence to produce the observed biomagnetic effect.
Biomagnetism

Alternating Fields and Phosphenes

The only biomagnetic effect that has been repeatedly demonstrated in human subjects, magnetophosphenes, is the result of alternating, rather than static, magnetic field. Early researchers with electromagnets often placed subject's heads in moderately large alternating fields; but because of the high driving frequency, no sensations were noted. In one such work, Peterson and Kennelly placed several men's heads and an entire boy in various powerful electromagnets, with fields between 1000-25000 c.g.s. lines/cm². The frequency of alternation was 140 c.p.s. and 280 c.p.s. and it is understandable that no phosphenes or other effects of the field were noticed. Several years later, Thompson had the good fortune to have an electromagnet with an alternating field of 50 c.p.s. and 1000 Oe. When a man's head was placed in the coil a dull, flickering, blue-white light (magnetophosphene) was noticed all over the visual field, whether the eyes were open or closed. In 1911 two Americans, Magnusson and Stevens conducted a methodical investigation of the phosphenel phenomena, again using a coil that slid down over the entire head. They tried various field intensities up to 2000 Oe. (28,000 ampere-turns), and varied the frequency from 5-70 c.p.s. There was no mention of exposure time, but it was probably significantly less than a minute because they noticed
a rapid decrease in the intensity of the phosphenes after 10-15 seconds, and the subjects soon became quite uncomfortable in the warm, stuffy coil. It was noticed that the magnetophosphenes produced were strongest between 20-30 c.p.s.; above and below that value they became significantly weaker. Out of the fifty-nine exposures, four were possibly within the subject's alpha range (8.5-12 c.p.s.), and it was noticed that stimulation at these frequencies caused the whole field to flicker in phase with the source. This is certainly a relevant finding for the possible existence of a magnetic driving effect, similar to photic driving.

In the last reported investigation of the effects of alternating magnetic fields on human subjects in 1947, few improvements were made on the techniques of earlier works, especially as regards the production of effects other than phosphenes. A number of male subjects were stimulated near the temple for 10-60 seconds, with a field of 200-900 Oe. concentrated by use of a soft-iron core. The frequency of alternation was 10-90 c.p.s. But, there was no detailed list of the exact stimulations, so that no conclusions can be drawn about the variation of other possible effects with frequency. For most of the stimulations, a 60 c.p.s. sinusoidal source was used to drive the magnet. It is possible that other effects might have emerged with a square-wave source. It was noticed that the phosphens fatigued after a few seconds, and that no phosphenes appeared when the stimulus was placed near the occipetal area. The authors concluded that excitation of the retina, rather than the optic nerve, was res-
ponsible for the effect, since there was no change in magnetophosphenes if the eyeballs were pressed during stimulation.

Valentinuzzi has investigated the quantitative relationships that are responsible for the phosphene effect. Equations are derived for the frequency dependency and the threshold in terms of known retinal properties, however, we needn’t go into them in detail. It has also been reported that recent investigations of the phosphene phenomena show that the effect can not be explained by magnetic induction alone; a part of it is due to the direct action of the magnetic field. Unfortunately, the sources of this work are not available to us, and we can say no more about the nature of magnetophosphenes, except that taken into account that underlying the phosphene phenomenon, are magnetic effects in addition to those due to the large currents induced whenever the field is turned on or off.

A brief consideration of the general sketchiness of data recording and misunderstanding of alternating stimulus in previous experimental designs, should make it clear that the conclusion that the production of phosphenes is the only effect on perception of an alternating magnetic stimulus is unwarranted and premature. Until recently, researchers had not thought of controlling one or more of the following crucial parameters in their experimental designs:

Intensity of the magnetic field: measurements have often been taken for the average field in the gap of the magnet, instead of the field at the point of stimulation. Measurement of gradient change of field has not generally been distinguished
from measurements of fields without gradients. It has also been assumed that greater field strengths will *a priori* produce greater effects. Our present lack of an adequate theoretical understanding of the biomagnetic mechanism makes this generalization premature. The effects of greater fields could easily produce qualitatively different effects through different mechanisms. There is also some indication that the field strength in certain instances, must be within a defined interval, lower or higher values having no effect.

**Frequency of stimulation:** many of the failures to find perceptual changes of a more subtle order can perhaps be attributed to an incomplete understanding of the effects of changes in the alternating frequency of the field. Since Magnusson first noticed that the phosphene effect was strongest at 20-30 c.p.s., subsequent work concentrated on stimulations in this range. However, if we may be permitted to generalize from photic stimulation techniques (not an unreasonable generalization since phase-locking is a property of cortical mechanisms and not of the specific sensory pathways), effects on perception and awareness are undoubt
edly strongest at frequencies in the alpha range (3.5-13 c.p.s.). There are very few recorded stimulations at these frequencies; and any possible more subtle effects would likely have been masked by the strength of the magnetophosphene and prior conditioning of expectation for phosphenes.

**Duration of stimulation:** when previously reported, the duration of the stimulus for human subjects has been from ten seconds to a minute because fatigue for phosphenes sets in rapidly.
The uncomfortable physical set up of the equipment incorporated in previous experimental designs made prolonged exposures difficult for the subjects to bear. It has already been mentioned that there is a rather long latency period in which the magneto-biologic effect gradually builds. It is therefore not unreasonable to suggest a minimum exposure time of one-three minutes for the investigation of subtle perceptual changes due to alternating magnetic stimuli. It has also been demonstrated that effects persist for sometime following exposure. Further stimulations during this period (which is approximately as long as the exposure time) will encounter interference from previous stimulations. It is therefore advisable that recording of data be made after each stimulation, allowing the previous effects to subside.

Placement and quality of stimulation: little attention has previously been given to the location of the stimulus and its relative concentration or difuseness. Because of the desire to produce phosphenes, the field has often been diffuse, encasing the entire head and possibly diminishing effects by vector cancellation. When a concentrated field was used, it has been directed at the center point between the eyes, omitting other placements that would perhaps influence cortical activity directly. Barlow's work placed the concentrated stimulus near the occipital lobe; but no attempt was made to determine whether the field actually penetrated the skull and protective layers covering the brain.

Prior expectations and experimental setting: conditions have improved remarkably from the early research of Peterson.
In 1892 in which the five experimenters who also served as subjects openly stated their negative expectations before the start. In that experiment the subject was lying on a hard board with his head and shoulders crammed inside the coil. He was surrounded by three assistants who held his wrist to determine pulse rate, placed their ears to his chest to monitor respiration and periodically tapped his knee to determine changes in reflex behavior. While modern research is more careful, the problems of investigating subtle perceptual changes have not been fully appreciated in connection with both alternating and static magnetic stimuli. In all previous work the expectations of both researcher and subject have been set for phosphenes, or an effect of similar strength. If phosphenes have been the produced effect in the first forty stimulations, there is a good chance that they will be seen on the forty-first even if there is no actual activation of the stimulus. It is even more likely that once expectations are so set, the subject will be insensitive under the pressure of continuous questions and answers during the time of exposure, it is also quite unlikely that a subtle change in awareness or state of being could take place or be discriminated.

The sophisticated techniques used in perceptual studies to eliminate response bias and prior conditioning of expectation, have not yet been applied to work with the magnetic stimulus to eliminate experimental artifacts.

Our survey of previous research in humans with alternating stimuli that has revealed in no research to date have all the above mentioned parameters been adequately considered. Further
research taking these factors into account is necessary before any definitive conclusions can be drawn about the effects of alternating magnetic stimuli on humans.
Conclusions: We have investigated the known biologic effects of static magnetic fields and given consideration to their possible modes of action at the neuronal and molecular levels. We have been rather broad-minded in considering, under the title of Psychomagnetism, that experimentation undoubtedly deals with psychogenic effects. We may summarize the following qualities of static magnetic fields: it is weak, non-specific, has a long period of latency, shows great inter-species variation, is predominantly inhibitory, persists after the stimulus is turned off, can probably be consciously sensed under proper conditions, and acts predominantly through an indirect biologic mechanism.

As for our initial aim, we may conclude that the static magnetic field is not the tool we are seeking for awareness research and at most could serve in a secondary capacity, possibly predictably modifying the effects of more potent stimulus. However the perception of a static magnetic field in humans is still an open-ended question. Lower organism sensitivity to fields of a few Oersteds and possible implications of the EEG of mammals in static fields of a few hundred Oersteds might lead us to believe that such humans could be trained for sensitivity. The results of Kamiya's training in the conscious production of alpha activity is possibly relevant in this connection. To our knowledge, no one has yet attempted to do this. Some of our proposed experimental work along these lines. Assumedly, it would be easier to discriminate static fields when such a stimulus is paired with a phase-locked alternating stimulus.

In our consideration of human sensitivity to the alternating
magnetic field, we have seen that the phosphene phenomena is to date the only reported effect, very likely because of inadequate control for one or more of the experimental parameters, such as frequency, and duration of stimulation. We would at this point suggest the use of an alternating magnetic field as a possible stimulus in awareness research because of the likelihood of an effect similar to photic driving. The chief advantage of such a stimulus would be its non-specificity; it could not be blocked by a shift in attention as could rhythmic photic stimuli which come over specific sensory pathways. In conjunction with one or several modal-specific stimuli, this would undoubtedly provide a useful new tool for investigations of awareness, perhaps by extending the rhythmic spillover discharges to even larger areas of the brain.

It will remain as a separate investigation to consider the physiological and behavioral effects of currents induced as a result of the alternating magnetic field, since their properties are likely to be qualitatively different from simple changes in the gradient. Current researchers have put off investigation of the alternating magnetic stimulus until the effects of the static stimulus are well understood. The next section defines an adequate experimental set and setting in which further investigations can be made of the effects of alternating magnetic stimuli on human subjects. Appendix A contains proposals for some preliminary research to deal with the possible magnetic driving effect of the alternating magnetic stimulus. Appendix B is a preliminary heuristic program to control brain-stimulus feedback, thus
providing the control unit for a flexible, automatic device to assist awareness research.
Preliminaries

Awareness is largely ignored today. Up till now, with the exception of its diseased manifestations in psychoses, it has been left to the wordy realms of the philosophers. This is not the right place for it, for above all, awareness is a practical matter, and as such should be investigated with modern laboratory tools and techniques. Some of the sources of an objective study of awareness are electroencephalography, clinical research with psychotics, neurophysiologic research employing brain stimulation techniques, the subjective disciplines of India, China, and Japan, research with psychogenic chemicals, and the techniques of current psychologic investigation.

Attempts to come to grips with the basic physiologic mechanisms underlying or supporting awareness are currently severely hampered by totally inadequate models. The limitations of the mechanistic physiological approach have repeatedly been demonstrated. All that presently can be said is that the phenomenon of conscious awareness is an emerging property of non-specific populations of cortical neurons activated upwards and downwards by specific reticular brain stem circuits. Awareness somehow manages to select certain cortical processes while excluding others, and is quite independent of neural data from sensory systems. Most researchers are quite willing to forgo any previous concept-
ions about its manner of functioning, especially the notion of an awareness center in the brain.\textsuperscript{213}

In the search for new conceptual tools, reference is made to the widely disparate fields of information processing\textsuperscript{214} and the Eastern awareness disciplines.\textsuperscript{215} Research with awareness does not have to wait for classical neurophysiology to uncover the mechanisms of perception, conscious control of action and memory before beginning an enquiry into the nature of awareness. It can and should take off on its own, equipped from the start with an adequate functional map of the states and properties of awareness, and having in mind fundamentally different attitudes and goals. Research with awareness is the next step in the evolution of the behavioral sciences --- the explanation, prediction and eventually, in some manner, the control of man's internal environment through induced changes in the powerful awareness function. To many this is a frightening prospect, conjuring visions of the control of an individual's thoughts by the societal manipulative machinery. But this paranoid nightmare represents only one of the possible uses that could be made of the findings of this emerging study. There also exists possibilities of rapid electrical learning, cure of mental disease such as anxiety neurosis and the psychosis, new synthetic forms of recreation, and even of aid to the initial phases of spiritual development, or as it is called in America today, consciousness expansion.\textsuperscript{216}

But it is too early in the game to discuss these things in their reality. For now the infant field of awareness research
must content itself with the mundane task of defining its terms, developing its tools, standardizing and duplicating its findings, and above all else, clearing away the many cobwebs of ignorance and superstition that have grown around it through its neglect in these Western realms. Our purpose here will not be to review the groundwork laid down by those previous investigators who worked with psychogenic chemicals, internal brain stimulation or the naturally occurring psychotics, but to outline the beginning of an external electric approach to awareness research which entails a rigid adherence to electrophysiologic data and provides adequate control of input and subjective output. Nor is it our purpose here to detail the practical subjective basis of our awareness models. We will be content to detail the information necessary to approach questions in awareness experimentally.

Underlying awareness research is the assumption that human beings possess a certain physiologically undefined ability to consciously control their mental and physical processes. This ability, called awareness, is not the same in any two persons, and is subject to an evolutionary principle whose ultimate aim is in part an ever more advanced use of the equipment of the nervous system by the reasoning mental individual. A further assumption is that there is at least a partial connection between the phenomenon of awareness and the physically measurable processes of the nervous system, and that it is possible to measure awareness and alter it to some extent from without through the control of some presently dimly defined parameters.
The question of goals in awareness research is particularly crucial since ethical questions are raised which should be dealt with at the outset. It is however impossible to control the use that will be made of any new information. In the case of awareness, certain aspects have long been kept guarded from the unprepared general populace through the use of metaphor. If it be pointed out that this is an area that should not be explored because of the possibilities of misuse by governments, corporations, and other misguided power-seeking groups or individuals, it should be noted that a great deal of success has already been achieved by such agencies in controlling and physically destroying people's minds through the use of subtle devices like schools, drugs, newspapers, books, radio, television, and "therapy." If we were to ascribe any political implications to our work, it would be to free the individual awareness phenomenon from the imprisonments imposed on it since birth by the social apparatus. But the use that will be made of the emerging data is largely out of our hands; we can only do our work and hope that civilization is ready to make a constructive use of the findings. Our goals in undertaking such an investigation is to gain further information about the mind-body interface and possibly to accelerate the mental evolutionary process in the individual and the race.

It should be noted that there are some inherent dangers in dealing with stimulations that influence awareness. One hears about them especially in connection with the current LSD fad in America. There are the possibilities of induced psychosis and
other unpleasant experiences, as well as the normal physiologic
dangers concommitent with stimulations of human beings. To over-
come these dangers, it is absolutely necessary that researchers
in this area be properly trained in the internal disciplines, as
well as in medical science. It is absolutely necessary that the
researcher be in touch with the subjective state of his subjects.
This is especially true for the early stages of research when
little can be decided about the internal subjective state from
external physiologic or behavioral measures. This requirement
for subjective training will no doubt meet with strong objections
from some. But these are the rules of this particular game. In
the past when these rules were not observed only further confusion
was added to our knowledge. The real dangers in awareness re-
search are that there will be further misunderstanding of the data
by researchers ill-equipped to understand and interpret the sub-
jective states associated with changes in physiologic and behav-
ioral parameters.

Awareness research considers a whole spectrum of states from
deepest coma through the conventional states of sleep and wakeful-
ness, to the most intense forms of waking concentration achieved only
by a very small percentage of the population. Many of the forms of
unconsciousness have been the subject of intensive investigation. Our focus will therefore be on the more intense states of waking
concentration, for by looking at the awareness phenomenon in its
most developed form, it is hoped that its properties and func-
tional boundaries will clearly emerge. The existence of intense
forms of mental activity quantitatively and qualitatively far beyond the standards measured by psychologic tests of intelligence, is a part of the evolutionary foundation we have given awareness research. The demonstration of their objective reality and the investigation of their electrophysiological characteristics is a mandatory first consideration for any study of awareness based upon a sophisticated subjective model of the states of human awareness. Progress has been made in this direction by the several scattered investigations of electrophysiological data in practitioners of awareness disciplines. In general the results show that the intense forms of concentration are not hypnotic trances or forms of sleep or stupor, as might be surmised from casual observation of persons in such states which reveals unresponsiveness to external stimuli, and an absolute immobility of the body. EEG recordings of practitioners of the awareness disciplines, called yogins, during the state of concentration, called meditation, often display patterns not found in any other known state. There are variations with the type of practice and the degree of development, but the existence of characteristic changes in all cases where there is some degree of proficiency in meditation, has been clearly demonstrated. Increased amplitude and/or changes in frequency of the alpha range, and a complete lack of alpha-blocking with strong external stimulation are common findings of recordings made during the state of high meditation. The results can only be considered preliminary and it is hoped that in further studies careful attention will be paid to the type of
meditation used by the subjects, as well as subject's descriptions of the states attained.

It is worthwhile to have in mind some descriptive definition that is general enough to take in the various states of meditation to use in connection with a discussion of the particular experimental results. It should be stressed, however, that we are not talking about a single phenomenon with a particular specific set of characteristics, but an entire class of subjective experiences, ranging from preliminary practices and experiences to very advanced ones. There are well-delineated plateaus that are reached during the progress of meditation, and one in particular, samadhi, has been a subject of electrophysiological investigation. We quote a definition of one type of samadhi, with the knowledge that such definitions can only be used for identifying these states for purposes of discussion. They are not descriptive in that they have no connection with the internal subjective state they try to define, and can not be used to discuss the qualities of the experience. Samadhi:

A state of one-pointed, quiet and yet attenuated awareness of I-ness that is so deep in the absorption of I-ness in the meaning of an idea, in a God-concept, in a syllable (like the sacred syllable Aum), in some body zone (like the middle of the eyebrow), in a color, form, sound or experience or in the internal representation thereof becomes so drastically complete that irrelevant and fluctuant specificities of perception or thinking disappear, only the identified I-ness with the object of thought remains and stimuli from the somatic
system or external world do not reach the consciousness of the meditator for a short or long time.\textsuperscript{224}

In practice, a meditator is seated in one of several cross-legged postures, which can be maintained without motion for several hours. EEG recordings in all reports show no significant muscular activity during meditation. The meditator begins with a fixation of attention, which leads into the ecstatic state of samadhi. In an early study, it was found that the cardiac rhythm showed clear and perfect parallels to those of the EEG.\textsuperscript{225} Later work found definite accelerations of cardiac rhythms during the high states of meditation; and a clear slowing down following the ecstatic period.\textsuperscript{226} In the same research, EEG recordings displayed a prominent acceleration of the alpha rhythm of 1-3 c.p.s. in the occipital parietal and temporal portions of the cortex, the increase being greater in those subjects with the greatest training. There was a diminution of the amplitudes and distributions of the faster compound waves with very few at fifteen, twenty or thirty c.p.s. In the Rolardic area there was the appearance of beta rhythms of 16-20 c.p.s. and it was noticed that the amplitude of particular rhythms were augmented if they appeared before the meditation session. Fast, low-amplitude activity was generalized over the two hemispheres, often exceeding 20-30 c.p.s. and sometimes even 40-45 c.p.s. During the highest period of samadhi the amplitude of these rapid rhythms often reached the immense value of 50 microvolts. As the meditation began to subside, long, frequent bursts of slow alpha activity of 7-8 c.p.s. appeared. Sensory stimulations during meditation did not inter-
with the rapid high amplitude rhythms.

There are several well-founded reasons for believing that the high-frequency, high-amplitude rhythms which appeared were not artifacts of muscular movement: (1) These patterns clearly develop from the Rolandic beta rhythm which gradually increases in amplitude, and from the dominant alpha rhythm that slowly and regularly undergoes changes in frequency. (2) Bi-polar recordings from the top of the skull, where there are no muscles, showed the same high-frequency, high-amplitude patterns. (3) EMG recordings displayed muscular relaxation and frontal polar electrodes showed that there were no movements of the head muscles. (4) These rapid rhythms persist unchanged for hours.

The conclusion can be drawn, with the elimination of possible muscular artifacts, that the state of meditation under study is a unique intense form of concentration of the thought processes. Intense, generalized cortical excitation is sufficient to explain the observations, without invoking processes involved with local or diffuse inhibition. It might be noted that several European and American subjects in this experiment, who claimed to reach the highest states attainable, displayed electrical activity characteristic of the early stages of meditation in the more advanced Indian subjects.

Another early study, made in India in 1957, recorded eight physiologic variables from forty-five yogins in ninety-eight sessions. The majority of subjects were practitioners only of the lower forms of physical yoga (hatha) that are commonly
associated with standing on the head and the like. None reported reaching the state of samadhi during the session, at least partly because of the disturbance caused by having electrodes and tubes connected to all parts of the body to measure EEG, EMG, EKG, plethysmogram, respiration, GSR, skin temperature and blood pressure. It is amazing that under these conditions they were able to enter into a state of meditation at all. The results revealed a definite stabilization and reduction in the rate of physiologic parameters. Respiration decreased up to 50% compared with the control period, and sometimes was so slow that it could not be counted. Blood pressure rose up to 106% over controls, characterizing a state of alertness. The GSR showed a 70% increase in resistance without any change in the EEG or EKG during that particular period of meditation, indicating an initial state of relaxation without diminution of waking activity. In addition, there were spontaneous variations of the GSR, without external stimulation, that might be associated with a shift in attention or a variation in central excitability during the warm-up period.

The EEG during the height of the meditation was not like any known state of sleep, drowsiness, dream, or coma. The alpha rate increased to 13-14 c.p.s. with some voltages between 150-300 microvolts. The normal alpha resting pattern was 8.5-11 c.p.s. with 20-100 microvolt amplitude. However, these great changes were only accomplished by a few of the masters. The majority were not advanced in meditation and did not achieve as high values.
A complete lack of EEG response to external stimulation was noted in several of the more advanced yogins, but it was more common for the external stimuli to produce small ripples in the EEG which apparently did not affect the meditative state. It is possible to conclude from this study that yogic meditation is accompanied by an initial deep relaxation of the autonomic nervous system and a high degree of conscious attention that is disconnected from external activity.

It is tempting to theorize as to why there was no blockage of the heightened alpha activity in response to the external stimulus. It could perhaps be some form of adaptation phenomenon often noted in the EEG of persons subjected to repetitious stimuli. But, more likely it involves an autonomous functioning of the RAS-cortical awareness "system" without the usual activation by sensory afferents. There is other evidence of the independence of awareness from sensory systems that might be of some relevance. Jasper's discovery of detectors in the sensory part of the thalamus (ventrobasal complex) that do not respond consistently to any form of sensory stimulation, indicates that factors relating to conscious awareness, rather than sensory discriminations are important in some cortical processes. The process of meditation could conceivably involve some higher order interaction with these novelty detectors. Implications of the phantom limb phenomenon as well as sensory deprivation research also indicate that there is significant independence of sensory information and conscious experience. But in no way is there any indication of the manner
in which the awareness "circuits" could be autonomous.

In Japan, studies were made of practitioners of Zen meditation. It was found that even with eyes open there was virtually continuous alpha wave activity with greatly increased amplitude. The alpha activity was not interrupted by hand claps or bells. It is not clear from this study what the differences might be between the Indian and Japanese practices. A new comparative study of practitioners of the various awareness disciplines is needed to elucidate quantitative and qualitative electrophysiological differences.

There is only recorded follow-up study of the physiological mechanism underlying the state of samadhi. Studies were again made of four yogins practicing meditation. All of them showed prominent alpha activity in their normal resting EEGs; which increased in amplitude during the meditation. One showed occasional hump activity in the parietal zone, although he reported being awake during the entire period. Before meditation the various flashing lights, ringing bells, hot test tubes, and vibrating tuning forks blocked alpha activity. During meditation no blockage occurred to external stimulation. One yogin practiced a concentrated "pinpointing of consciousness" on the vertex. The frontal electrodes recorded clear blips during this period. This is the clearest evidence offered to date of the conscious control of intrinsic brain waves. The authors note that the significance of such prominent alpha activity during meditation is not clear, although it is noted that the RAS is capable of autonomous discharge without activation by sensory afferents.
Alpha activity may be a reflection of this discharge. Alpha and beta rhythms undoubtedly arise from a system of subcortical pacemakers. The authors conclude that the basis of the meditative state are internal loops between the cephalic RAS and the cortex without activation from sensory afferents. It is also noted in this study, that beginners with prominent resting alpha activity have greater ability to continue the practice of yoga. Further studies of the more advanced yogins would be very desirable, but such subjects are unfortunately often sceptical of the merits of scientific investigation.

Electrophysiological studies made of hypnotic and psychchemically induced states clarify the differences between these states and the concentration of awareness induced by meditation. In the hypnotic state there is a reduction in the amplitude and continuity of alpha waves and a fluctuation of the base line, similar to a naturally occurring drowsy state. It was found that there are two stages to hypnosis: the hypnotic sleep and the hypnotic trance. In the latter, brain waves are generally inhibited, and there is the regular appearance of slow, low voltage waves. In the case of deep hypnotic sleep, there are slow waves of high voltage which sometimes display spindles. It is apparent that the state of samadhi is nothing like either the hypnotic sleep or the hypnotic trance. A great deal of interest has recently been focused on the psychogenic chemicals, especially LSD-25. Claims are often made that the experiences induced by these chemicals are similar, if not identical, to those achieved by the practitioners of the awareness disciplines.
The results of one EEG study of ten normal adult males who were given moderate doses of LSD-25 indicates that during certain portions of the drug-induced experience there are gross electrophysiological similarities to the meditational states. A large amount of continuous alpha activity was noted, 1-2 c.p.s. faster than during the control period. During periods in which the eyes were closed and the subjects reported visual hallucinations, the alpha activity was suppressed. There were regular changes in the amplitude modulation of alpha which varied with the kind of subjective experience reported. When the subject reported a large amount of mental activity, the average values of alpha were lowest. During periods with great emotional content, alpha assumed a characteristic repeating two peaked pattern. When emotional content was suppressed the EEG assumed a "valley" configuration. It is possible to conclude that the state induced by LSD-25 does not show the sustained regularity of EEG activity that characterized the studies of the yogins. The fluctuations in the amplitude with variation in emotional content are not indicative of a continuous state of intense concentration. Nor was there any indication of an ability to suppress external stimuli. It is now well established that there are several previously unknown states and modes of awareness. It will be necessary to develop methods for carrying on investigations with normals, since highly trained yogins are hard to find, while the chemical stimulus in question is highly unpredictable and might have unfavorable physiologic effects of its own.
Suggestion and Subjectivity

In dealing with awareness it is likely that artifacts of set and setting will influence the outcome of experimental work. There are many possible ways in which extremely subtle cues may enter into experimental design. It has been demonstrated that laboratory environment itself produces undesirable effects on the perceptions of subjects who are under the influence of psychogenic drugs. When the environment changed from a laboratory to a more supportative setting, the content of the hallucinations was greatly changed. In the case of electrical stimuli, it is not necessary to carry on all work in the middle of the forest since it can be expected that the effect of the external setting will overcome the blocking of normal visual and auditory stimuli. However, it is important to control the initial reactions of the subject prior to stimulation and it is suggested that the effect of the laboratory setting be minimized by the elimination of all spurious equipment and the isolation of the subject in a room apart from as many of the experimental games as possible. It would be ideal for the subject to be in a light attenuated, sound proof, virtually empty room, while the work of setting equipment and recording data went on in an adjacent chamber. It is true that such a situation will cause subjective elaborations of its own, perhaps like those of the subjects in Hebb's sensory deprivation research, but by holding the parameters of external setting constant we will take a first step to improve the situation as it is in current research.
Observers are often the most significant stimulus in subjective research. Relevant in this connection are the findings that the amount of mescaline needed to induce the oral syndrome in monkeys is greatly reduced when an "observer" is present.\textsuperscript{236} In the case of research with humans it is quite important that the possibilities for such things as unfavorable elaborations to the researchers tone of voice, impersonal treatment of subjects, or any one of a number of other factors be taken into consideration. Since, for the most part, such effects are quite unpredictable it would be best to eliminate them by having minimal contact between researcher and subject prior to and during the period of stimulation. It might even be best to have instructions previously recorded on tape. When it is necessary for a researcher to talk to a subject he should be extremely careful to provide as neutral a stimulus as possible by carefully controlling his tone of voice and gestures and spurious conversation with subjects. He should especially avoid crisp, authoritative, or over-friendly tones of voice. The aim here is not to eliminate all artifacts of the external setting and their psychological elaborations in the subject, since this is presently impossible, but to hold them fairly constant in experimental designs to facilitate the reproduction of results by other investigators.

Another source of artifacts are overly suggestible subjects. For initial work, one should select stable subjects who have a significant percentage of resting alpha activity. It is also important to control the information that the subject receives about the nature of the experiment, to avoid bizarre prior expect-
ations. The use of double-blinds and control runs also serves to isolate and minimize artifacts due to suggestion. (See "Appendix A, Discussion").

It is important to decide how subjective changes might be reflected behaviorally since it seems desirable to have as many sources of data as possible. But there are grave dangers when one draws inferences about subjective states from outwardly observable data. Objective observations based on motor behavior are not adequately correlated with degrees of awareness to sensory stimuli, especially in unusual subjective states. Kluver correctly criticizes current investigators for their lack of concern with the conscious significance of these "objective" behavioral measures. An objective measure of time-perception might be of some significance (See "Appendix A, Discussion"), but it would perhaps be best for future investigations of subjective phenomena to shy away from behavioral measures of any kind, and deal strictly with electrophysiological data and subjective reports, neither of which have received adequate attention. Lack of respect for subjective reports in current work can best be understood as a disinclination to isolate the underlying constancies from the voluminous reports.
New Tools—Photic Driving and BSF

In the search for new ways of investigating awareness in the laboratory, attention has been focused on the driving of brain waves in response to rhythmic photic stimulation and the technique of brain-stimulus feedback (BSF). It has been found that at a critical threshold of approximately 2.7 c.p.s. rhythmic photic stimulation, the evoked response (after-discharge) shows a sinusoidal form different from the response to single or multiple non-rhythmic stimuli. These responses are very similar to intrinsic alpha activity, and can be made to appear even when there is no prominent alpha rhythm in the resting EEG. The frequency of the evoked response is not related harmonically to the flash frequency, but its amplitude increases with frequency and reaches a maximum at 10-12 c.p.s. stimulation in most subjects. At this frequency the cortical interactions, and hence the subjective effects are greatest (See Appendix B). The alpha-like after-discharge at lower frequencies is most likely a form of synchronized intrinsic alpha wave, but when the stimulus reaches 10 c.p.s. it is hard to determine whether it is an evoked response or a modulation of intrinsic alpha activity. At lower frequencies, the phenomena of after-discharge results from the summation of responses -- the phase where the stimulus is given is on the rising phase of the evoked wave preceding the stimulus. The phenomena of photic driving as it applies to awareness research
may be summarized as follows: at approximately 10 c.p.s. rhythmic stimulation, there is a pacemaking effect on the intrinsic alpha rhythm with associated subjective changes. It is not necessary for our purposes to consider differences between the average evoked response and the average waves of the background EEG.

BSF consists of triggering an external stimulus exactly in phase with some parameter of cortical activity by using feedback from the EEG as a signal to trigger the stimulating device. The parameter is usually the presence of some specific range of frequencies as determined by a band-pass filter, although it could equally well be the amplitude of the signal. In practice, it is found that frequencies of stimulation within the subject's alpha range produce the greatest amount of synchronization for reasons discussed in the last paragraph. For photic stimulation the response is strongest in the occipital area, but shows marked "spillover" in the frontal and temporal areas. When using BSF for awareness studies, the stimulation may either be modal-specific—visual or auditory—or of a non-specific modality (the search for such a non-specific stimulus for use with BSF led us to an investigation of alternating magnetic fields). It is also suggested that stimulation may be multi-modal for the study of the cortical interaction of the sensory systems, but as yet this has not been tried.

There are striking changes in awareness associated with BSF which were investigated in the early 1950's by Walter and others, although in subsequent investigations these
changes were rarely mentioned. It was noted by Walter that the responses to flicker varied with the mental state of the subject. A description of the subjective effects is quoted in "Appendix B." Electroretinograms during the period of stimulation revealed no unusual changes, although there were sensations of movement and pattern along with the changes in "state of being." Correlation of subjective accounts with EEG recordings revealed that when the sensations are visual, responses showed up primarily in the visual projection and association areas of the brain, and when the response was non-visual, activity was increased in the area traditionally associated with the type of sensations. Walter uses these findings to support the notion that cortical mechanisms for the elaboration of sensory systems are non-specific, and further that the illusory perception of motion is due to an intrinsic cortical scanning mechanism, which is the basis for what we call attention and awareness. The concept remains a useful model for the functioning of awareness and attention.

In 1962 Mulholland found that BSF could be used to train subjects to increase alpha activity. His method was simple: a filter network extracts the desired frequencies from the EEG and triggers a relay which turns on the light stimulus. Thus the light is on when alpha activity is present and off when alpha has been blocked in response to another external stimulus, or a shift in attention. When the subject is given an instruction to maintain constant attention (no-alpha), the pattern of on's and off's is different — the alpha's are shorter and fewer and
the no-alpha's are longer and more numerous. In a later work, Mulholland\textsuperscript{247} found a quasi-periodic variation of the latency and duration of successive cortical activation responses through the feedback loop, but the relevant variables accounting for the periodicity could not be identified. There were subjective changes associated with the quasi-periodic response, although they were unfortunately, not recorded. If something about the cortical elaborations associated with awareness are to be uncovered, it is necessary to repeat Mulholland's work, making provision for the recording of subjective changes.

Subsequent unpublished uses of Mulholland's technique by Kamiya and Barlow\textsuperscript{248} reveal that in a few weeks time subjects can learn to increase the amount, amplitude and quality of their alpha activity, and further that selected subjects can learn to generate alpha at will, without the feedback system. This was done with both a visual stimulus and a frequency modulated tone. In the latter case, when the alpha tones were filtered out and played back to the subject, continuous alpha activity was generated. Perhaps this is the basis of a primitive meditation machine. Awareness changes associated with the conscious production of alpha have not been studied, but marked subjective changes show up in response to the question: "Do you notice any unusual sensations?" These are presently being catalogued by Kamiya\textsuperscript{247}.

The limitations to present ESF technique stem from the need for more sophisticated analysis of the EEG output, to reveal temporal and spatial EEG patterns of which we are presently
completely unaware. On the basis of these new patterns, changes could be made in the pulsing routine to phase lock for complicated patterns associated with the specific characteristics of complex stimulus parameters. We would then be able to study these steady-state recurring patterns and determine precisely the manner in which changes in stimulus parameters affect intrinsic brain activity. (See BARDO, Appendix B).


3. The reader is referred to Brain and Conscious Experience, ed. by J.C. Eccles (New York, Springer-Verlag, 1966), a symposium in which numerous illustrations of the current plight of physiologists who attempt to chart the correlates of mental phenomena without an adequate "subjective" model of awareness can be found.

4. L.L. Vasiley, ("Psychomagnetism; Effects on the Brain and Psychologic Occurences") Nauka i Zhizn, 28 (July 1961), pp. 7, 80-84.

5. Blavatsky, Isis Unveiled (Point Loma, Calif., Theosophical Pub.) pp. 125,162.


10. Carlo Maggiorani, La Magnet e i Nervosi (Milano, Vallardi, 1869), cited by Colombo in Mottelay, p. 195.

12. A.T. Paracelsus, Archidoxorian (1512?).


15. Ibid., vol I, p. 136.


17. Quoted from misc. Medieval sources by Mottley, p. 27.


20. Mottley, p. 64.


23. Ibid., pp. 8-9.

24. There is some disagreement. Gilbert Frankau in Mesmerism (London, 1948), P. 10; states that he believes this was proper order of events since there was no record of Hell's previous involvement either with magnets or curing the sick, Margaret Goldsmith, Mesmer, the History of an Idea (New York, 1935) adheres to the version which maintains that Hell used the magnets independently; but her sources are incomplete and the later version is probably the correct one.
26. Ibid., p. 11.
27. Frankau, p. 25.
30. James Esdaile, Mesmerism as an Anesthetic and Anative In the Hospitals of India (Perth, Dewar & Son, 1852).
31. See "Psychomagnetism."
33. Mottelay, p. 65.
34. Valentinuzzi, Magnetobiology.
35. Later attempts are detailed in "Psychomagnetism" (next section).
39. Ibid.
40. See "Biomagnetism-Current Research".

43. A prolonged application might be responsible for the production of increased symptoms previously reported by the German physicist, Bolten in 1775 (Nachricht van eihein mit dem Kunstlichen magneten germacten Versuchein einer Nerver-Krankhert; Hamburg) and others. Curiously enough, flexibility in the application schedule was never recorded before in magnetotherapy. It is an important parameter in magnetic research, since there appears to be differential sensitivity in subjects. (see "Psychomagnetism").


45. Valentinuzzi, Magnetobiology.

46. Leger, Psychodunamy, pp. 292-293.


52. Ibid.


55. Ibid.


59. Ibid.


66. These aspects of the internal set of the subject will be discussed in a later section: "Awareness Research".

67. Vyalov,

68. Beischer, Human Tolerance.


73. Ibid., p. 10.


86. Ibid.


95. Ibid.

96. Ibid.


101. Ibid.


104. Ibid.


114. F.H. Barnwell and F.A. Brown, "Responses of Planarians and


121. Ibid., p. 2.


126. Ibid., p. 197.

127. Ibid.

129. Ibid.
131. Kholodov and Veryevkina, "Salt Water Fish."
133. Ibid.
134. Ibid.
135. Kholodov and Veryevkina, "Salt Water Fish."
137. Ibid.
139. Ibid.
146. Ibid.
147. Kholodov, "Mag. Field as Stimulus."
148. Ibid.
150. Ibid., p. 19.

152. See next section: "Theoretical Considerations".


155. L. Hermann, "Has the Magnetic Field a Direct Physiological Effect?," Pflugers Archiv fur die Gesamte Physiologie, 43. (1888).


159. Valentiruzzi, "Magnetobiology".

160. Barnwell and Brown, "Responses of Planarian and Snails."


163. Ibid.


167. Mulay, "Basic Concepts".


172. L.N. Mulay, "Basic Concepts," p. 44.

173. Articles byEURATH, Mulay, Barnothy, Valentinuzzi, and Gross in *Biol. Effects* provide the most current representation of these theories.


175. Ibid., p. 16.


177. Valentinuzzi, "Magnetobiology".


182. Gerencser, et. al.


188. Valentinuzzi, "Rotational Diffusion," p. 70.

189. Ibid., p. 72.


192. Ibid., p. 76.


196. Ibid., p. 83.

197. Ibid., p. 82.

198. Ibid., p. 83.


204. Valentinuzzi, "Magnetobiology," pp.60-72 (?).


207. Barlow and Kohn, "Visual Sensations in Mag. Fields".

208. Peterson and Kennelly, "Phys. Exper. with Magnets".

   See section on BSF in "Awareness Research", and also, "Appendix B".

210. See "Appendix A".


214. Mackay.


218. This is a restricted definition suitable for research.

219. Aurobindo.


The point is that the actual reality of the experiences of other states of awareness can not be explained to someone who has not experienced them. Could one discuss Hamlet with a fish?

222. In particular the investigations of psychic research have long been immersed in obscurity because of their sole dependence on behavioral tests, and also because of a basic misunderstanding of the phenomena. The attempt to understand the experiences of the psychogenic drugs as forms of psychosis is another unfortunate illustration of the pitfalls of inadequate knowledge. Therefore, as preparation for research in awareness, it is suggested that there be a four year preparatory period of daily practice of one of the awareness disciplines, as well as medical studies.


227. Bagchi and Wenger, pp. 132-149.
237. Ibid., p. xii.
239. J.S. Barlow, "Rhythmic Activity Induced by Photic Stimulation In Relation to Intrinsic Alpha Activity of the Brain in Man," RLE, MIT, QPR 48, (Jan., 1958), pp. 128-133.


244. Walter, p. 101.


APPENDIX A

RESEARCH PROPOSALS—Magnetic Driving of the Brain In Response To an Alternating Magnetic Field and Its Possible Experimental Uses.
Statement of Purpose

It is the purpose of this research to determine whether a moderate, well-defined magnetic field, alternating in the alpha range produces a magnetic driving effect similar to photic driving; and to compare the subjective effects with those of other specific and non-specific stimuli such as phase-locked strobe-lights, psychogenic drugs, and electrical currents applied directly to the brain.

Equipment List

Outline of Experimental Procedure

I: Preliminaries

Prospective subjects will fill out a preliminary questionnaire to determine their suitability for research (see Discussion and Preliminary Questionnaire). EEG recordings will determine which potential subjects have a high incidence of alpha activity. Subjects will then be selected on the basis of the quality of their resting alpha activity. Time averages to determine the range of alpha activity will then be taken of those chosen as subjects.

II: Magnetic Driving

Operators and assistants will not be informed which parts are controls. Ordering of parts will be randomized; with the exceptions noted. Subjects will be seated in a cushion chair in the semi-darkened, sound-attenuated laboratory. They will be reassured that what follows will not be harmful or unpleasant (see Discussion). Subjects will be informed the session consists of four parts, each lasting about thirty minutes. During each part subjects will be instructed to tap the telegraph key every five seconds by their best judgment (they are told that they may count one-one-thousand, two-one-thousand, and so forth if they wish to keep track of the time). Following the first three parts EEG readings will be recorded for one minute and subjects will respond to a brief oral questionnaire (see Oral Questionnaire) which will be recorded on tape. During the fourth part, EEG recordings will be made for fifteen seconds after each two minute stimulation. After the fourth part, EEG
activity will be continuously recorded for two minutes and then for fifteen seconds per minute for the next ten minutes. Subjects will then fill out a comparative questionnaire (see Comparative Questionaire).

Part One: Strobe only. Subject is seated in cushioned chair, feet elevated, eyes closed. Strobe positioned one foot from nasion. Intensity four (on Grass Strobe). Flashing frequency adjusted to median frequency of the previously determined alpha range (tolerance is +/-1 cycle). Exposure time: three minutes. Subject instructed to tap key every five seconds by his best judgment, recorded as dots on the cumulative recorder. After exposure, EEG is taken for one minute and subject responds to questionnaire which is recorded on tape.

Part Two: Strobe and Magnet. Subject positioned as in One. Strobe and Magnet in phase (they are driven by the same generator). Strobe Intensity same as One. Magnetic field intensity is 800 Oe. as measured at scalp by gaussmeter. Frequency is same as in One. (If a CAT processor is available it can be re-set to a newly determined value of median alpha). Exposure time: eighteen minutes for strobe; three minutes for each position of the magnet. Magnet Positions: gap of magnet is situated as close as possible to skin without actual contact. Positions are numbered 1-6 (see chart next page). Subject instructed to tap key as in One. Data collection: EEG for one minute and oral questionnaire.
Part Three: Magnet and Time-Perception Control. (N.B. it is important to have this as the first part in some cases, to determine the cumulative effects of the magnetic field by comparison with a control recorded before exposure.) Subject positioned as before. Strobe covered. Magnetic field intensity is zero (both coils are activated). Frequency is same as in One. Exposure time: eighteen minutes; three minutes at each position. Magnet Positions: same as Two. Subject instructed to tap key as before. Data collection: same as Two.

Part Four: Magnet only. Frequency same as One. Three exposures of two minutes each at positions 1, 3, 5, 6. Field intensities of 800, 400, 200 for each position. Data collection: EEG for fifteen seconds after each two minute stimulation. After Part Four, EEG will be recorded for twelve minutes and subject will fill out Final Questionaire.
POINTS OF STIMULATION
FOR THE MAGNET

1. vertex (sutura sagittalis)

2. midpoint between eyes (Glabella)

3. left temple (linea temporalis)

4. right temple (linea temporalis)

5. base of skull (Fossa mandibularis)

6. occiput (Protuberantia occipitalis)

7. forehead (linea nasofrontalis)
III: Ability to Discriminate Low Intensity Alternating and Static Fields.

There are three parts in which the stimulus will be a field of varying intensity alternating at previously determined median alpha, a static field of varying intensity paired with a fixed-intensity alternating field and a static field of varying intensity alone. Subjects will be positioned as before, blindfolded. Intensity of the test stimulus will be initially set at 800 Oe, as measured at the point of stimulation in the second part. Intensity of the alternating paired stimulus will be set at 400 Oe. Position of the test stimulus will be at the point that showed the greatest EEG and behavioral and subjective changes as revealed in the second section, part four (magnet only). The paired alternating stimuli in the second part is located at a different responsive site. The procedure for all three parts is the same. Subjects will be asked to signify when they are aware of the presence of the field by a yes or no response. When a yes response is repeated twice in a row the test field will be lowered by a small amount and the testing procedure repeated. Data will be recorded at each yes or no response.

The control portion will repeat the three passes, except that both coils of the test magnet will be activated, producing no net field. For the second part, the alternating paired stimulus will only have one coil activated.

IV: Alternating Magnetic Stimulus in Brain-Stimulus Feedback (B.S.F.)

An alternating field of various intensities of up to 1000 Oe.
will be used as a stimulus for the output of BARDO (see appendix B). An autocorrelation routine will separate the signal from the magnetic artifacts in the EEG. Stimulation will run in closed-ended mode (the program will not attempt to boost the median alpha frequency) for varying times up to thirty minutes. Subjects will perform a time-perception test during exposure, and answer oral questionnaires after the system is de-activated. EEG records and behavioral and subjective data will be compared. In a second part, a modification will be made to BARDO to activate the stimulus only when alpha activity has been blocked, to determine if it is possible to maintain a consistent level of alpha activity without observable interruption for an extended period of time.

Other modifications of BARDO could allow the decision routines to modulate the intensity of alternating magnetic stimulus, in addition to frequency, and activation cycles, to determine if a continuously variable magnetic driving phenomenon will be elicited.
Preliminary Questionaire

1. Name.
2. Address.
3. Phone Number.
4. Times during the day or evening when you have at least three hours available.
5. Age and Occupation.
6. Do you have a history of epilepsy or diabetes?
7. Do you have any physical disabilities?
8. Are you presently receiving medical treatment?
9. Have you ever had regular psychiatric treatment?
10. Do you regularly use any of the following: hallucinogenic drugs, tranquilizers, alcohol? If yes, specify.
11. Do you practice any one of the following: auto-hypnosis, Christian Science, one of the forms of yoga (e.g.: hatha; laya; bhakti; shakti; karma; raja; integral; chemical; mantra), Mahayana, Tantric or Zen Buddhism, Brahminism, Taoism, Macrobiotics, Gurudgivian analysis, meditation, other ______? If yes, which one? How regularly (hours per day)? Number of months since you began?
12. Have you ever had a mystical experience (out of the body or beyond the mind)? If yes, indicate briefly predominant visual, auditory, esthetic, emotional, and intellectual qualities. How many and how often of these experiences have you had?
13. Would you describe any of your senses as being especially sensitive, as, for example, from artistic training? If so elaborate briefly.
14. Do you have difficulty sitting in one position comfortably for one hour?
15. Do you often daydream?
16. How many hours per week do you: watch television? watch movies in a theatre? listen to music?

17. Are you easily irritated by daily activities that don't go as planned?

Oral Questionnaires

Parts I-IV:

1. How do you feel?

N.B. Questions two through four may be omitted if response to first question includes answers to these questions.

2. Do you think anything has significantly changed as regards your state of mind or being since the beginning of this part?

3. Describe any unusual sensations you might be having now or that you experienced during this part.

4. Describe what you were thinking and feeling during this part.

Parts II, III, IV:

5. How was this part different from the preceding one?

6. Look at the chart on the wall (indicating points of stimulation for the magnet). What were you thinking and feeling at position I?...II?...III?...IV?...V?...VI?

7. Was there any difference between the different points?

Final Written Questionnaire

1. How do you feel?

2. Were you nervous or apprehensive at any point during the session?

3. Did you experience any unusual thoughts, emotions, or sensations during the various parts?

4. Was your awareness of the external environment altered during the course of the exposure?

5. What were you expecting to happen while you were waiting for
the session to begin?

6. How do you feel about pressing the telegraph key?

7. Which part did you like the most?

8. Did you notice any difference between the positions of the magnet?

9. Can you compare the effects (if any) to anything you have experienced previously?

10. Would you like the intensity to have been greater?

11. Would you like to repeat this experiment at some later date?

12. Do you have any suggestions for improvements in our procedure?
Discussion

Subjects: Selection of subjects by the preliminary questionnaire is designed primarily to eliminate those physically and psychologically unacceptable. Drug users will not be used in this preliminary research because of their suggestibility to altered states of awareness. Other questions aim to determine the subject's special experience with sensory discriminations. In general, subjects will be selected for stability, high incidence of alpha activity and ability to relax in the experimental situation. (Kamiya, 1967). Practitioners of one of the awareness disciplines would be ideal subjects because of their prominent alpha activity, and their ability to relax and remain unaffected by external suggestion. Several questions seek to determine whether any of the applicants practices these disciplines.

Set and Setting: An attempt has been made to keep set (internal state of subject including mood and expectations) variables fairly constant by: (1) selecting stable subjects; (2) instructing them to eat lightly the night before and day of the session and not to schedule a session on days when there are many prior commitments; (3) holding sessions on the same day of the week and time of day for each subject whenever possible; (4) giving little information to influence expecting. Setting (the laboratory environment and its influence on the results) variables have been selected to provide a neutral, relaxing, supportive environment. A sound-attenuated, semi-darkened room is kept as free as possible from equipment which might influence expectations. A comfortable chair with footrest has been selected to keep the spinal chord
straight, while allowing maximum comfort. The presence of a researcher has definite effects on the outcome of any experiment dealing with subjective phenomenon (Kluver, 1966) and these variables are largely uncontrollable. In all sections double blind procedures are being used, as regards the state of the magnet. It is further suggested, that when the operator speaks to a subject, he will be careful to speak in a warm, friendly, tone of voice, avoiding technical terms and the crisp, impersonal voice quality customarily used in laboratories as these can induce unfavorable elaborations in the subject.

Field Intensity: The choice of magnetic field intensity at 800 Oersteds in Section II (magnetic driving) is well below known physiologic safety levels (Beischer, 1962) and the need for a minimal level to produce physiological effects (magnetophosphenes-200 Oe.; Barnothy, 1964). In Section III (discrimination of fields) the paired alternating stimulus is kept at 400 Oe. to avoid a masking of the stimulus. However, the choice of 400 Oe. is arbitrary and the value should be determined from the results of Section II, Part 4 (magnet only).

Frequency of Alternation: Work done with stroboscopic stimulation at the alpha frequency indicates that optimal stimulation for phase locking (and hence maximal subjective and electrophysiological changes) is at this frequency (Walter, 1953; Kitasato, 1966), is at this frequency. The rate of alternation is quite critical. A variation of more than $\frac{1}{2}$ cycle from median alpha
will result in a greatly diminished phase-lock. (Annliker, 1966).
This raises the question of the normal variation of median alpha in an individual and the need for continuous feedback from the EEG to the alternating source that drives the strobe and magnet. The method of autocorrelation developed by Barlow (Barlow, 1959), is ideal to accomplish this purpose. However, it involves the use of additional equipment and will not be considered until later in the experimental program (Section IV-alternating fields and B.S.F.) Our assumption that we will be able to stay within the half-cycle tolerance with a mechanical setting to median alpha from a previously determined EEG reading is based upon several well-established results from EEG research: (1) Recording EEG and applying stimulation at the same time of day, we can hope to eliminate some of the gross daily variations in median alpha. Further controls to insure some similarity of subject's internal set have already been mentioned; (2) More important, however, is the phase locking effect of photic stimulation at approximate median alpha. The EEG tends to "follow" the strobe (Barlow, 1958, 1964). By alternating the field of the magnet in phase with the strobe, it is reasonable to expect that the stimulation will be orderly and the field effects on the brain will be less chaotic.

Experimental Procedures: Section II (Magnetic Driving):
Part III (Control) is to precede Part I (Strobe Only) in 50% of the runs, to insure that control is not effected by any cumulative field effects. Comparison of subjective, behavioral, and EEG data from the four parts should allow for the separation
of field effects from strobe effects and the subject's anticipatory "background noise".

**Experimental Procedures:**

**Section III: Magnetic Field (Discrimination)**

This section depends on the successful demonstration of magnetic driving in Section II of the third part (Static Field Only), however the results should be an amusing check on our procedures in this section, in addition to the controls. Part I seeks to determine a lowest threshold for Magnetic Driving, while Part 2 pairs the more potent alternating, phase-locked stimulus with the static field to test the possibility that phase-locking will increase the ability to discriminate the static field. There is good reason to believe it will from the results of Perkhanyantz (1948) and Vasilev (1919), who demonstrated that ability to perceive magnetic fields is greater during states of heightened or unusual perceptions. The Yes-No, forced discrimination tracking procedure, eliminates many response bias problems (Richards, 1967).

**Positions:** The positions of stimulation shown in the chart have been determined from informal preliminary research and are in agreement with Kholodov's (1964) findings that the diencephalon and forebrain are directly sensitive to the inhibitory magnetic field effects. One position (2) will produce magnetophosphenes. Subjective data at this position will be considered as such.

**Data Collection:** One assumption that is being made is that possible effects of the alternating magnetic field will be distinguishable from those of the strobe, by the following
procedures: (1) A comprehensive list of subjective reactions to photic stimulation at median alpha is being compiled with which to compare our results; (2) Part I (Strobe Only) seeks to separate behavioral and subjective effects due to photic stimulation alone; (3) Part IV (Magnet Only) seekd to distinguish the magnetic field effects, and EEG data from this part will be quite helpful.

There are three kinds of data being collected: electrophysiological, logic, behavioral, and subjective which will be inter-correlated. EEG data reflect cumulative changes rather than the ongoing state during stimulation. There is no known meaningful behavioral measure of the internal state of a person's awareness. Tachistoscopic tests give information about sensory perceptions. However, in lieu of doing nothing, we can use a measure of the subjective time sense to give some reflection of the internal state, since it is claimed that some altered states of awareness affect the sense of time (Annliker, 1963). (Motor reflex tests do not necessarily reflect changes in perception) (Kluver, 1966). It must be emphasized that his is only a makeshift procedure, since it is not established that subtle alterations of awareness such as we might expect from a moderate alternating magnetic field, affect the subjective time sense. A response of no change in the telegraph key record would indicate only that if something is happening, it is not affecting the sense of time. One could not conclude that there was no change in the internal state of awareness. This will have to be taken into account when the data are correlated. Since current research (Kholodov, 1964) reveals that magnetic field effects fade away gradually in the
few minutes following exposure, it is considered worthwhile to look for changes in the post-exposure EEG record of alpha activity, as a better objective indication of changes.

The type of signal-detection tracking used in Section III (Magnetic Field Discrimination) leads to a set of asymptotes if there is a significant ability to discriminate the fields.

**Controls:** Operators are in a double-blind situation as regards the presence of the magnetic field. The control for spurious subjective reactions is simple and clear-cut. When both counter-wound coils of the magnet are activated, there will be no net field; other artifacts of the magnet, such as humming sounds and heat will be present. Subjective effects from these, as well as background noise (response bias) from prior expectations and suggestibility should show up here.

A measure of the depth of penetration of the magnetic field will be made in a mock-up brain to determine whether the field is effecting cortical and subcortical levels. The possibility of alternating field effects on the cranial nerves must also be given experimental consideration.
REFERENCES FOR APPENDIX A


Barlow, J.S., "Rhythmic Activity Induced by Photic Stimulation in Relation to Intrinsic Alpha Activity of the Brain in Man," MIT RLE QPR, 48, Jan. 1958, pp. 128-133.


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APPENDIX-B

BARDO* - A Program to Alter Intrinsic Brain Rhythms

*Written in conjunction with S.M. Zinc.
Introduction

It is the purpose of this program to develop a tool to predictably alter rhythmic brain-wave activity through an external stimulus. The technique is a modification of the well-known method of brain-stimulus feedback (BSF) based upon the incorporation of a heuristic package which attempts to maintain phase-lock under varying conditions. The stimulus may be modalspecific, a strobe-light or a frequency modulated tone, or nonspecific, possibly an alternating magnetic field. In the section on goals, the subjective effects connected with BSF and the possibility of incorporating other goals in addition to the maintenance of a steady-state phase-lock, will be discussed.

Briefly, BSF consists of the phase-locking of intrinsic alpha activity to a rhythmic external stimulus, which in turn is activated by feedback from an ongoing EEG recording. This effect is based upon the phenomenon of photic driving in which the uniform evoked potentials due to single photic stimuli summate for repeated rhythmic stimulation. One of the limitations of BSF is that once the phase-lock is broken, either by some distraction of attention from the stimulus, or by fatigue, the driving system loses control until the subject re-establishes the lock (in a manner not well understood). The heuristic under consideration would attempt to introduce a novel stimulus by altering the frequency or count of stimulation in a manner intended to compensate for stimulus accommodation. Another major limitation of present BSF is that once phase-lock has been established,
the system does not change, even though an increase in frequency or amplitude might be desirable as determined by a consideration of subjective goals. Present BARDO could be updated to allow for a smooth, even pacemaking of rhythms to alter the intrinsic activity according to the criteria set forth under goals.

GOALS

In order to set the parameters in the heuristic weighting functions it is necessary to have in view some desired goals, which would vary with the experimental aims of the researcher. For this exploratory program we are using a set of goals designed to maximize the reported subjective effects of BSF. These effects have reticently been described by only a few of the researchers in the area for reasons that are not at all clear to us.5 Quoting a paragraph from Walter's popular account of subjective phenomena of the sort under consideration:6

I lay there holding the green thumbless hand of the leaf while things clicked and machinery came to like, and commands to gasp, to open and shut my eyes, reached me from across the unseen room, as though by wireless. Lights like comets dangled before me, slow at first and then gaining a fury of speed and change, whirling colour into colour, angle into angle. They were all pure ultra unearthly colours, mental colours, not deep visual ones. There was no glow in them but only activity and revolution.
The purpose given to the weighting functions, then will be to try to maintain the steady-state phase-lock of alpha, associated with these and similar subjective effects, for as long as desired. It will attempt to eliminate the stimulus fatigue reported by Alexander\textsuperscript{7} to occur when BSF is continued for more than a couple of minutes. By using the hill-climbing technique to vary the frequency of stimulation when there is a significant difference between EEG and stimulus phase, a suitable new steady state will be established according to the principle of photic driving, and the vividness of the subjective productions will be restored. The ability of the program to effect these changes exceeds the limits of manual dexterity. In searching for another goal for the heuristic package, it was decided as a result of the findings of EEG studies of practitioners of the introspective disciplines,\textsuperscript{8} to allow the program to attempt to increase the amplitude and frequency of intrinsic brain-wave activity simultaneously. Because it is extremely difficult to effect an increase in amplitude of cortical activity with modal-specific stimulation, the present version of BARDO, contents itself with maintaining the steady-state amplitude, while increasing frequency. The subjective results at best could be somewhat greater than steady-state operation and significantly less than those reported by the yogins and Zen masters.
Processing

Hardware: LINC 8 System chosen to meet following criteria:
(1) Need for rapid operation to maintain continuous real-time control of experimental situation. (2) Need for output relay registers under program control. (3) Need for Analog to digital conversion without use of auxiliary C.A.T. processor. (4) Option for visual display of input and output.

Software: (see flow chart)

**Analog to Digital Routine:** Continuously selects 400 data points per second from EEG input. Average of 40 points per wave for 10 c.p.s. Lower limit of 10 points per wave for 40 c.p.s. input. Number of data points determined by real-time limitation and need for synchronization of input and output.

**Input Analyser and Autocorrelation Routine (CALC):** Prepares information about average amplitude, average frequency, and decay for every 5 second period. It reinitializes variables every five seconds. The detailed flow of information within CALC is as follows: The amplitude of each point is read and stored in an array P. A test is performed to determine if the incoming point is a maximum. If it is the time of the maximum amplitude of each wave is stored in location t1. If not, control is returned to either the steady-state routine or the transitional decision routine as determined by the mode of an internal switch. If the point is a maximum it is added (A1) on to the previous maximum to compute A and counts the number of maxima (K) so far in that 5 second period. It then performs autocorrelation to get the decay function. The autocorrelation
function is given in standard form by \[ \lim_{T \to \infty} \frac{1}{T} \int_{0}^{T} f(t) - f(t-\gamma) \, dt \], where the integral is replaced by a summation, T=5 seconds, and \( \gamma \) is determined by the time between the first two maximum peaks of the five second interval. \((\gamma = N - M/400 \text{ seconds})\) Then the modified function is \[ \phi(T) = \frac{1}{N} \sum_{i=1}^{N} p(i) \cdot p(i-m) \], where \( M \) is the number of points from the beginning of the 5 second period to the first maximum and \( N \) is the number of points from the beginning of the 5 second period to the second maximum. There are two arrays for the autocorrelation. The first set of data points is read into the first array, the second into the second array, and the two compared. The third array is read into the first array and the third and second compared; the fourth is read into the second array and compared with the third, and so on. \( \Lambda_p \) and \( \Lambda_n \) are then calculated, respectively the difference between the minimum and maximum of the first and last cycle of the autocorrelogram, and also their times, \( T_p \) and \( T_n \). This is used in calculating \( d \), the decay factor. Finally, the following are calculated:

\[
\Delta = \ln \left( \frac{AN}{AP} \right) \quad \text{using the first four terms of the ln series}
\]

\[
\gamma = \frac{K}{T} + \frac{M_0 + 950 - N}{400} \quad \text{where } T=5 \text{ seconds.}
\]

The internal clock \( t \) is set to zero and control is shifted to the beginning of the transitional decision point.

**Steady State Routine:** Phases the strobe output pulse \( D \) with the peak amplitude of the EEG input \( A \) for peak to peak synchronization. There are three entry points into steady-state package. The first is called DRIVEN, which is entered after...
the bio-phase-lock is established to start the program and initialize time parameters. The second entry point is RETURN which shifts control between STEADY STATE and CALC when a data point is reached which is not a maximum. When it is a maximum ($A_1$) it stores $A_1$ and $t_1$ (the time $A_1$ occurs). It then calculates the difference in time $t_0 = t_1 - t_0$, between the incoming EEG pulse and the time of the last strobe pulse. If the output has not been pulsed slightly before the incoming EEG pulse, it transfers control to CALC and comes back in through the third entry point FIRE. When the output pulse fires, it stores the time $t_1'$. Then it calculates $\Delta_1 t = t_1' - t_1$ and checkes to see if $\Delta_0 t$ is greater than $\Delta_1 t$. If it is, output has been pulsed after $t_1$. We next compare $\Delta_1 t$ to determine if greater than $0.05/d$, the modified decay factor. If it is, the new pulse time $t_1'$ is equal to $t_1 + 1/\sqrt{J}$. If it is greater than $0.05/d$ then we decrement the difference in time-lag between the next predicted EEG pulse and the next output pulse. If the output pulse came before the EEG pulse (i.e. $\Delta_0 t < \Delta_1 t$), we increment the difference. In any case, the output pulse will be set to fire at time $t_1' = t_1 + 1/\sqrt{J} + \Delta_2 t$.

If $t = t_1'$ (i.e. if the clock time = time for next output pulse), it goes to CALC unless $t = 5$ seconds in which case it transfers control to Transitional 5 second Decision Point.

Transitional Decision Point Routine: At the end of a five second period, the primary decision is whether to maintain steady state for the next five seconds or, if there is a sufficient deviation in $\sqrt{J}$, whether to make changes in the frequency of output pulsation. The ultimate goal in the latter
case is to return the frequency and amplitude to the steady-state range. This could also be accomplished by a more complicated changing of the phase of the output to influence the intrinsic brain frequency by the driving effect and by selective pulsing of output (not hitting all the pulses in a train of output—e.g., hitting say only 5 out of the 10 in a one second series) to reduce the amplitude of intrinsic brain activity. The criteria used to decide when phase-lock has been broken could be more sensitive including one parameter that would reflect simultaneous changes in both amplitude and frequency (A up & V down or A down & V up) and another parameter to reflect changes in the crosscorrelation of the four electrode inputs. However, for our present purposes we have made the phase-lock decision on the basis of only substantial changes in frequency (V), and likewise have made the only output parameter from the Transitional Decision Box the alteration of frequency (V). We have done this to test the basic concepts of the system for a simple case.

If the frequency has dropped (V≤8) it increments the frequency of the output pulse by .5 c.p.s. and the next output pulse is set at \( t'_1 = t_1 + 1/(V_3 + .5) \). It tests for the next peak from EEG. If it has not come, control is transferred to CALC and back to PEAK. If it has come in, it calculates \( V' = 1/(t_1 - t_2) \). It compares this frequency with \( V \). If \( V' < V \), it checks if has gone out of the alpha range in the other direction (V≤3) if it has, it decrements the output frequency and proceeds as before. If \( V' \) is still less than \( V \), it adds another
.5 c.p.s. and goes through loop again.

If \( \sqrt{\frac{1}{2}} \), it increments the output frequency \( \sqrt{\nu_D} \), multiplies it by 1.5 and sets the new output time at \( t_1' = t_1 + 1 / \sqrt{\nu_D} \). If the clock registers \( t = t_1' \), then control is transferred to STROBE and back to PEAK. If not it goes directly to PEAK.

The same general procedure is followed if \( \nu > \frac{1}{2} \), using decrements instead of increments. Finally it exits to Steady State.

The previous procedure is a simple hill-climbing technique using two types of weights: a first approximation weight \( (\nu, .5) \) and a successive weight \( (1.5, .67) \) when the frequencies are approaching each other. The first is additive, the second is cumulatively multiplicative.

**Output Function (STROBE):** Fires output by ATR loops, records time of firing by RTA loops for use in calculating (running frequency of the strobe), and then transfers control to RETURN or PEAK.
OVERALL FLOW CHART

SCALP ELECTRODES

EEG + AMPLIFIERS

ANALOG TO DIGITAL ROUTINE

INPUT ANALYSER + AUTOCORRELATION ROUTINE (CALC)

TRANSLATOR

RETURN FIRE

PHASE PARAMETER SPECIFICATION (STEADY-STATE ROUTINE)

RETURN

OUTPUT ROUTINE (STROBE)

TRANSITIONAL S-SECOND DECISION POINTS ROUTINE

RETURN
TRANSITIONAL SECOND DECISION POINT

PRIMARY DECISION: HILL CLIMBER OR STEADY STATE?

\[ \sqrt{N} \text{ in d-range?} \]

- \[ \text{YES} \rightarrow \text{STEADY STATE} \]
- \[ \text{NO} \]

\[ \text{Hill Climbed} \rightarrow t_0 = 0 \]

- \[ \sqrt{N} \leq 8 \]
- \[ \sqrt{N} > 8 \]

\[ \text{SET} \]

- \[ N = 0 \]
- \[ N = 1 \]

\[ \sqrt{N}_d = \sqrt{N}_d + 0.5 \]

\[ \text{i.e. Five Strobe} \]

\[ t_0' = t_1 + \frac{1}{\sqrt{N}_d + 0.5} \]

PEAK

- \[ \text{HAS NEXT PEAK (Ai) COME IN?} \]
  - \[ \text{YES} \]
    - \[ \text{COMPUTE} \]
    - \[ \sqrt{N} = \frac{1}{t_1 - t_2} \]
    - \[ t_2 = t_1 \]
    - \[ \sqrt{N} - \sqrt{N}_d \geq 0? (n=0) \]
      - \[ \sqrt{N} - \sqrt{N}_d 
      \]
      - \[ \sqrt{N} - \sqrt{N}_d > 0? (n=0) \]
        - \[ \sqrt{N} - \sqrt{N}_d < 0? (n=1) \]
          - \[ \sqrt{N}_d = \sqrt{N}_d \times (1.5) \]
            - \[ n=0 \]
              - \[ \sqrt{N}_d = \sqrt{N}_d \times (0.69) \]
                - \[ n=1 \]
      - \[ \sqrt{N}_d \]
    - \[ \text{GO TO STROBE} \]
    - \[ \text{SET INTERNAL SWITCH} \]
    - \[ \text{GO TO CALC} \]
  - \[ \text{NO} \]
    - \[ \text{SELF INTERNAL SWITCH} \]

- \[ \text{t} = t_1' \]

\[ \sqrt{N}_d = \sqrt{N}_d \]

- \[ \text{NO} \]
  - \[ \text{n=0} \]
    - \[ \text{GO TO STROBE} \]
    - \[ \text{SET INTERNAL SWITCH} \]
  - \[ \text{n=1} \]
    - \[ \text{GO TO CALC} \]

\[ \text{TURN OFF INTERNAL SWITCH} \]
STEADY STATE SUBROUTINE

PROCEDURE FOR PHASING D (STROBE OUTPUT PULSE) A (PEAK AMPLITUDE OF EEG INPUT) FOR PEAK TO PEAK SYNCHRONIZATION.

DRIVEN

\[ \Delta_2 t = 0, \quad j = 0 \]
\[ t_1 = 0 \]
\[ t = 0 \text{ initial cond.} \]

GO TO CALC SUBROUT.

STORAGE

IF NEXT PEAK \( A_1 \) COME IN?

\[ t_0 = t_1 \]
\[ \Delta_0 t = t_1 - t_0 \]

HAS STROBE FIRED \( A_1 \)?

\[ \Delta_1 t = t_1 - t_1 \]
\[ \Delta_1 t - \Delta_0 t \leq 0 ? \]

\[ \Delta_2 t = \Delta_1 t x (1.67) \]

IF \( \Delta_1 t > 0.5 \frac{\text{sec}}{d} \)

\[ t_1 = t + \frac{t_1}{\sqrt{t}} + \Delta_2 t \]

IF \( \Delta_0 t > 0.5 \frac{\text{sec}}{d} \)

GO TO TRANSITIONAL 5-SEC DECISION POINT

GO TO STROBE OUTPUT FUNCTION

\[ t = t_1 ? \]

SET SWITCH 2

GO TO CALC SUBROUT.

IS 5-SEC OVER? (\( t = 5 \text{ sec?} \))

NO

NO

FIRE

\[ \Delta_2 t = \Delta_0 t x (1.5) \]

YES

\[ \Delta_1 t > 0.5 \frac{\text{sec}}{d} \]

\[ \Delta_1 t - \Delta_0 t \leq 0 ? \]

\[ \Delta_2 t = \Delta_1 t x (1.67) \]

YES

\[ t_1 = t + \frac{t_1}{\sqrt{t}} + \Delta_2 t \]

NO

NO

\[ \Delta_1 t - \Delta_0 t \leq 0 ? \]

\[ \Delta_2 t = \Delta_1 t x (1.67) \]

NO

NO

\[ \Delta_1 t > 0.5 \frac{\text{sec}}{d} \]
OUTPUT FUNCTION

\[ \Sigma V = 0 \]
\[ j = 0 \]
\[ j = j + 1 \]

SEND ATR
OUTPUT RTA
PULSER

\[ t(j) = t_i \]

CALCULATE

\[ V = \frac{1}{t(j) - t(j-1)} \]

\[ V_0 = \frac{\Sigma V + V}{2} \]

is INT. SWITCH ON?

NO

GO TO STANDBY STATE
RETURN

YES

GO TO TRANSITIONAL S-SECOND DECISION POINT PEAK
REFERENCES for BARDO, Appendix B

1 Barlow, J.S. "Rhythmic Activity Induced by Photic Stimulation In Relation to Intrinsic Alpha Activity of the Brain in Man."

--------------- "Rhythmic Afterdischarge to Flashes."


Mulholland, T. "Cortical Feedback of a Recurring Stimulus."

2 Ciganek, L. "EEG Response to Light Stimulus In Man."


5 Dr. Joseph Kamiya of the Langley-Porter Neuro-Psychiatric Clinic, San Francisco, is currently constructing a model in which to
catalog the reported subjective states. He explains that subjectivity in physiological research has always been undesirable, especially in connection with the production of "unusual" perceptions.


7 Alexander, OpCit.

8 Refer back to section entitled "Preliminaries" in chapter on awareness research.
SELECTED BIBLIOGRAPHY

There are very few complete sources covering all the topics we have discussed. Those interested in the topics covered in "Magnetobiology," are referred to the one source on this topic, by Barnothy, *The Biological Effects of Magnetic Fields*, ed. by M.F. Barnothy (Plenum Press, New York, 1964).


The field of awareness research is rather young and does not have any comprehensive sources. Present physiological knowledge concerning awareness are to be found in two international symposia: *Brain Mechanisms and Consciousness*, ed. by J.P. Delafreresnaye, (Alden Press, Oxford, 1954); *Brain and Conscious Exper-

Readers are urged to look for the soon to be published research of J. Kamiya, who is presently conducting a program of very fine awareness research.

Everyone is urged to investigate for himself the subjective aspects of awareness research. For information about the techniques and theoretical basis of the awareness disciplines see: *The Synthesis of Yoga*, by Sri Aurobindo, (Sri Aurobindo International University Center, Pondicherry, India, 1958); *Yoga*, by M. Eliade, (Bollingen Foundation, New York, 1958); and the Oxford Tibetan Series (four volumes by W.Y. Evans-Wentz (Oxford University Press, London).