Gross Differential Activity of the Dog's Cortex as Revealed by Action Currents.

by

S. Howard Bartley

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A. M. University of Kansas, 1928.

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# TABLE OF CONTENTS

Acknowledgements.

I. Introduction ............................................................................................................... 1

II. History ....................................................................................................................... 3

   A. The Older Work.

   B. Some Consideration in Current Investigations.

      i. Head and the notion of release of function .......... 12
      ii. Head and co-workers on the sensory pathway and the role of the thalamus 13
      iii. Magnus and co-workers on posture ................. 15
      iv. de Barenne and strychnine poisoning .............. 21
      v. Lashley on mass action, functional equilibrium, equipotentiality, and reaction to ratio .... 24
      vi. Pavlov and the synthetic approach ................. 26

III. The Experiments

   A. Apparatus and Technique .......................................................... 26

   B. Classification of the Electrode arrangements ................. 32

   C. Classification of the Records ............................................... 33

   D. Classification of the Behavior-Situations ................. 35

   E. The Experiments Themselves ............................................. 36

IV. Utilization of the Data.

   A. Presentation by Maps.

      i. The mapping scheme .................................................. 69
      ii. The maps presented ................................................ 71
      iii. The situations which presented but few records .... 96
      iv. Summary of the map data .................................... 103

V. Interpretation of Data

   A. Logical basis of a field theory ................................. 105

   B. The relation of the present study to contemporary work 108
(table of contents continued)

V.

B.

| i. Cutsforth | .................................. | 108 |
| ii. Gelb and Goldstein | .................................. | 114 |
| iii. de Barenne | .................................. | 114 |
| iv. Lashley | .................................. | 115 |
| v. Pavlov | .................................. | 117 |

VI. Summary | .................................. | 121 |

VII. Bibliography | .................................. | 137 |
I. Introduction

The purpose of the present study has been to investigate by methods that are as yet relatively gross the phenomena occurring in the cerebral cortex in the intact animal under several sets of fairly well known conditions. It is believed that such a study will throw light both upon facts of overt behavior and of experiential phenomena that already exist but are little understood. Indeed it might be supposed that the facts of cerebral function and the facts of behavior would be mutually dependent.

For the purpose of orienting the reader to this study, it might be well to review the 'hues in the spectrum' of psychological interests and standpoints. At the one end, there are those who lean upon the periphery for their explanations of many behavior phenomena, at least in accounting for sensory phenomena. A great variety of chemical and mechanical processes have been postulated to explain the selective nature of vision and hearing. Still among the group of investigators who emphasize physiology, there are those who do not lean so heavily upon the periphery but seek explanatory factors in the central nervous system. They attempt to show how the cerebral cortex alone accounts for complicated behavior, and for the absence of a one-to-one correspondence between a selected stimulus and an organism's response. In addition, they have attempted to find restricted areas in the brain that somehow control specific cases of observed behavior. Supposedly, these areas had been found.
Still other investigators approached the problem of physiological analysis in terms of neural bonds in a hope of showing how the complex organism learns.

In the middle of the spectrum of psychological stand-points are found attention theories of behavior, a group of relatively non-physiological theories, as stated. These are as diversified among themselves as the physiological group. Finally, at the other end of the range lie social theories of behavior couched in terms of sympathy, imitation, habit, and suggestion.

The fact that all these theories can be reduced to one, under a common set of principles has not been as evident to psychologists as it should have been. The present investigation owes its motivation to a set of principles which promise to become widely applicable in all phases of psychology, hence achieving unity in the science. These principles are laws of dynamics. They are not located in the spectrum at any particular place but correspond to the light itself from which the colors were derived. Though we shall attempt to test their serviceability in dealing with the nervous system directly, we are no more concerned with physiological than with any other 'brand' of psychology, for the reason that all psychology raises physiological questions. We are interested in the function of the cortex in relation to psychological situations, and in testing conventional theories of brain activity.
II. History

Inasmuch as our experimentation has been directed upon phenomena as recorded from the cerebral cortex, and inasmuch as much will be said about the historic and current views of brain functioning in contrast with the view presented, a history of the former will be given in brief.

Investigations on the central nervous system fall conveniently into 3 categories: (1) the clinical or pathological, (2) the anatomical and embryological, both gross and microscopic, and (3) the experimental. The history of the latter reveals three methods, first, the faradization of the cortex and other brain parts, second ablation, and third chemical poisoning by such drugs as strychnine.

It has been suggested that the Russian school, led by Pavlov, presents a fourth direct method of study of the central nervous system. Such is not the case, however, for with all of the precision of method of the school, and their postulates regarding the cortex, they have experimented directly upon the cortex only as they have used ablation which has already been mentioned as a separate method in itself.

Although Willis, a couple of centuries ago, attempted to assign functions to different parts of the brain, considering it an assemblage of organs, nothing of note followed until the time of Gall and Spurzheim. Gall, in 1805, declared that there were 35 faculties. Flourens, in 1842, although he credited Gall with being a skilled anatomist, opposed the compartmentalizing the brain in order to account for faculties. He insisted that the cerebrum was functionally an indivisible unit.
Herbart opposed Gall's phrenology on the ground that it destroyed the unity of the mind. Finally the ideas of Gall, which nevertheless became popular, were somewhat modified by the work of Carus and Emil Huseke, who stated that the brain had three main sections, the forepart for ideation, the middle of the cerebrum for sensation, and the cerebellum for volition. This formula held sway till about 1850, when from then until about 1870 Flourens' idea of the unity of the cerebrum came into vogue.

The work of Bouillard on aphasia antedates that of the better known Broca and the later Wernicke. The former, led by his erroneous notions of phrenology, attempted to map out functions for various portions of the brain. In 1825, he declared the frontal lobes were concerned with speech. In present-day terminology, they would have been called the "center" for speech. In 1833, Andral produced 14 cases which contradicted Bouillard, hence the latter was overshadowed until 1836, when Marc Dax found evidence of right-sided paralysis due to frontal lesions in the left hemisphere and vice versa, thus evidently pointing to localization of function.

Longet, Magendie, Matteuci, Van Deen, Flourens, and Schäff had declared up to the time of Broca that cerebral functions were not localized. The first mentioned had used mechanical irritation, cauterization, and faradic stimulation on dogs, rabbits and kids without obtaining evidence for localization.

In 1864 Bandolet removed the cerebral hemispheres from
fishes, producing an artificial sluggishness. However, when forced to move they did so in a normal fashion. If ablation went further and destroyed the midbrain, both sight and equilibrium were lost. In 1869 Goltz and Blanschko, removed the cerebral hemispheres of the frog only to find its behavior slightly modified except for "initiative." The various reflexes were present, though forced stimulation was required to arouse the animals. Under these conditions, they would swim and would avoid objects. Bechterew performed the same operation upon birds, finding them to be passive also. They would remain in one position making continuous head movements; if thrown into the air they would fly. However, they would alight indiscriminately on harmless and dangerous objects. Substantially the same lack of initiative, and the refusal to eat food unless forced, was found in the case of cerebral ablation in dogs by Goltz in 1892. One might have expected that these findings would have led to greater caution in the supposition of localized functions but they seemingly had little effect.

Broca (1861) announced that the loss of motor power of speech was due to lesions of the posterior part of the third frontal convolution in the left hemisphere. This behavior disturbance he called aphrenia, later termed aphasia by Trousseau. The affected brain area came to be called Broca's area. In contradiction to Broca's assertion, Charcot maintained that centers were fictitious, and that the loss of
speech was due to lack of coordination between higher and lower levels.

Wernicke, in 1874, distinguished between motor and sensory aphasia, accepting Broca's area for the former and assigning a different seat to the latter. He also introduced the idea of cortical, subcortical and transcortical aphasia. The first type, a case of destruction of the center, was thus a complete loss of function; the second was a case of intact center, but a loss of connection between the ear and the muscles of articulation, so that the patient became word deaf or else incapable of actually enunciating. The third type was said to depend upon the severance of association fibres between other parts of the brain used in language. Kussmaul, in 1876, divided sensory aphasia into verbal deafness and verbal blindness.

The first functional area to be definitely "localized" by experimental investigation was the motor area in dogs. (Fritsch and Hitzig, 1870) Their findings were anything but precise and have been verified and refined as far as the exactness of the area is concerned. However, much confusion has arisen because of the false assumptions that a verification of this excitability validated the logic of Fritsch and Hitzig in postulating localization of function. In 1876, Ferrier extended their method to small monkeys where he found a much more detailed 'localization' possible. He believed the motor area to extend along both sides of the fissure of Rolando. Beever and Horsley, in 1890, 'confirmed' Ferrier in virtually every point, but Grünbaum and Sherrington,
using unipolar stimulation, which was a much better method for delineation, found that the 'motor area' did not extend to the posterior side of the Rolando's fissure. Otherwise they 'confirmed' Ferrier's localization.

Ferrier, in 1875, stimulated the cuneus and obtained eye movements. Munk, several years later, observed blindness to result from tumors in the cuneus. In 1855, Panizzi found that the dog was unable to see after injury to the occipital lobe. In 1905, Panichi demonstrated that the destruction of the visual area did not render the animal permanently blind though destruction of the whole occipital lobe did.

The 'body sense area' was studied by Luciani in 1885, von Monakow in 1902, by Flechsig in 1904, by Campbell in 1905, and later by others.

Meynert, in 1872 published the first modern work of note upon the histology of the cerebrum. His observations, pointing out the association fibres, the projection areas, and other structures, were essentially like those of recent times. Lewis and Clark, in 1878, made a study of the brain, examining its strata with a view toward distinguishing their differences and relative positions. Following this, Flechsig accomplished a notable piece of work on the study of the development of brain tissues by observing the myelination of the various parts at different stages of brain growth. In 1898, he reported 40 myelo-genetic fields, but in 1901, reduced the
number to 36. However, he was opposed by Hitzig who, nevertheless, admitted the general truth of Flechsig's findings but in a less positive way. Vogt directly contradicted many of Flechsig's results, although the latter's contribution stands as one of a unique type, and his plates are in many of the latest textbooks.

In 1895, there was a posthumous publication of a study by Hammarberg on the laminations of the cortex, in which the greatest cell deficiency was found in elements. This deficiency varied from area to area, sometimes including the precentral and postcentral gyri. Also, there was no greater deficiency in the 'association areas' than in any other parts of the cortex.

About this time (1880) there was a three-cornered controversy between Munk, Goltz, and Luciani and Seppill. Munk maintained localization, Goltz denied it, and the latter two declared functional areas to be complex and to overlap. Ferrier was really a party to this general discussion when he exhibited a monkey at the same time that Goltz exhibited a dog at a congress in England. Ferrier, of course, insisted upon localization.

Incidentally, it might be stated that the improvement in the microscope from time to time had enabled Schleiden and Schwann to formulate the cell theory in 1838-39. Twenty years later began the development of staining methods in histological technique. Although Descartes postulated animal spirits which coursed up and down the various channels of the body, it was not until 1891 that Waldeyer coined the
term "neurone" in stating his general theory of nerves. In the same year (1842) that du Bois Reymond discovered the demarkation current, von Leibig introduced the term "metabolism" into scientific literature.

From the time of du Bois Reymond on, countless studies have been made on the nature of the nervous impulse. The calculation of its rate by Helmholtz was an historical achievement. Though its predictions were considered worthless by Müller because he considered experimental proof impossible, it was but a short time until Helmholtz had obtained evidence from his work on frogs.

These facts are mentioned, first, to show the stage of thinking that existed about the close of the nineteenth century, and second, to show the proximate time of the origin of concepts now so familiar that they are regarded through tradition, to be the only possible bases of neurological theory.

Curiously, about the time that the cell theory was advanced by Schleiden and Schwann, Marshall Hall announced the distinction between reflex acts and those of conscious volition. Only development in the histology of nerve pathways was then necessary to make the concept of reflex action a tradition. Even Flourens, an ardent advocate of cerebral unity, established with Legallois in 1826 a reflex center for respiration.

In 1902, Loeb summarized both the work of Goltz and his own, and found evidence opposed to the restriction of "associative memory" to any part of the cerebrum. He evolved the theory of functional periodicities in the various parts of
of the cortex. In 1909, Munk constructed a theory of 'aggregation of sensory spheres', in which he considered the entire cerebral cortex as the aggregate, and to be the seat of intelligence, which he defined as the combination and product of all the ideas arising from the sense-perceptions. For him the interconnections between these spheres were entirely adequate for the most complex integrations, so that there was no need for the postulation of any specialized association centers or areas set aside for the intellectual processes. Monakow (1914) essentially agrees in believing the evidence inadequate to establish any special intellectual function in the association areas and points out that while the simple sensory and motor functions may be definitely localized in different parts of the cortex, the more complex processes of memory, and the like, involve the coordination of several of the special areas.

In a broad sense of the term, all of the views that have been mentioned are localization theories, in that they at least make the brain the seat of some function even though it be intelligence. Intelligence and the sensory functions resided there, consequently it was only a matter of deciding about the 'internal government.'

The theories with reference to brain functioning in intelligent behavior can be divided roughly into four classes: (1) cerebral unity theories, (2) aggregation theories, (3) association area theories, and (4) special area theories.
To the first one it may be said that Longet, Magendie, Matteuci, Van Deen, Flourens, and Schiff adhered. In their day and even to the present, the common interpretation of unity has been that of homogeneity. And, as such, this interpretation has stood in the way of progress in coping with the problem. The assumption of homogeneous unity did not lead to experimental problems. The notion of aggregation did, however, for it fitted the mechanistic attitude of the times, and as a consequence derived unity and synthesis became popular suppositions. Monakow's view of a number of sensory spheres stands out as an example of the aggregation theory, inasmuch as intelligent behavior was supposed to accrue from the relationships between the spheres. Monakow was opposed to locating intelligence in the association areas. Loeb's notion of the establishment of functional periodicities within the various parts of the brain is said to be a unity theory (Lashley) but since the unity was thought to come about by integration, it falls into the class of aggregation theories. In the notion of the exalted role played by the association areas in intelligent behavior, the frontal lobes come in again for their share of the credit. Most writers who are concerned with the brain regard it from the third point of view.

Eitzig, in 1884, stated very plainly the standpoint of the fourth theory. He believed that intelligence was to be sought in all parts of the cortex, or rather all parts of the brain, but that thinking demanded a special organ, which he sought provisionally in the frontal lobes.
Some Considerations in Current Investigations. There has been an inclination on the part of physiologists and neurologists to retain in well kept form Hughlings Jackson's notion of levels in the central nervous system, so that we read in Bad of its application to the phenomena of nervous disease. Jackson originally stated that destructive lesions never cause positive effects but induce a negative condition, thus allowing positive symptoms of the action of some lower center to appear. Before injury, the higher centers greatly modified or checked the lower, according to the level theory. It seems almost as if the latter are supposed to be dormant or latent, lying in wait till something happened to the higher centers. Jackson stated that no behavior was pathological but so-called disease was the expression of the lower centers in exaggerated form. His plainest expression of the idea was in connection with organic hemiplegia. He declared that this depended upon two factors, namely, the loss of voluntary power, especially in the fingers, the parts most directly under voluntary control. This was the negative effect. The 'positive' symptom, the massive overaction called "spasticity", was the result of the unchecked energy of the lower centers. The difficulty was not due then to what was ordinarily known as "irritation", but the release of centers from higher control. This functional notion along with the types of localization just outlined has been the stock in trade of clinical neurology for many years. Thus there are current the ideas that both inhibition and excitation are discrete pro...
discrete processes, each possessing its own properties. They are construed as abstract functional units, or unit processes, just as reflex arcs are the discrete things composed of so many nerve cells. Accordingly conventional physiological psychology favors the use of so many reflexes (antagonistic or summative) and so much facilitation and inhibition all algebraically applied in a linear fashion.

In describing the currents of thought in recent times and in applying meaningful theory to the present study, something must be said about the alleged role of the brain stem and the cerebellum. Much has been written about the various nuclei in the stem. It is in order to sketch here the conclusions of two sets of studies, namely those of Head and his colleagues and those of Magnus and his fellow-workers. Their problems relate directly to the role of the interbrain and the midbrain.

Head and his co-workers hold that afferent impulses are rearranged three times before they reach the cerebral cortex. The first re-arrangement is in the spinal cord, so that impulses relative to heat, cold, and pain, cross to the opposite side of the cord soon after entry, and thus are carried upward in secondary nerve paths. Those of postural recognition and spatial discrimination ascend in the same side as they enter, travelling along primary paths. Those of contact sensibility ascend by a double route, partly on the same side and partly on the opposite. The second re-arrangement takes place in the nuclei of the posterior columns of the cord in the medulla. From there the pain, heat and
and cold impulses continue, unaltered, up the same side, to the optic thalamus, though the paths of each are independent. The fibres carrying postural discrimination impulses end in nuclei in the medulla. From thence the impulses are carried by two independent columns, or secondary paths, one for postural recognition and one for spatial discrimination. Here, too, the other uncrossed paths now cross. All of the paths from here are secondary and end in the optic thalamus. In addition to the nerve cell at which the nerve fibres end, there is a mass of gray matter called by them, the "essential organ of the optic thalamus". They concluded that this forms the center for certain fundamental elements of sensation, those having to do with pleasure and displeasure. One can see how nicely this fits in with the notion that all sensations must have either pleasurable or displeasurable aspects. The thalamus is the seat for the pain-pleasurable aspect of consciousness. The impulses, or some derivative of them, that had to do with this emotive aspect were sent to the essential organ by way of short tertiary fibres, while there were longer tertiary ones reaching to the cerebral cortex. In the thalamus the third re-arrangement of the afferent impulses took place so that from there up to the cortex there were five separate paths, one for the impulses of postural recognition and passive movement; another path for tactile impulses, such as for the discrimination of weights upon a supported member of the body; another for spatial discrimination, such as occurs in sensing two points simultaneously applied, or the size and shape of
shape of objects applied to the skin; a fourth for the localization of stimulated spots of the skin, and the recognition of the double nature of two points successively applied; and a fifth for heat and cold. The office of the cortex was to relate one of these with the other. And by this is told the story of one kind of localization theory we have to-day. It has been derived from investigations in pathology. Magnus and fellow-workers. Magnus and his fellow workers have dealt experimentally with posture in a series of animals whose brain stem was transected in one of seven places. Their investigations intended to show the function of the various specific segments of the brain stem and cord in the maintenance of posture. The authors point out three aspects of posture, namely, (1) reflex standing, (2) attitude, and (3) righting function. A study of eye movements was made in relation to posture, both in animals whose visual fields overlap and in those whose eyes are laterad.

(1) If the spinal cord is in functional connection with the bulb, decerebrate rigidity is brought about by transection of the brain stem some where between the posterior half of the medulla and the fore part of the mid brain. In such cases the flexors have little or no tone, the extensors a great deal. Here then is a picture of an abnormal distribution of tone. To insure a normal distribution of tone, the foremost half of the mid brain must be present.
If the transection takes place in front of the mid-brain the
"thalamic" or midbrain animal results. In such cases there
is normal tone in both extensors and flexors. The animal
will thus stand in a normal manner and not in a hyper-extended
fashion. The nucleus ruber is necessary for the change from
decerebrate rigidity to the normal distribution of tone, the
rubro-spinal tract carrying the efferent impulses. It is
said that the cerebral cortex by way of the pyramidal tract
has the same effect but to a lesser degree.

(2) The picture presented by the various relations of the
parts of the body to each other is called attitude. Magnus
states that the most fundamental attitudinal reflexes can be
best studied in decerebrate animals. If one places a decere-
brate animal in an upright position, he stands alone. Pinch
a fore paw, and the foot is drawn up, the other three support-
ing the whole weight of the body. The other fore-limb must
now be more rigidly extended, so along with the homolateral
flexion of the disturbed limb, there is a crossed extension
reflex. This, taken in its completeness, is called a "segmental
attitudinal" reflex. The attitudinal reflexes are most easily
evoked from the head and other anterior parts of the animal.
Distance stimulation, as well as tactile, impresses attitudes
upon the whole body. It was shown that attitudinal reflexes
are the result of the combined action of two sets of factors,
the tonic labyrinthine and the tonic neck reflexes acting on
the body muscles. In changing the position of the head, two
things occur, a change of its position in space stimulating
the otolithic apparatus, and a change in its relation to the
body, therefore flexing or twisting the neck and stimulating the proprioceptors of the deep muscles of the body. The two factors may be studied separately in the following manner: eliminate the neck reflexes either by nerve section or by firml bandaging. If one brings such an animal into different positions in space, only one position of the head is found in which standing tone is maximal, that of the supine position of the head, with the snout a little above the horizontal. There is another position in which standing tone is minimal, 180° from the first. Under the influence of the labyrinthine reflexes the tone of all of the standing muscles changes in the same direction. The flexors are influenced in the opposite way. In the decerebrate preparation when the tone of the extensors is maximum, the flexors are relaxed; when the extensors have minimal tone, the flexors acquire some tonicity.

In order to study tonic neck reflexes alone, the labyrinths are extirpated. Under these conditions, flexing, bending and twisting of the neck evoke tonic reflexes in which, usually, one half of the body reacts in an opposite way from the other half. If the forelimbs are extended, the hind limbs would be released, although there are neck reflexes to which all four limbs react in the same way. It is said that the force to which the body muscles react may be expressed by the algebraic sum of the effects of the neck and the labyrinthine reflexes. The centres of these attitudinal reflexes are the most caudally located of all postural centers. The centers for tonic neck reflexes are in the two most anterior cervical segments and the tonic labyrinthine centers are located in the posterior part of the bulb behind the entrance
of the VIII cranial nerve. These reflexes are called tonic for they last as long as the head remains in any one position.

In pathological conditions of the central nervous system, for example in cortical lesions, the attitudinal reflexes are released, and are employed as diagnostic signs. Thus in some cases of hydrocephalus, turning the head causes the arm or leg toward which the face is turned to be extended as long as the face maintains this position. However, there are but few cases in human beings where labyrinthine functions have been demonstrated with certainty.

In cases of gunshot wounds, resulting in unilateral paralysis, strong movements of the head on the non-paralyzed side evoke movements of the paralyzed arm and leg. In many patients, the turning of the head fails to elicit direct tonic neck reflexes, but influences the "associated movements". If the face is turned toward the paralyzed side the "associated movements" will be those of extension, and vice versa. In this way, the position of the head determines the type of movements induced by indifferent stimuli.

Magnus next considers the problem of "righting functions". The decerebrate animal has no righting function, so that if pushed while standing, it will fall over. The mid-brain animal, however, possesses an adequate righting function. In order to study these responses under simple conditions, a mid-brain animal is used. Thus the role of volition is deliberately ruled out and a so-called "reflex machine" is under investigation. Under these conditions there are found four factors in the righting mechanism. First, by means of the labyrinthine righting reflex
the head is brought into a given position in space, and maintained there, regardless of the position of the rest of the body. If the reflex is destroyed, the head will take up a position in keeping with that of the rest of the body.

In such an animal, if the body is placed in a lateral position upon the floor, the head is at once brought into normal position in space the instant the floor is reached. This reflex is supposedly evoked by the asymmetrical stimulation of the exteroceptive sense organs of the body. These sense organs are the second mechanism. The mechanism is demonstrated further by placing a weighted board on the upper surface of the animal's body. There is now asymmetrical stimulation and the animal's head quickly takes a lateral position like that of its body.

The third factor is the neck righting reflex, demonstrated while the animal is suspended in air. In such cases the head resumes a lateral position, but if the neck is turned into an upright normal position the thorax first and then the posterior part of the animal twists into the upright normal position. The body righting reflexes acting upon the body itself constitute the fourth factor. If the head is held in the lateral position and the body is made to touch the ground, the body twists into the upright position, although the head is in a lateral position. If the body is suspended, it will retain the lateral position without resistance.

These four mechanisms are the only righting reflexes possessed by any of the animals such as rabbits and guinea pigs. Cats, dogs and monkeys reveal an additional mechanism, that of the optical righting reflex. Supposedly, this is the only righting reflex whose center is not in the brain stem but in the cortex.
The functions just described make it intelligible how labyrinthine mutes can orient themselves in space while in air but when put in water, where optical impressions are limited and inadequate, the subjects are in danger of drowning.

The Cerebellum.

Next, in discussing the mechanism of the central nervous system, there is the cerebellum. Little is actually known of its functions; in fact, investigators have had difficulty in assigning functions to it. It has been ruled out as an important or necessary factor for numerous overt activities. On the one hand, there has been a difference of opinion with regard to the division of function within the organ. Bolk, Andre-Thomas, van Rynberk, and Barany, have declared that identifiable structural units of the cerebellum control specific muscle groups, while, on the other hand, Luciani and Sherrington have considered it a single unit with each side governing the muscles in the corresponding side of the body. F. R. Miller takes a middle position under the assumption that there may be a "prevalence of representation" of muscle regions in certain of the larger anatomical divisions of the cerebellar lobes.

It can be seen from the word of Magnus on posture that postural reflexes are considered independent of the cerebellum. He says: "Experiments have proved that all postural reflexes are present and perfectly undisturbed after total extirpation of the cerebellum. Therefore, their centers as well as their afferent and efferent tracts are extracerebellar. Through the brilliant investigations of Luciani and others we know that the loss of the cerebellum is followed by severe motor and postural
disturbances. These symptoms, however, cannot depend on the cerebellum, which has been removed, but are evoked by the rest of the central nervous system which has been spared. Unfortunately we know not a single function or reflex positively connected with the cerebellum, in such a way that it is absent after cerebellar extirpation, and present after ablation of other parts of the brain, as long as the cerebellum remains uninjured.

Our evidence of the postural activity of the cerebellum is purely negative. The great advantage during the investigations of the postural functions of bulbo-mid-brain was, that we could there deal with positive reflexes (righting and attitudinal) which are present as long as the hind part of the brain stem is intact. I am convinced that so soon as we succeed in finding positive reflexes connected with the cerebellum, it will be possible to elucidate of this undoubtedly very important part of the central nervous system. Only then can the question of the importance of the different cortical centres for posture be raised."


iv. De Barenne's Strychnine Experiments in Determining Sensory Areas

A history of brain functioning would be incomplete without a mention of de Barenne's work on the cerebral cortex of cats (1916) and monkeys (1924). In both cases he used a weak solution of strychnine on variously selected areas of cortex, a few square millimeters in size. If the solution were applied to a small area in the posterior sigmoid gyrus, the cat would bite at the forepaw on the contralateral side, it would lick the fore-paw or seize a fold of it in its teeth and shake it. It would resist violently the attempt on the part of the experimenter to touch the limb. In this resistance it might strike with the limb but
during the defence would stop and attack the limb itself.

This and other behavior of the animals gave rise to the belief that the cat suffered pain both cutaneously and in the muscles and joints. Check was made to ascertain whether both cutaneous and deep sensitivity were involved, by sectioning the cutaneous nerves in some cases and in others by removing the skin of the forelimb. The disturbances in cutaneous sensitivity were manifested by (a) spontaneous excitation (paresthesia), (b) hyperesthesia, and hyperalgesia and (c) exaggeration of Munk's "beruhungsnreflexe"; while the disturbances to deep sensitivity occurred as abnormal hypersensitivity to pinching and pressure of the bones, tendons, and muscles.

In cutaneous sensitivity, both sides of the body are represented on one hemisphere, although on the contralateral side to a greater extent, whereas in deep sensitivity the representation is always unilateral and contralateral.

De Barreme finds that there are four zones, the head zone, the fore-limb zone, the hind limb zone and the zone of crossed symptomatology. The head zone includes the anterior sigmoid gyrus, the part of the posterior sigmoid in front of Campbell's compensatory ansate fissure, and the frontal half of the anterior suprasylvan gyrus. For this zone the anterior sigmoid seems to be the focal area. The forelimb zone consists of the anterior sigmoid gyrus, and the same parts of the posterior sigmoid and of the suprasylvan as in the head zone, along with the middle third of the anterior ectosylvian gyrus. The focal area of this zone involves the anterior sigmoid and the part of the posterior sigmoid just mentioned. The hind limb zone consists
of the frontal half of the marginal gyrus, where the anterior part is focal. The zone of crossed symptomatology includes the following: (1) the posterior sigmoid gyrus behind the Campbell's compensatory ansate fissure, (2) a small part of the marginal gyrus behind the ansate sulcus, (3) the frontal third of the middle suprasylvian and a small part of the anterior suprasylvian gyrus, (4) and part of the cortex in transition from the middle ectosylvian to the anterior ectosylvian. The more frontal the area the greater the symptoms. Thus, de Baronne finds that the forelimb and the head zones almost entirely overlap, contrary to the findings of Munk and Rothmann. (cf. p. )

Insofar as the sensory zone overlaps the motor (the position of the latter being detected by a different method) there may be said to exist in the cat and probably also in the dog, a common sensori-motor cortical zone as Munk and others have held.

The sensory disturbances were more marked in the distal parts of the limbs, and in only one instance out of thirty-four animals was there evidence for a segmental distribution of the sensory disturbances caused by strychnine applied to the cortex.

Finally, he found no evidence for the sensory character of the frontal lobe in the cat. However, according to the terminology of other authorities, part of the zone that de Baronne indicated as sensory lies in the frontal lobe. (cf. Papez p.13.)

Substantially the same findings resulted from a study of 20 monkeys. Diagrams of the areas found both in cats and in monkeys are included here for purposes of comparison with the conventionally accepted motor and sensory zones.
with experiments in which head symptoms appear, foreleg symptoms also appear.

Strychnine experiments of Dusser de Barenne.
ZONE OF CROSSED SYMPTOMATOLOGY (Cat)

Experiments of Dusser de Barenne with Strychnine.
The results found in these two studies are very significant although de Barenne himself has failed to make adequate use of them. Problems of cortical functioning are solved in terms of irradiation and a "firing" process.

To quote: "strychnine brings the cortical areas poisoned by it into a condition of abnormal and hyperexcitability. Now it is possible that this condition irradiates from the area poisoned over the whole of that part of the cortex which is in close functional (sensory) connection with it. Therefore, when only a small part of any one area, e.g. of the fore-limb zone, is poisoned by the strychnine, acting primarily on the poisoned area, indirectly "fires", as it were, the entire sensory fore-limb zone, the abnormal condition of hyperexcitability of the zone manifesting itself at the periphery of the body by the symptoms of excitation described: of cutaneous sensitivity in both fore limbs and of deep sensitivity in the contralateral limb only." (Quarterly Rev. of Exp. Physiol., 1916, Vol. 9, p.355)

II-B-v. Lashley's Work. The extended experiments by Lashley are better known for their content if not for their true significance, by American psychologists than the work previously described. Accordingly, little need be said in reviewing what he has done.

In the early part of his investigation he attempted to apply the reflex arc concept to brain functioning. He admits failure, however, and has come to doubt the usefulness of the reflex concept even in dealing with so-called spinal reflexes, for there are many indications from his investigations that the latter are no more dependent upon isolated conduction paths than are cerebral functions.
In addition, he denies the validity of synaptic resistance, and its supposed role in learning.

His position relative to localization of function in the brain is summarized in his definitions of equipotentiality, mass action, functional equilibrium, and reaction to ratio.

vi. Another of the widely known series of contemporary studies, is the work of the Russian Conditioned Reflex School, led by Pavlov. Its influence has very deeply and broadly permeated present day psychology and physiology. Ever since the century began investigation by the method so well known to all psychologists, has been going on. The present study, though it need not contain a description of the experiments themselves, would not be complete, should it fail to include a discussion of the interpretations offered by Pavlov and his students. Their concepts regarding the brain will be discussed in Section V.

III. The Experiments: A Apparatus and Technique.

The purpose of the present study, as was stated in the beginning, has been to investigate, by methods that are as yet relatively gross, the phenomena occurring in the cerebral cortex in the intact animal under several sets of fairly well known conditions. It is believed that such a study will throw light upon a number of phenomena of behavior already recognized but little understood. In pursuing this thesis we are in the end concerned no more with "physiological psychology" than with any other kind for the reason that all psychology raises physiological questions. We are interested in the function of the cortex in relation to psychological situations, and shall
test the conventional theories of brain functioning.

Method and Apparatus. The dog was selected as a subject for the following reasons: (1) It is a very responsive animal, (2) it is relatively high in the animal scale, (3) it is easily available, and (4) it is of rugged constitution. Access to its brain was made under both general and local anesthesia, the latter applied in a way appropriate for the reduction of discomfort both during the operation and the subsequent recording. The operative technique and the many precautions necessary in a study of this kind are given in detail by Bartley and Newman *, and will not be repeated here in detail. From 1½ to 2 hours after the completion of the operation and the removal of the general anesthetic, action currents were led off from the cortex by means of surface electrodes securely fastened to the animal's skull so that the animal's movements would not affect the contacts. The action currents so obtained were magnified from 200–400 thousand times by an audio-frequency electron tube circuit, and then led into a Westinghouse Oscillograph whose excursions were photographed on either standard size or the new 70 mm. motion picture film, by a camera driven either by hand or carefully regulated motor. A second oscillograph similar to the first was used to produce a time line on the

film. The source of the timing was the alternation in the 60 cycle A.C. lighting circuit. With the use of a wholly metal recording room, the A.C. field could not be totally eliminated as a disturbing factor in the amplifier circuit. As such, however, it did not destroy the usefulness of our records, for as yet, no attempt has been made to utilize the very finest temporal variations in them.

Unless otherwise specified, the animals were destroyed immediately after recording.

Additional artifacts and precautions. In an attempt to record electrical phenomena so minute as cerebral action currents, the experimenter must guard against many other electrical changes incidentally brought about in the experimental environment, otherwise the records will contain artifacts with respect to the original problem. Loose connections in the circuit are instrumental in bringing about much larger fluctuations in the recorded patterns than the most violent neuromuscular phenomena. Along with this there is the possibility of induced effects from the experimenter and from the muscles lying near the cranial opening. The latter has been found inappreciable, for the system used does not record any patterns from muscular activity unless the electrodes actually come into contact with the muscles. This has been tested by bringing the hand near the electrodes without touching them, and by bringing the electrodes close to active muscle. Contact was found necessary for recorded disturbances.
Temperature and moisture conditions on the exposed brain surface was controlled within limits of 1 to 2 degrees by the administration of Ringer's solution held constant within .03 degree Centigrade. Sherrington found at least 10 or 12 degrees fluctuation in temperature beneath the skull of monkeys when an external range of temp-erature was set up by the application of heat and of ice packs. During this time the animal's behavior did not seem to be disturbed.

The amplifier itself was shielded mechanically and acoustically in such a way that only jars occasioned by careless walking about on the floor near it produced measurable disturbances of it. To offset this type of artifact thick felt pads were used to stand on and all unnecessary walking about in the room during recording was eliminated. None of the noises occurring in the room seemed to affect the system.

Careful inspection of the system and a close watch upon the experimental situation for artifacts during recording were made at frequent intervals. Now and then records were discarded on account of temporarily poor switch contacts in the A battery circuit, or on account of a loose connection in the electrode circuit, or improper contact of the electrodes with the brain surface. If the animal turned out to be in poor condition and not responsive, as was the case of animal 9, the records were not regarded comparable
to those obtained from other animals. The greatest number of records, however, was eliminated on account of scanty notes telling of the conditions under which the records were obtained. Also a number of records made from explorations on the animals reported here, was reserved for a special study by Mr. Theodore Perkins. In these, the stimulation involved the use of sound.

**Stimulus conditions.** In the records reported upon here, three general types of stimulation were utilized, namely;

1. **Painful,** in the form of pinching or abruptly doubling the tail, or pinching the animal's back in the lumbar region,
2. **Motor stimulation,** by moving the animal's whole body as it rested on the canvas topped table with its limbs suspended through slots in the canvas, (the motion was a rolling one brought about from pushing the body from side to side. ) and,
3. **Visual stimulation** in the form of a single stationary bright point on a dark field, or a number of moving points on a dark field, some of which appeared intermittently, or an intermittent flashing of a stationary bright point. In a few instances, the difference between an illuminated and a darkened room was used as a stimulus condition. In all of the above cases of visual stimulation, the room was dark or very dimly illuminated with tiny red lamps out of the animal's sight. The apparatus producing the intermittent light, was a rotating open sector disc, referred to as an episootister; the stimulation was called 'flicker.'
The following discussion has to do with three groups or classifications of the data, as follows: (1) the electrode arrangements, (2) types of records, and (3) the behavior situations.

In order that the first classification may be clear to the reader, the multiple sliding switch will be described. Virtually all of the electrodes used had more than one conducting contact. That is, they consisted of an anchor to hold them securely to the cranium, and either a holder on this anchor for the flexible wire-like electrodes, or a holder in the form of a matrix also extending from the anchor, having a flat base carrying the contacts flush with it. The former contacts could be placed in widely separated cortical positions while the latter were used for recording between small separations, or for slight alterations of position in the active electrode. In the circuit leading to the amplifier from the animal there was a sliding switch, by which various electrode contacts could be selected and used at will. This made it unnecessary to change an electrode from place to place on the brain in order to obtain records from different gyri. The change of position was effected by sliding the switch handle. Thus, while the animal was making a series of movements, the switch could be moved so that recording occurred successively from place to place on the brain.
B. Classification of Electrode Arrangements.

1a. Exploration of the left hemisphere using one of the electrodes as a neutral point. By the latter is meant that one electrode did not lie directly on neural tissue itself, but on top of the dura mater, generally at the anterior or end of the lateral gyrus. Under this condition, the potential at the neutral electrode represented a constant relative to any point in the cortical field represented by the other electrode. Thus variations in potential pictured in our records are fluctuations with reference to a more or less general level and whatever the potential at the 'neutral' point may mean, it functions as a convenient standard held constant throughout the experiments from animal to animal.

1b. Exploration of the right hemisphere under the same conditions.

2. The recording of fluctuations in potential between corresponding and non-corresponding points in the two hemispheres, without the neutral electrode. In this case there is no constant standard of comparison.

3. The recording within the boundaries of one hemisphere with no neutral electrode. In such cases, both electrodes were placed either at two points within a gyrus or at widely separated points in the cortex as well as close together but in adjacent gyri.
It is obvious that each of the three arrangements and their modifications has its own significance, and that the records are to be interpreted accordingly. The greater part of the recording was done with arrangement la which is the basis of the maps that are to follow.

B. Classification of the records. The records which were obtained from this study, regardless of the electrode arrangements, were classified with reference to amplitude, complexity of pattern, and its duration.

They fell into the following 13 groups that are illustrated in the accompanying photographs.

Table I.

<table>
<thead>
<tr>
<th>Class of record</th>
<th>Group number</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Negative or equivocal</td>
<td>1.</td>
</tr>
<tr>
<td>II. Positive</td>
<td></td>
</tr>
<tr>
<td>A. Intermittent pattern</td>
<td></td>
</tr>
<tr>
<td>a. amplitudinous</td>
<td></td>
</tr>
<tr>
<td>(a) regular in form</td>
<td></td>
</tr>
<tr>
<td>short in duration</td>
<td>2.</td>
</tr>
<tr>
<td>long in duration</td>
<td>3.</td>
</tr>
<tr>
<td>(b) irregular in form</td>
<td></td>
</tr>
<tr>
<td>short in duration</td>
<td>4.</td>
</tr>
<tr>
<td>long in duration</td>
<td>5.</td>
</tr>
<tr>
<td>b. small</td>
<td></td>
</tr>
<tr>
<td>(a) regular in form</td>
<td></td>
</tr>
<tr>
<td>short in duration</td>
<td>6.</td>
</tr>
<tr>
<td>long in duration</td>
<td>7.</td>
</tr>
<tr>
<td>(b) irregular in form</td>
<td></td>
</tr>
<tr>
<td>short in duration</td>
<td>8.</td>
</tr>
<tr>
<td>long in duration</td>
<td>9.</td>
</tr>
<tr>
<td>B. Extended or prolonged activity</td>
<td></td>
</tr>
<tr>
<td>a. amplitudinous</td>
<td></td>
</tr>
<tr>
<td>(a) regular in form</td>
<td>10.</td>
</tr>
<tr>
<td>(b) irregular in form</td>
<td>11.</td>
</tr>
</tbody>
</table>
(Table I. continued.)

<table>
<thead>
<tr>
<th>Class of record</th>
<th>Group number</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B.</strong></td>
<td></td>
</tr>
<tr>
<td>b. small</td>
<td></td>
</tr>
<tr>
<td>(a) regular in form</td>
<td>12</td>
</tr>
<tr>
<td>(b) irregular in form</td>
<td>13</td>
</tr>
</tbody>
</table>

* On account of the fact that the records showed so many amplitudes, an intermediate grouping was found necessary between 'amplitudinous' and 'small'. Such are designated by the use of plus and minus signs.

Photographs of small sections of the 13 types of records are shown on the plate that follows this page. Type 1 is to be found at the top of the left-hand column, type 2 just below, and so on consecutively for the whole 13.
On the following plate, 4 records are shown. The one at the top was taken while the animal was in the throes of a clonic spasm. The low frequency wave so prominent in the record is a 60 cycle A.C. wave superimposed upon the action current. The other 3 records are simply for the purpose of comparison of their characteristics with the 'spasm' record. (cf. Animal 20. page 59.)
D. Classification of Behavior Situations.

The following are 18 experimental situations under which records were obtained. Out of these 18, 10 situations were repeated a sufficient number of times under favorable conditions to permit generalizations from the data.

1. Dog Passive with no Particular Stimulation.
2. Dog Passive with Brightness Stimulation.
6. Dog Wincing or Slightly Squirming to Pain.
7. Forelimb Movements to Pain.
8. Limb Movements with Motor Stimulation.
13. Wincing to Brightness Stimulation.
14. Head Movements to Pain.
15. Head Movements to Motion of Body.
18. Narcotic in Right Hemisphere.
19. Experimental Injury to Sensori-motor Region.

* It was thought best to transfer the records of situation 7. elsewhere on account of their equivocal nature.
B. The Experiments themselves. It was our purpose in the experiments described below to lay bare the cortex and by the technique already described, explore the cortex from gyrus to gyrus under conditions which would allow for later comparison or records.

In all there were 24 animals used, though some of them for various reasons did not yield usable records for this study. The original numbers have been retained for the sake of ease in transfer from the original data to this thesis and elsewhere.

Animal 1. December 12, 1929. Left Hemisphere. Site, 2 x 2 cm.

Diagram on page 38 shows the size and location of the opening made on this animal. The dots, A, B, C, and D in the opened area indicate the location of the electrodes. A and C both lay on the anterior lateral gyrus, while the others lay on the juncture between the anterior ectolateral and the anterior suprasylvian gyri. Certain of the records were made from gyrus to gyrus and the remainder from the two points in the lateral gyrus. In this experiment no neutral electrode was used; the four points were connected to the multiple sliding switch so that the following pairs of contacts could be used; pair 1 was A-B; Pair 2. A-D; pair 3, A-C; and pair 4, C-D.

Recording was begun about 1 hour after operation. Fourteen separate trials were taken, eight of which were from all four switch positions, the combinations of electrode
points just mentioned. In the cases in which all four positions were used, the shifting from one to another was done while the film was in motion and while the animal remained passive or continued the movements it had been making.

The following is a summary of the records obtained with the location of electrodes as indicated.

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of records</th>
<th>Types</th>
<th>Activity</th>
<th>Stim.</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-D</td>
<td>10</td>
<td>1</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
</tr>
<tr>
<td>A-B</td>
<td>6</td>
<td>2</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
<td>A-D</td>
<td>1</td>
<td>1</td>
<td>gross</td>
<td>spont'ous</td>
<td>16</td>
</tr>
<tr>
<td>A-B</td>
<td>1</td>
<td>2</td>
<td>gross</td>
<td>spont'ous</td>
<td>16</td>
</tr>
<tr>
<td>A-C</td>
<td>3</td>
<td>1</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
</tr>
<tr>
<td>A-C</td>
<td>1</td>
<td>1</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
<td>A-C</td>
<td>1</td>
<td>2</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
</tbody>
</table>

Animal 2. December 20, 1929. We failed to obtain usable from this animal.
Diagram on page 38 gives the place and extent of the opening made. In this experiment the electrode contacts lay along the posterior part of the ectolateral gyrus; thus the variable in the situation was the amount of separation between contact points, the exact locations not counted as significant. The stimulation was "light" versus "darkness". A summary of results follows.

<table>
<thead>
<tr>
<th>Location</th>
<th>Record type</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>post ectolateral gyrus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 mm. separation</td>
<td>5</td>
<td>quiet</td>
<td>light on</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>quiet</td>
<td>light on</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>quiet</td>
<td>light on</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>quiet</td>
<td>light on</td>
<td>2</td>
</tr>
<tr>
<td>6 mm. sep.</td>
<td>5</td>
<td>quiet</td>
<td>light on</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>quiet</td>
<td>light off</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>quiet</td>
<td>light off</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>quiet</td>
<td>light on</td>
<td>2</td>
</tr>
</tbody>
</table>

In the above table the 3 mm. separation denotes the use of points 1 and 2 of the electrode, while the 6 mm. separation denotes the use of points 1 and 3.

After recording was finished, about 1/4 of the ectolateral gyrus, or most of that at the region of exposure was extirpated and the animal saved. Subsequent defects in gross vision; if any, were slight. The animal was one of the most active and tireless individuals that we have ever seen.
Animal 4. January 4, 1930. Left hemisphere. Site 2.1 x 1.2 cm.

Diagram 6 on page 38 shows the site of operation.

On account of artifacts in the records, the results on this animal were discarded.

Animal 5. January 31, 1930. Left hemisphere. Site 1.4 x 1.4 cm.

Diagram 5 on page 38 shows the place and extent of the opening. Although the lateral apex of the triangle extends across the middle suprasylvian gyrus, the greatest area exposed is on the middle ectolateral gyrus. It was from this region that the recording was made. The stimulation was flickering light produced by an episcotister---frequency from 2 to 10 per second. Again the same four-contact electrode was used with the point numbered 1 in the diagram the common contact. Position 1 on the switch utilized electrode contacts 1 and 2; position 2, 1 and 3; position 3, points 1 and 4. The following is a tabulation of the results.

<table>
<thead>
<tr>
<th>Switch position</th>
<th>Record type</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4-</td>
<td>slight wince</td>
<td>2-5 p.s.</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>13+</td>
<td>slight wince</td>
<td>2-5 p.s.</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>15+</td>
<td>slight wince</td>
<td>2-5 p.s.</td>
<td>13</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>quiet</td>
<td>dark</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>quiet</td>
<td>8-10 p.s.</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>quiet</td>
<td>dark</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>quiet</td>
<td>8-10 p.s.</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>quiet</td>
<td>dark</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>quiet</td>
<td>8-10 p.s.</td>
<td>2</td>
</tr>
</tbody>
</table>
Animal 6. Feb. 6, 1930. Left hem. Site 1.4 x 1.4 cm.

The opening on the dog is indicated in diagram 6 on page 43. This experiment was the first attempt to gain access to the mesial surface of the left hemisphere. (the lingual and suprasplenial gyri.) Both flicker and the difference between dark and illuminated room were tested.

The electrode used was spoon-shaped, with contacts on its lateral surface. The electrode was inserted in such a way that it penetrated between the hemispheres, with the contacts on the left. Recording was then from one contact to the other.

The results were as follows:

<table>
<thead>
<tr>
<th>Record type</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>quiet</td>
<td>room light</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>quiet</td>
<td>flicker 1-2 p.s.</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>quiet</td>
<td>room light</td>
<td>2</td>
</tr>
<tr>
<td>I</td>
<td>quiet</td>
<td>flicker 7-10 p.s.</td>
<td>2</td>
</tr>
<tr>
<td>I</td>
<td>quiet</td>
<td>room dark</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>quiet</td>
<td>flicker 7-10 p.s.</td>
<td>2</td>
</tr>
</tbody>
</table>
Animal 7. March, 14, 1930. Left hemisphere Site 1.5 x 1.7 cm.

Diagram 7 on page 43 gives the nature of the opening made in this experiment. In this case, as in the last, the attempt was to place the electrode contacts upon the mesial surface of the left hemisphere, in order to record from a part of the mesial visual area. The same electrode as for animals, was used. Both visual and motor stimulation were employed as indicated in the table of results.

<table>
<thead>
<tr>
<th>Location</th>
<th>Record type</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>all from lingual</td>
<td>1</td>
<td>passive</td>
<td>room dark</td>
<td>1</td>
</tr>
<tr>
<td>and suprasplenial region</td>
<td>1</td>
<td>passive</td>
<td>flash, left eye</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>passive</td>
<td>flash, right eye</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>passive</td>
<td>jaws pulled apart</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>passive</td>
<td>jaws pulled apart</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>lifted head p. jaws apart</td>
<td>3 bit E's thumb</td>
<td>3</td>
</tr>
</tbody>
</table>
Animal 8. March 19, 1930. Left hem. Site 1.5 x 1.8 cm.

Diagram 8 on page 43 represents the location and nature of the opening. This was the first animal on which a neutral electrode arrangement was used. A connection was soldered upon the jack clamp which supported the electrode. The metal surface of the clamp lay on the dura mater, thus providing a non-neural contact with the animal, and at the same time, a contact located close to the brain. A contact so located would not be picking up and conducting currents from the muscles. More will be said about this matter in discussing behavior situation 17.

Two rows of four stripes will be noticed pictured on the exposed area in the diagram for this animal. The anterior four lay on the anterior sigmoid gyrus, while the others lay on the posterior sigmoid. Each of the rows represents a position of the electrode which bore the four contacts. All but two of the records were taken from the points on the anterior electrode position.

Two series of records were taken, 12 in the first series and 22 in the second. From this total there are 22 records suitable for study.

<table>
<thead>
<tr>
<th>Rec. No.</th>
<th>Type</th>
<th>Location</th>
<th>Activity</th>
<th>Stim.</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>ant. sig. leg</td>
<td>voluntary</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>gross</td>
<td>vol.</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>gross</td>
<td>motion</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
<td>gross</td>
<td>motion</td>
<td>11</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>2</td>
<td>gross</td>
<td>motion</td>
<td>11</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>2</td>
<td>head</td>
<td>motion</td>
<td>3</td>
</tr>
</tbody>
</table>

This animal was a very poor specimen, young, poorly fed, weak, and non-responsive. In this condition, it was in some respects similar to a reflex preparation. Between attempts at recording, the dog was used for exploration by faradic stimulation, especially for the elicitation of various types of eye movements. The same four contact electrode was employed as was in the case of dog 8, and in the positions represented by the two rows of black stripes in diagram 9 on page 45.
The brain exposure for this animal pictured in diagram 10 on page 48 laid bare a large portion of the anterior and posterior sigmoid gyri, the anterior end of the suprasylvian, a middle portion of the eotosylvian, and a small median section of the sylvian gyrus. Two types of electrodes were used in this experiment; first a large surfaced one having two contact areas; second, the usual four point electrode. The anterior surface of the former lay in the lateral sigmoid gyrus, the posterior surface on the anterior eotolateral. The two anterior contacts of the second electrode lay in the lateral sigmoid within the area covered by the one surface of the first electrode. The third contact lay posterior to the two just mentioned and on the coronal sulcus, while the fourth point lay on the coronal gyrus itself.

The outcome of the four series of records taken are given below.

<table>
<thead>
<tr>
<th>Rec. no.</th>
<th>Type</th>
<th>Location</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-6</td>
<td>5</td>
<td>lat. sig. gross</td>
<td>motion</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>7-11</td>
<td>1</td>
<td>mid. supra. gross</td>
<td>motion</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>bd. sig. gross</td>
<td>motion</td>
<td>11</td>
<td>and crus.</td>
</tr>
<tr>
<td>Rec. no.</td>
<td>Type</td>
<td>Location</td>
<td>Activity</td>
<td>Stimulation</td>
<td>Situation</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
<td>-------------</td>
<td>----------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td>13-14</td>
<td>3</td>
<td>lat. sig. gross motion</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>bd. sig. and cruc. gross motion</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>5</td>
<td>coronal gross</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-18</td>
<td>11</td>
<td>lat. sig. gross motion</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>11</td>
<td>bd. sig. and cruc. gross motion</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-21</td>
<td>11</td>
<td>coronal gross</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22-23</td>
<td>2</td>
<td>lat. sig. gross motion</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>11</td>
<td>bd. sig. and cruc. gross motion</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>11</td>
<td>coronal gross</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>5</td>
<td>coronal spontaneous</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27-32</td>
<td>5</td>
<td>coronal head spontaneous</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>11</td>
<td>coronal passive head mvt.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34-36</td>
<td>1</td>
<td>lat. sig. passive head mvt.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>1</td>
<td>bd. sig and cruc. passive head mvt.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>11</td>
<td>coronal passive head mvt.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Diagram 11 on page 48 indicates the location of the electrodes as well as the areas exposed. The anterior electrode was a large silver disc 17 mm. in diameter lying over both the anterior and posterior sigmoid gyri as well as most of the cruciate gyrus. Records 7 to 12, inclusive, were obtained under motor stimulation while the others were taken with intermittent light stimulation.

<table>
<thead>
<tr>
<th>Rec. no.</th>
<th>Types</th>
<th>Location</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>p. supra.</td>
<td>passive</td>
<td>flicker</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>p. supra.</td>
<td>passive</td>
<td>&quot;</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>sig-crus.</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>p. supra.</td>
<td>leg mvt.</td>
<td>leg mvt.</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>sig-crus.</td>
<td>leg mvt.</td>
<td>leg mvt.</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>13</td>
<td>sig-crus.</td>
<td>passive</td>
<td>b. rolled</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>p. supra.</td>
<td>leg mvt.</td>
<td>b. rolled</td>
<td>8</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>sig-crus.</td>
<td>passive</td>
<td>h. mvt.</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>sig-crus.</td>
<td>passive</td>
<td>h. mvt.</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>11</td>
<td>sig-crus.</td>
<td>passive</td>
<td>light fl.</td>
<td>2</td>
</tr>
</tbody>
</table>

The six brain diagrams on page 52 show the electrode positions used in the several parts of the experiment, as well as the extent of the brain exposed. In series A, a neutral electrode was used, and recording was made from the coronal and from the boundary of the sylvian and middle ecto-sylvian gyri. In series B, with the same "neutral", records were taken from the lateral and the ectolateral gyri. Records 1 to 11 belong to series A and 12 to 23, inclusive, to series B. Series C includes records 24 to 27, made without the use of a neutral, and obtained from the posterior sigmoid to the posterior lateral gyrus. Series D, again with no neutral, and from the coronal to the posterior lateral gyrus, is composed of records 28 to 31, inclusive. The last series (E) includes records 32 and 33 from the posterior lateral gyrus, using a neutral electrode. Certain of the records mentioned in these series and obtained under auditory stimulation, are not applicable in the present study.

Rec. no. Type Location Activity Stimulation Situation
3     12  cc. syl. quiet  l. flash  2
      syl. - m. lat.
16    12+ m. lat. quiet  no stim.  1
19    6  m. lat. quiet  motion  4
20    13  p. ect lat. quiet  l. flash  2

* Used in special study of Mr. Theodore Perkins.
<table>
<thead>
<tr>
<th>Rec. no.</th>
<th>Type</th>
<th>Location</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>13</td>
<td>m. lat.</td>
<td>quiet</td>
<td>light flicker</td>
<td>2</td>
</tr>
<tr>
<td>22</td>
<td>6</td>
<td>p. ectolat.leg mvt.</td>
<td>leg mvt.</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>23</td>
<td>7</td>
<td>lateral</td>
<td>gross</td>
<td>b. mvt.</td>
<td>11</td>
</tr>
<tr>
<td>32</td>
<td>11</td>
<td>lateral</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
<td>33</td>
<td>11</td>
<td>lateral</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
</tbody>
</table>

**Without the use of neutral.**

<table>
<thead>
<tr>
<th>Rec. no.</th>
<th>Type</th>
<th>Location</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>4</td>
<td>p.s.-1.</td>
<td>gross</td>
<td>b. mvt.</td>
<td>11</td>
</tr>
<tr>
<td>25</td>
<td>5</td>
<td>p.s.-1.</td>
<td>gross</td>
<td>b. mvt.</td>
<td>11</td>
</tr>
<tr>
<td>26</td>
<td>2</td>
<td>p.s.-1.</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td>p.s.-1.</td>
<td>h. mvt.</td>
<td>b. mvt.</td>
<td>15</td>
</tr>
<tr>
<td>28</td>
<td>2</td>
<td>co.-1.</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
<td>29</td>
<td>2</td>
<td>co.-1.</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
<td>31</td>
<td>13</td>
<td>co.-1.</td>
<td>quiet</td>
<td>none</td>
<td>1.</td>
</tr>
</tbody>
</table>

The area exposed on this animal is shown in diagram 13 on page 48. The records were obtained from 3 gyri, the posterior lateral, the coronal, and the sylvian. A number of the records obtained were under conditions of auditory stimulation (for Perkins) and thus are not used in this study. Out of a total of 25 records, 14 apply and are listed below.

<table>
<thead>
<tr>
<th>Rec. no.</th>
<th>Type</th>
<th>Location</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>11</td>
<td>sylvian</td>
<td>h. mvt.</td>
<td>motion</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>sylvian</td>
<td>h. mvt.</td>
<td>motion</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>p. sig.</td>
<td>h. mvt.</td>
<td>motion</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>coronal</td>
<td>h. mvt.</td>
<td>motion</td>
<td>15</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>coronal</td>
<td>quiet</td>
<td>light</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>coronal</td>
<td>quiet</td>
<td>h. mvt.</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>5</td>
<td>sylvian</td>
<td>quiet</td>
<td>c. neck</td>
<td>17</td>
</tr>
<tr>
<td>18</td>
<td>7+</td>
<td>coronal</td>
<td>quiet</td>
<td>c. neck</td>
<td>17</td>
</tr>
<tr>
<td>19</td>
<td>5</td>
<td>sylvian-</td>
<td>quiet</td>
<td>c. neck</td>
<td>17</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>coronal</td>
<td>squirm</td>
<td>c. neck</td>
<td>17</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>coronal</td>
<td>squirm</td>
<td>c. neck</td>
<td>17</td>
</tr>
<tr>
<td>22</td>
<td>2</td>
<td>sylvian</td>
<td>squirm</td>
<td>c. neck</td>
<td>17</td>
</tr>
<tr>
<td>23</td>
<td>5</td>
<td>sylvian</td>
<td>squirm</td>
<td>c. neck</td>
<td>17</td>
</tr>
<tr>
<td>24</td>
<td>11</td>
<td>sylvian</td>
<td>squirm</td>
<td>c. neck</td>
<td>17</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>sylvian</td>
<td>quiet</td>
<td>c. neck</td>
<td>17</td>
</tr>
</tbody>
</table>
The last 8 records were taken with the dog's neck anesthetized with curare. Three minutes previous to the taking of the first of the 8 records about 15 cc. of 2% curare solution had been injected into the dorsal and lateral neck muscles. During recording, some head movements were observed, but as nearly as could be told, these occurred only as a result of the shifting of general posture or from the relaxation from the effects of the drug. The use of curare, among other things, provided further check in determining whether there might be an induction of muscle action currents in such a way as to affect the records. Large records of the usual character were still obtained with curarization.

Another fact that may be mentioned is that the largest records in our animals were not consistently obtained from the gyral positions closest to the edge of the cranial opening as would be expected were the source of our records other than genuine cortical phenomena.

Animal 14. Sept. 27, 1930. Left hemisphere. Site 2.7 x 1.8 cm.

Diagram 14 on page 56, shows the opening exposed practically all of the posterior sigmoid, a part of the cruciate, and a small strip of the anterior lateral, all of the area where the anterior ectolateral and the middle supra-
Sylvian gyri join, as well as a part of the sylvian, and a large part of the ectosylvian gyri. Within this entire area, records were taken from 4 places, the lateral sigmoid, the coronal, the middle ectosylvian, and the anterior ectolateral gyri.

Below are the results.

<table>
<thead>
<tr>
<th>Rec. no.</th>
<th>Type</th>
<th>Location</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 m.ectosyl.</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>13+ lat sig.</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10 coronal</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1 m.ectosyl.</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>13+ latcsig.</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>11 coronal</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1 m.ectosyl.</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>11- coronal</td>
<td>quiet</td>
<td>1.flash</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>12 lat sig.</td>
<td>quiet</td>
<td>1.flash</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1 a. ectolat.</td>
<td>quiet</td>
<td>1.flash</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>1 lat sig.</td>
<td>leg mvt.</td>
<td>leg mvt.</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>11 a. ectolat.</td>
<td>leg mvt.</td>
<td>leg mvt.</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>13+ coronal</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>1 lat sig.</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>1 a. ectlat.</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

In spite of the large exposure shown in diagram 16 on page 56, the only records that are available are taken from the anterior sigmoid gyrus. They are as follows:

<table>
<thead>
<tr>
<th>Rec. no.</th>
<th>Type</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>quiet</td>
<td>lifting head</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>quiet</td>
<td>none</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>gross</td>
<td>moved body</td>
<td>11</td>
</tr>
</tbody>
</table>


The brain exposure and electrode positions for this dog are shown in diagram 19 on page 56. The electrode positions were situated in the posterior ectolateral, the middle ectosylvian, the coronal, and the lateral sigmoid gyri. In all there were 31 records taken, 6 of which were used by Mr. Perkins.

<table>
<thead>
<tr>
<th>Rec. no.</th>
<th>Type</th>
<th>Location</th>
<th>Activity</th>
<th>Stimulation</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>m. ect.</td>
<td>passive</td>
<td>flash 1.</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>sor.</td>
<td>passive</td>
<td>flash 1.</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>lat. sig.</td>
<td>passive</td>
<td>flash 1.</td>
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<td>quiet</td>
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</table>

The 6 positions recorded from, in this animal, are shown in diagram 20 on page 56. They were the following; the coronal, the anterior ectosylvian, the posterior ectosylvian, and the posterior suprasylvian. In addition, a two contact electrode was inserted under the posterior edge of the bone at the operation site, so that the contacts lay on the posterior ecotolateral gyrus. In all, 20 records were made; the first 8 were from the two point electrode just mentioned, and the rest with the four point electrode. After 15 records were taken, the animal exhibited clonic spasms, involving at least the front quarters and the head. The last five records were taken while the animal was in these spasms.

In operating upon this animal, the blood supply in the anterio part of the brain was disturbed. A small amount of surgical wax became lodged under the bone and possibly bore on the medial part of the sigmoid region, so that by the time the animal had taken the usual one hour or more to recover from the anesthetic, and after additional time had been spent in recording, the consequences of operative accidents began to appear. The symptoms in this case were quite similar to the spasms manifested in animal 5, two weeks after operation. This animal had been housed along with another animal which would not allow the incision of the first to heal but continued to lick it open. Whether due to infection or to direct injury, the vascular system in the sigmoid and coronal region of animal 5 was later found injured.
<table>
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**Animal 22. Feb. 18, 1931. Both hems. L. site 2.1 x 2.8 cm. R. site 1.7 x 2.4 cm.**

The work on this animal marks the first attempt to open both sides of the cranium to record from both hemispheres, and from hemisphere to hemisphere. The electrode positions, as well as the areas opened are shown in diagram 22 on page 63. On the left hemisphere, the two electrode positions are the coronal and the posterior ectosylvian gyri; on the right hemisphere, they were the anterior ectolateral, the middle ectosylvian, and the boundary of the coronal and anterior ectosylvian gyri. The first 14 records were made with one electrode on one hemisphere and the other one on the other.
In the left hemisphere, the electrode was on the coronal gyrus, while in the right hemisphere, it lay on the anterior ectolateral. For records 15 to 23 inclusive a neutral electrode was used, located on the left hemisphere in the usual place. The electrodes were in the same position as in the first set of records. In the left hemisphere, the electrode was attached to point 2 of the switch, and the one in the other hemisphere to point 4 of the switch. Records 24 to 42 inclusive were taken with the electrodes reset, both in the right hemisphere. The number 2 lay on the boundary of the coronal and anterior ectosylvian. Electrode 4 was in the middle ectosylvian. Records 42a to 48 inclusive were obtained from the left hemisphere, the anterior electrode was number 4 and lay on the coronal gyrus. Electrode 2 lay on the posterior ectosylvian, approximately in the position during the first set of records.

<table>
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<tr>
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<td>&quot;squirm&quot;</td>
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<td>&quot;gross&quot;</td>
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<td>&quot;</td>
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</table>
Animal 23. March 4, 1931. Both hems. R. Site 3.1 x 2.5 cm. L. Site 3.2 x 2.6 cm.

The nature of the exposures in this dog was similar to those in the last animal, as seen from the diagram 23 on page 63. There were two electrode contacts in each hemisphere. Those on the left were situated in the coronal and middle ectosylvian, those on the right, in the middle and posterior sigmoid gyri. Thus almost homologous locations were used in the two hemispheres.

<table>
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The last 4 records in the above table were taken after an injection of chloral hydrate was given in the right hemisphere. Prior to the injection the animal had been unusually active, and at one time while the electrodes were being adjusted, struggled and snapped viciously at the experimenter's hand. After the injection, the animal remained passive during the recording, but when the harness bands were being unfastened in order to take the animal from the operating table, it again began the wild snapping, even though it showed every symptom of passivity before being disturbed.
This incident suggests that under the influence of the narcotic, the dog must either be passive or highly active, bordering on a condition of mania. The interpretation is suggested that the motor activity of the animal as well as the sensory aspects of behavior exhibited a threshold according to conditions. The animal seemingly failed to respond to pain stimulation from the tail. It felt nothing and was passive. But when the animal was handled and its head moved, it began at once to struggle vigorously. The type of stimulation now given was above the raised threshold, partly because it involved the animal’s head region. The resulting movement was, of necessity, intense, or it would not have occurred. When placed on the floor, the animal immediately became passive again, taking four or five steps and sinking down to the floor.

Animal 24. April 18, 1931. Left hem. Site. 4.9 x 2.5 cm.

Diagram 24 on page 63 shows the variety of electrode locations and boundaries of the opening. In all, 7 widely separated places were used for recording, namely, the anterior and posterior sigmoides, the anterior and posterior ectolateral, the middle and posterior suprasylvian, and the sylvian gyri.

<table>
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<th>Activity</th>
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<th>Situation</th>
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<td>Activity</td>
<td>Stimulation</td>
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<td>11</td>
</tr>
<tr>
<td>15</td>
<td>13</td>
<td>sylvian</td>
<td>passive</td>
<td>leg mvt.</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>11</td>
<td>sylvian</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
<td>17</td>
<td>11+</td>
<td>sylvian</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
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<td>head m.</td>
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<td>wince</td>
<td>pain</td>
<td>6</td>
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<td>head</td>
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<tr>
<td>26</td>
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<td>pain</td>
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<td>gross</td>
<td>pain</td>
<td>10</td>
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<tr>
<td>30</td>
<td>11</td>
<td>m.supr.</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
</tr>
<tr>
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<td>m.supr.</td>
<td>leg mvt.</td>
<td>leg mvt.</td>
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<td>m.supr.</td>
<td>wince</td>
<td>pain</td>
<td>6</td>
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<td>13</td>
<td>m.supr.</td>
<td>passive</td>
<td>light</td>
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<td>Rec.no.</td>
<td>Type</td>
<td>Location</td>
<td>Activity</td>
<td>Stimulation</td>
<td>Situation</td>
</tr>
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<td>----------</td>
<td>----------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td>34</td>
<td>1</td>
<td>a.e.l.</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
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<tr>
<td>35</td>
<td>13+</td>
<td>a.e.l.</td>
<td>gross</td>
<td>pain</td>
<td>10</td>
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<tr>
<td>36</td>
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<td>wince</td>
<td>pain</td>
<td>6</td>
</tr>
<tr>
<td>40</td>
<td>13+</td>
<td>p.sig.</td>
<td>head</td>
<td>pain</td>
<td>14</td>
</tr>
<tr>
<td>42</td>
<td>13+</td>
<td>p.sig.</td>
<td>passive</td>
<td>flash 1.</td>
<td>2</td>
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</tbody>
</table>
IV. Utilization of the Data

A. Presentation of data by maps

1. The mapping scheme

For convenience, the data already presented in the form of tables in section III were condensed in the form of maps. Note that in Table I, the different types of records are given a type number found in the right-hand column. These numbers were not immediately interpretable in terms of magnitudes (amplitudes; energy). Accordingly, type 1 is assigned the value of zero. When records showed continuous and very weak fluctuations caution demanded that they be interpreted as possible artifacts due to an unsteady base potential. They (types 12 and 13) were given, therefore, a value of 1. Intermittent weak fluctuations were given the value of 2 on the assumption that they were safer records, that is, more likely from the dog rather than from the apparatus, since long experience with the apparatus showed that intermittent variations of an artificial character were readily identifiable. Thus, records of types 6, 7, 8 and 9 were given the value of 2. Records of type 2, 3, 4, 5, 10 and 11 were given a value of 4 because, uniformly, the amplitudes of these records were considerably greater than the amplitudes valued as 1 and 2. Intermediate between 2 and 4 fall a few records which, as indicated on page ____ were designated by plus and minus signs. These are given the value 3.

Having assigned each type of record a value, all records obtained under similar stimulus and behavior conditions were averaged, and maps drawn using no finer steps than .5. These maps indicate the concentration of kinetic energy, as measured
by our technique, occurring in the various parts of the cortex. In other words the maps are intended to show the gradient of activity found to exist across the cortex under our conditions of experimentation. The higher the number, the greater is the concentration indicated. Striking uniformities, far greater than expected, were found in the records obtained in specific behavior situations. These uniformities can be seen, by inspection, from the tables of section IV,A,ii and iii.

Since it was the purpose of this investigation to demonstrate whether the action current method would yield evidence of general principles in brain functioning, and since the conditions of the work were so numerous, varied and difficult to control, it is evident that a rough method of evaluating the data is more appropriate and meaningful than an attempt to make fine distinctions. In fact hundreds of fine measurements of the records were made, concerned with (1) duration of a single impulse, (2) frequency of impulses, (3) durations of volleys, (4) lengths of intervals between volleys, (5) amplitudes of single impulses (6) diphasic versus monophasic waves, (7) frequencies and durations of various irregularities of pattern. It was found impossible, however, to ascertain the full significance of these refined measurements under the conditions of experimenting upon an intact animal, because single stimulus conditions could not be isolated, nor could single movements be placed under control.
11. The maps presented.

1. Dog Passive with no Particular Stimulation. Table II shows the gyri from which records were taken, the number and types of records and the magnitudes assigned to the kinetic energy involved and used in constructing the map. (Page 26.)

Note the wide distribution of the 6 different locations from which records were obtained. The map indicates two general regions of energy concentration, one in the sensory-motor area, with its peak in the coronal gyrus, and the other in the occipital pole, or the visual area. The former concentration is higher, though the indicated high level is not so widespread as that of the concentration in the occipital pole.

In terms of the localization theory, the coronal gyrus is the area for neck and fore-limb sensibility. Our results consistently show a peak in the anterior maximum, or concentration, in a situation where the animal is overtly quiet, and under no particular stimulation by the experimenter. In spite of the local anesthetic it seems that the dog was actually receiving stimulation from the skin and muscles of the head and muscles out in the operation. This view does not postulate any "localization" of functions, however, for it does not suppose the gyrus to be the "center" that controls either the motor or sensory activity of the neck and fore-limb region. On the contrary this region represents the part of the cortex which lies functionally nearest the part of the animal's periphery under greatest stimulation. Here would be found a relatively great amount of kinetic energy, under the stimulus conditions that have just been suggested, regardless of any
localization theory.

Diagram 1, on page 79 also shows the results from intra and inter gyri electrode arrangements. Only very slight fluctuations were obtained as seen, as indicated by the magnitude 1. The numbers found on this and the subsequent diagrams of this series (a) are values calculated by the same scheme as for the large maps, but their meaning is different. In the former, the neutral electrode represented a common level from record to record and from animal to animal about which the potential of the other electrode fluctuated. Here, there is no standard of reference, consequently the scale of values represents merely the amplitude of the fluctuations between the two electrode positions.

Table II

1. Passive with no Particular Stimulation

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Left</th>
<th>Mapping Value</th>
<th>Right</th>
<th>Mapping Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior sigmoid</td>
<td></td>
<td>1, 13, 1</td>
<td></td>
<td></td>
<td>.3</td>
</tr>
<tr>
<td>lateral sigmoid</td>
<td></td>
<td>13+, 13+, 1</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>coronal</td>
<td></td>
<td>10, 11, 13+</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bd. cor. &amp; ant. ectosyl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>mid ectosyl</td>
<td></td>
<td>10, 1, 1, 1</td>
<td>1.5</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>ant. ectolateral</td>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>post ectolat</td>
<td></td>
<td>12, 13</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Inter-hemispherical records

anterior ectolat (right) to coronal (left) 1,13,1

Intra-hemispherical records

anterior lateral to mid ectolateral 1,1,1,1,1,1,1,1,1
anterior lat. to anterior lat. 1,1,1
lingual and suprasphenial 1,1
coronal to post lat. 13
mid ectolat. to mid ectolat. 1,1,1

2. Passive with Brightness Stimulation. On page 76 a table is presented with the data from which the map on page 77 was constructed. From this map, it will be seen that again there are anterior and posterior energy concentrations, such as were found in the preceding behavior-situation. In this case, however, the peak of the anterior maximum lies in the lateral part of the anterior sigmoid gyrus instead of the coronal, and it is somewhat higher than was found in situation 1. In fact, the whole area of concentration in this present case, is located more toward the median aspect of the hemisphere. The posterior concentration, as far as can be ascertained, is similar to that in situation 1, but somewhat higher. This result does not harmonize with the suggestion that the cortex is not involved in the perception of mere brightness, on the evidence that the visual cortex is more active when the animal is stimulated with strong light. One cannot suggest all of the conditions that may explain the shift of the peak of the anterior maximum from its lateral position in situation 1 to its more medial position in
situation 2. The difference, in part, however, suggests a change in the role played by the unnatural neck conditions under strong stimulation of the animal's periphery elsewhere. If we could liken the animal's behavior to human experience, we could say that with the brightness stimulation, the neck discomfort ceased to be figured perceptually as it was before, but became part of the "ground". Diagram 2 on page 73 shows the results from additional electrode arrangement. The places recorded from are few, but nevertheless show that such places as the lingual and suprasplenial gyri are the loci of high concentrations of kinetic energy, and are in keeping with the interpretation given the map for this behavior situation.

Table III.

2. Passive with Brightness Stimulation

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Left mapping value</th>
<th>Right mapping value</th>
</tr>
</thead>
<tbody>
<tr>
<td>lateral sigmoid</td>
<td></td>
<td>6,13,1,1,1,12</td>
<td>13+</td>
</tr>
<tr>
<td>posterior sigmoid</td>
<td></td>
<td>12+,12+,12+</td>
<td>12+</td>
</tr>
<tr>
<td>posterior cruciate</td>
<td></td>
<td>1,1,12,7,9,13,11+</td>
<td>12+</td>
</tr>
<tr>
<td>coronal</td>
<td></td>
<td>12,13,13,1,9,9</td>
<td>1.0</td>
</tr>
<tr>
<td>middle ectosylvian</td>
<td></td>
<td>4,13,10</td>
<td>3.5</td>
</tr>
<tr>
<td>bd post sigmoid &amp; coronal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>middle lateral</td>
<td></td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>anterior ectolateral</td>
<td></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>posterior ectolateral</td>
<td></td>
<td>13,13,13+</td>
<td>1.2</td>
</tr>
<tr>
<td>middle suprasylvian</td>
<td></td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>post suprasylvian</td>
<td></td>
<td>1,1,1</td>
<td>0</td>
</tr>
<tr>
<td>sigmoids &amp; cruciate</td>
<td></td>
<td>12,12,12,12,1</td>
<td>1</td>
</tr>
<tr>
<td>bd ectosylvian &amp; sylvian</td>
<td></td>
<td>12</td>
<td>1</td>
</tr>
</tbody>
</table>
Intra-hemispheral records

post ectolat to post ectolat (left) 5,5,4,13,1,11,8,8
lingual & supra splenial 11,11,11,1,1,13,1
mid ectolateral to mid ectolateral 1,13,13

3. Dog Passive with Motor Stimulation. (experimenter moves animal's head.)

From the map on page 79\(a\) it will be immediately seen that in this situation, also, there is an anterior and a posterior maximum. The former includes at a level of 4, the coronal gyrus, and the lateral aspect of the anterior and posterior sigmoids, and the rest of the posterior sigmoid and the cruciate. The central and medial portions of the anterior sigmoid gyrus are included within the maximum at a level of 2.5. No data are available for much of the occipital pole, but since the lateral portion of it is high the remainder of the pole is presumably high, also.

In this situation the dog's head was moved from side to side. Here, although the dog was passive at the time of initial stimulation, the character of the anterior or somatic maximum is essentially different in both extent and amplitude than in situations 1 and 2. The map shows then that all cases of overt passivity are not alike in terms of the stresses within the animal. In situations 1 and 2 the posterior maximum was not as high as the anterior one, but here we find it equally as high. In other words, the relation between the anterior and posterior maxima has changed in terms of both their mutual relation of height and extent.
Table IV.

3. Passive with Motor Stimulation—Experimenter Moving Head

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Left</th>
<th>Mapping Value</th>
<th>Right</th>
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</thead>
<tbody>
<tr>
<td>lateral sigmoid</td>
<td>1,1,1,1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>sylvian</td>
<td>13,13</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>posterior suprasylvian</td>
<td>11,11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>sigmoids &amp; cruciate</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>coronal</td>
<td>5,11,11,5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>bd sigmoids &amp; cruciate</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>anterior sigmoid</td>
<td>12,2,6</td>
<td>2.3</td>
<td></td>
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</tbody>
</table>

Intra-hemispheral record

lingual & supra splenial   1,3,5

4. Passive with Motor Stimulation. (Experimenter moved dog's limbs.)

On page 79 is the map showing the distribution of energy concentrations. There is a known difference between this situation and the last. On the former case the animal's head was moved and in this case the limbs. As far as the outward behavior of the dog was concerned there was no describable difference. In both cases the animal was passive. However, just as if the animal could tell us of differences in its experience in the two situations, we find differences in the cortical field. In the present situation, the anterior maximum is more restricted and is not as high as in the former situation, neither is the posterior concentration as high as it was in the last case. The animal apparently was disturbed less by moving its limbs than by moving its head, for either or both of two
reasons. The first may be that the anterior end of the animal may ordinarily be more sensitive; the second, that the animal is already disturbed at the head end by the operative wound.

Again there is evidence that any given area plays a very different rôle from time to time as the stimulus conditions change that impinge upon the animal.

Table V

4. Passive with Motor Stimulation—Experimenter Moving Limbs

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
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<th>Mapping Value</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior sigmoid</td>
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<td>5,13+</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>lateral sigmoid</td>
<td></td>
<td>13+,7</td>
<td>2.5</td>
<td></td>
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<tr>
<td>posterior sigmoid</td>
<td></td>
<td>13</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>cruciate</td>
<td></td>
<td>6,13</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>coronal</td>
<td></td>
<td>1,7</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>middle ectosylvian</td>
<td></td>
<td>8</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>sylvian</td>
<td></td>
<td>13</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>middle lateral</td>
<td></td>
<td>6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>posterior ectolateral</td>
<td></td>
<td>1+,13+</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>posterior supr-sylvian</td>
<td></td>
<td>12</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>sigmoids &amp; commissate</td>
<td></td>
<td>13</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Inter-hemispherical Record

anterior ectolateral (right) to coronal (left) 9

Intra-hemispherical Record

post. sigmoid to post. lateral (left) 2
5. Passive with Pain Stimulation. It will be seen from both the table of data on page 82 and the map on page 83 that the material for this situation is not as complete as would be desired, but in the few available records, some idea of the energy distribution can be obtained. The map shows again that there is a posterior as well as an anterior maximum in concentration of kinetic energy. The level of the latter is now only medium high, suggesting that though the animal was given stimulation intended to be painful, there was only a moderate result. Outwardly the animal was passive, and as far as the cortex was concerned, there seemed to be less kinetic energy involved than when the head was moved. The stimulation seemed in this case to be no more effective in disturbing the animal than moving its limbs, though what disturbance there was furnished a different pattern than before, as attested by the maps of this and situation 4.

Results from the single record taken with electrode arrangement 2 are shown in diagram 5 on page 84. It was negative.

Table VI
5. Passive with Pain Stimulation

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
</tr>
<tr>
<td></td>
<td>Type</td>
</tr>
<tr>
<td>posterior ectolateral</td>
<td>12, 11</td>
</tr>
<tr>
<td>middle ectosylvian</td>
<td>9</td>
</tr>
<tr>
<td>coronal</td>
<td>8</td>
</tr>
<tr>
<td>lateral sigmoid</td>
<td>8</td>
</tr>
</tbody>
</table>

Inter-hemispherical record
bs post sigmoid & coronal (right) to coronal (left) 1.
6. Wincing or slightly squirming, with pain stimulation.

The map on page 6 shows the outcome of this situation (6). The locations explored are most numerous in the anterior half of the cortex. Little can be said about the existence or nature of the posterior maximum. The anterior maximum extends into the auditory area, where a level of 3 is found in comparison to that of 4 in the middle and anterior ectosylvian gyrus, the coronal and the lateral sigmoid gyri. This situation represents the case in which the intended pain stimulation was evidently becoming superliminal. As outward evidence, there was wincing, or slight squirming. The somatic cortical field is in kinetic energy and widely extended.

Table VII

6. Wincing or slightly squirming with pain stimulation.

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Map Value</td>
<td>Type</td>
</tr>
<tr>
<td>anterior sigmoid</td>
<td>13</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>lateral sigmoid</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>coronal</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>bd coronal &amp; anterior</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ectolateral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>middle ectosylvian</td>
<td>11</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>sylvian</td>
<td>11</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>anterior ectolateral</td>
<td>9</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>middle suprasylvian</td>
<td>3, 13</td>
<td>2.5</td>
<td></td>
</tr>
</tbody>
</table>
Inter-hemispheral records

ant. ectolateral (right) to coronal (left) 13, 7, 13
bd post sigmoid & coronal (right) to coronal (left) 12+

Intra-hemispheral record

bd post sigmoid & coronal to mid ectosylvian (right) 13+

8. **Limb Movements with Motor Stimulation.** (Artificial movement of limbs)

The table on page 89 and the map on page 88 show the energy distribution for situation 8. The map at once suggests both an anterior and posterior concentration, though the fact that no records were obtained from the area between the cruciate gyrus and the anterior ectolateral limits the evidence for the posterior maximum. Neither are there records from the coronal gyrus; thus one cannot make a rigid comparison between the extent of the anterior maximum in this situation and any of the others. The anterior maximum, when recorded, is very high. The few records obtained from the occipital area, indicate that the concentration is high there also. It probably is true, then, that whenever the animal begins to make movements involving a large part of its musculature, such as in walking, pawing, and in making sweeping head movements, vision is involved more appreciably than in passive situations. This is interesting when it is reflected that the animal was not walking about, but was strapped in harness.

The two records taken with arrangement 3 are shown in diagram 8 on page 84. Fluctuations of the very largest kind occurred in these records, showing a highly fluctuating potential between the somatic and visual areas.
8. Limb movements with motion stimulation.

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Type</th>
<th>Map Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2,6</td>
<td>3</td>
</tr>
<tr>
<td>lateral sigmoid</td>
<td>left</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>sigmoids &amp; cruciate</td>
<td>right</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>anterior ectolateral</td>
<td>right</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>posterior ectolateral</td>
<td>right</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>middle suprasylvian</td>
<td>right</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>post suprasylvian</td>
<td>right</td>
<td>13+,6,3-</td>
<td>2</td>
</tr>
</tbody>
</table>

Intra-hemispherical record

posterior sigmoid to posterior lateral (left) 4,5

10. Gross Movements with Pain Stimulation. The map giving the cortical energy distribution for this situation is found on page 70. Of all the 10 maps this shows the greatest amount of kinetic energy. There is both an anterior and posterior maximum, and both are at a level of 4. Records from a wider variety of locations are available for the latter maximum than for the former; this high level is found to extend into the auditory area, making it a part of the posterior concentration. The high level and broad extent of the posterior maximum in the present situation suggests that the animal looks around him during his struggles to free himself and to jump from the operating table. This is not of necessity true, but as a postulate, gives meaning to the distribution of energy.
on the cortex. If the above supposition concerning the animal's behavior be true, then one would expect that its perceptual field would be more highly structured visually than in the case of passivity.

The results obtained in both inter-hemispheric and intra-hemispheric recording are given in diagram 10 on page 84. The records with the former arrangement show a great deal of fluctuation in the potential between hemispheres with marked sensory and motor activity of the animal. The qualitative type of record from within the one hemisphere without the use of the neutral is different than that obtained with inter-hemispheric recording. The type generally found in the former case is 2, while in the latter it is 11.

Table IX


<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Type</td>
<td>Value</td>
</tr>
<tr>
<td>anterior sigmoid</td>
<td></td>
<td>11+</td>
<td>4</td>
</tr>
<tr>
<td>coronal</td>
<td></td>
<td>12, 10</td>
<td>2.5</td>
</tr>
<tr>
<td>bd coronal &amp; ant. ectosylvian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>middle ectosylvian</td>
<td></td>
<td>13+</td>
<td>3.5</td>
</tr>
<tr>
<td>sylvian</td>
<td></td>
<td>11, 11</td>
<td>11+</td>
</tr>
<tr>
<td>anterior ectolateral</td>
<td></td>
<td>13+</td>
<td>1</td>
</tr>
<tr>
<td>posterior ectolateral</td>
<td></td>
<td>11, 11</td>
<td>4</td>
</tr>
<tr>
<td>middle supra sylvian</td>
<td></td>
<td>11, 11</td>
<td>4</td>
</tr>
<tr>
<td>posterior suprasylvian</td>
<td></td>
<td>11, 3</td>
<td>4</td>
</tr>
<tr>
<td>posterior lateral</td>
<td></td>
<td>11, 11</td>
<td>4</td>
</tr>
</tbody>
</table>
Inter-hemispheral records

anterior ectolat (right) to coronal (left) 11,11,11
mid. ectosylvian (right) to coronal (left) 11
bd. post sigmoid & coronal (right) to mid ectosylvian (left) 11
mid. ectosylvian (right) to mid ectosylvian (left) 11

Intra-hemispheral records

anterior lateral to mid ectolateral (left) 2,2,2,2,2,2
anterior lateral to anterior lateral (left) 2,1
post sigmoid to post lateral (left) 2
coronal to post lateral 2,2
mid ectosylvian (right) to bd post sig & coronal (rt.) 12+

11. Gross Movements to Motion of the Body. According to the map on page 492, for this situation, it will be seen that the majority of the gyral positions utilized are in the somatic field. While evidence is limited concerning the action of the occipital pole, it is evident that there are again two maxima. The anterior maximum is widely extended and high, and involves the auditory area. The possible differences between the distribution of the maxima in this situation and the last (gross movements to pain) lie in the fact of a broader anterior maximum at a high level in the present case, and a more restricted posterior maximum. It is probably of a lower level, in the present case, also.
Table X

II. Gross Movements to Motion of Body

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Left</th>
<th>Type</th>
<th>Map Value</th>
<th>Right</th>
<th>Type</th>
<th>Map Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior sigmoid</td>
<td></td>
<td>11,2,2,5</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lateral sigmoid</td>
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<td>5,11,3,11,3,11,5,5,5.5</td>
<td>4</td>
<td>5,3,11,2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>posterior sigmoid</td>
<td></td>
<td>11</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bd sigmoid &amp; cruciate</td>
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<td>2,11,11</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>coronal</td>
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<td>5,11,11,11</td>
<td>4</td>
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<td></td>
</tr>
<tr>
<td>sylvian</td>
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<td>9+</td>
<td>3</td>
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<td></td>
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<tr>
<td>posterior lateral</td>
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<td>7</td>
<td>2</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>mid supra sylvian</td>
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<td>1,1,1,1,1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Intra-hemispherical record

post sigmoid to post lateral (left) 4,5

14. Head Movements to Pain. For this situation, see map on page. Though the locations recorded from in this situation are not quite the same as those in situation 3, the maps are somewhat similar. In situation 3 the head of the animal was moved by the experimenter, while in the present situation the animal moved its own head. In both maps the posterior supra sylvian stands out with a high level. There are no records in situation 3 to show the activities of adjacent gyri, while in the present case the gyri on either side are not as high in kinetic energy as the suprasylvian. It must be realized, however, that definite conclusions from a single record in a given location are not justified.
Table XI

14. Head Movements to Pain Stimulation

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Left Type</th>
<th></th>
<th></th>
<th></th>
<th>Right Type</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>posterior sigmoid</td>
<td></td>
<td>13+</td>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
<td></td>
<td></td>
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<tr>
<td>coronal</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>anterior ectosylvian</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sylvian</td>
<td></td>
<td></td>
<td>13</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>posterior ectosylvian</td>
<td></td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>posterior ectolateral</td>
<td></td>
<td>1+</td>
<td></td>
<td></td>
<td></td>
<td>.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>posterior suprasylvian</td>
<td></td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IV.-A-iii. Situations which Yielded only a few Records

9. Hind Limb Movement with Pain Stimulation. Table 12 shows the results obtained in this situation. The two areas investigated lie in the somatic field of the right hemisphere. The records obtained were high with a value of 4. This is in keeping with the outcome from similar situations, when recording on the left hemisphere.

12. Gross Movements to Brightness Stimulation. In this situation 2 records were obtained from one position, the anterior sigmoid gyrus. One was highly active and the other medium active, giving the location a value of 3, which is slightly lower than for the other situations involving gross movements.

13. Wincing to Brightness Stimulation. Only one record was obtained with electrode arrangement 1a, from the anterior
sigmoid gyrus. Magnitude of activity was a value comparable
to that for the same gyrus in situation 6, in which wincing
also occurred.

Three other records were taken, this time with electrode
arrangement 3. Each of these was obtained when both electrodes
were in the middle ectolateral gyrus, and yielded a magnitude of 2.

Table XII

9. Hind Limb Movements with Pain Stimulation

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>bd coronal &amp; anterior ectosylvian</td>
<td></td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>middle ectosylvian</td>
<td></td>
<td>11,11</td>
<td>4</td>
</tr>
</tbody>
</table>

12. Gross Movements to Brightness Stimulation

anterior sigmoid                        | 5,8 | 3

13. Wincing to Brightness Stimulation

anterior sigmoid                        | 12  | 1

Intra-hemispheral record

mid ectolateral to mid ectolateral (left) | 4,13+,13+

15. Head Movements to Motion of the Body

posterior sigmoid                       | 1   | 0

Intra-hemispheral record.

coronal to posterior lateral (left)     | 2   |
15. Head Movements to Motion of the Body.

Three gyri were used in situation 15, all representative gyri for the anterior half of the cortex. Both the sigmoid and the coronal showed a level of 0, while the sylvian (auditory) was at 4. As far as response, alone, is concerned, the situation most nearly analogous to this one is 14, in which there were head movements to pain. There, the posterior sigmoid was at 2.5, the coronal at 4 and the sylvian at 1. A single record was obtained, with one electrode in the coronal gyrus and the other in the posterior lateral. Wide fluctuations were obtained.

16. "Spontaneous Movements" of the Animal. Movements defined as spontaneous are those occurring when no intended stimulation is given. Two records, both of type 2, were obtained from the coronal gyrus, showing an anterior maximum in cases of so-called spontaneous activity.

In addition, 2 records were obtained with electrode arrangement 3 in which the potential fluctuation between the anterior lateral gyrus and the middle ectolateral gyrus was measured. One record was negative and the other showed wide fluctuations.
Table XIII


<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Hemisphere</th>
<th>Type</th>
<th>Map Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior sigmoid</td>
<td>Left</td>
<td>2,2</td>
<td>4</td>
</tr>
<tr>
<td>coronal</td>
<td>Left</td>
<td>5,5,5,5,5,5</td>
<td>4</td>
</tr>
</tbody>
</table>

Intra-hemispherical record

anterior lateral to mid ectolateral (left) 1,2


<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Type</th>
<th>Map Value</th>
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<tbody>
<tr>
<td>coronal</td>
<td>1,7</td>
<td>1.5</td>
</tr>
<tr>
<td>sylvian</td>
<td>5, 5, 11,1,2,5</td>
<td>4</td>
</tr>
</tbody>
</table>

17. Curare in the Neck Muscles. Toward the end of the experiment on one animal, a solution of curare was hypodermically injected into the lateral and dorsal neck muscles. Even after 3-5 minutes were given for the solution to act, slight head movements were observed. These movements may have been due in part to the relaxation of the muscles themselves and to the shift in posture of the animal's body. About 8 records were made during the time the neck was curarized, 2 on the coronal gyrus and 6 on the sylvian. The former gave an average magnitude of 2 and the latter a magnitude of 4.

One of the reasons for the administration of the curare was to prevent the use of the neck muscles which lay nearest to the operative site so that there might be the very minimum of chance for the spread of muscle impulses by way of non neural
routes to the electrodes. Such a spread seemed very unlikely in the first place, but inasmuch as the suggestion was made, it was thought wise to test their possible role in producing artifacts in our records. The results brought out the fact that the records that were obtained by our technique were not gained from the muscles rather than from the cortex itself.

18. Narcotic in the Right Hemisphere. At the end of the recording with one animal, a narcotic solution containing chloral hydrate was injected into the right hemisphere. Two of the electrodes lay on the right hemisphere and two on the left, so that after the injection had been given time to act a record was taken from each of the four electrodes. The positions on the left hemisphere were the coronal and the middle ectosylvian gyri, which exhibited a level of 1 and 2 respectively. The positions on the right hemisphere were the boundary of the posterior sigmoid and coronal and the middle ectosylvian. These showed a level almost at zero. In this situation, however, the records, although obtained from virtually corresponding places in the two hemispheres, were very different. The ones from the right were simpler and "smoother" in pattern, and less amplitudinous. The stimulation, given the dog, was pain; the animal was virtually passive. It is interesting to note that with the animal passive to pain, when the narcotic was not used, the coronal and middle ectosylvian exhibited a level of 2.
Table XIV

18. Chloral Hydrate etc. in Right Hemisphere. (otherwise situation 5.

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Left Type</th>
<th>Map Value</th>
<th>Right Type</th>
<th>Map Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>corona</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bd. of post. sig. &amp; coronal</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>middle ectosylvian</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mid. ectosylvian</td>
<td></td>
<td></td>
<td>12</td>
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</table>

19. Experimental Injury (Vascular and pressure)

spontaneous movements — clonic spasms.

<table>
<thead>
<tr>
<th>Gyrus</th>
<th>Left Type</th>
<th>Map Value</th>
<th>Right Type</th>
<th>Map Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>corona</td>
<td>5</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>anterior ectosylvian</td>
<td>11</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>posterior suprasylvian</td>
<td>5</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>posterior ectosylvian</td>
<td>5, 11</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


that developed clonic spasms is given on page 57. During the

removal of the dura mater one of the superficial vessels of the

cerebro-motor area was ruptured. In the attempt to stop the

hemorrhage, some pressure was used. Additional pressure came

from surgical bone wax lodged between the brain and the skull.

The resulting attacks occurred at intervals of one or two

minutes and lasted for two or three minutes at a time. The

animal's head and whole body developed a rapid tremor; its

jaw rapidly opened and closed. The posture of the animal was

asymmetrical with its body in a lateral curl and the head drawn
to one side.

Records were obtained from four different gyri, the coronal,
the anterior ectosylvian, the posterior suprasylvian and the posterior ectosylvian. Each of these areas gave results which were intermittently amplitudinous, paralleling the rhythm of the spasm. An example of the type of record obtained is shown on page 34a. The tetanic phase of the spasm occurred twice every three seconds.

iv. Summary of the Map Data.
In the 18 different behavior situations investigated, there was a marked consistency in the type of record obtained from any given gyrus under a given set of conditions. These records have been treated in two ways. First, they have been classified on the basis of amplitude, regularity of pattern and duration of volley, into 13 types. Second, they have been evaluated on the basis of amplitude in a scale of from 0 to 4 in steps of .5. With this scale, the records obtained by means of electrode arrangement la have been used to construct activity distribution maps for 10 behavior situations. The characteristics of these maps may be summarized as follows: (1) The cortex is a unified field, inasmuch as there does not appear to be an independence or isolation of any particular area. The level of any area seems to depend as much on the distribution of energy in the rest of the cortex as upon peripheral conditions impinging on any small area. For example, the first five situations brought out differences in the levels and extents of both the anterior and posterior maxima. Aside from the fact that all these cases the maxima existed, the maps were strikingly different in pattern. In each situation, the animal was passive as far as overt
movement was (a criterion). The motor periphery in each instance was in a constant condition but the cortical distribution maps showed differences in the motor or somatic arc. Thus it is impossible to predict from what is occurring at the motor periphery to activity in the somatic cortical area and vice versa.

Furthermore, the auditory area in three of the situations was found to be at maximum, with no auditory stimulation beyond that given in the other situations. Corresponding irregularities between the visual area and visual stimulus situations were also observed. Maximum kinetic energy was recorded from the visual area with the animal in dim illumination and in complete darkness.

The maps show that for any one area there is a changing set of relationships with the cortex as a whole. (3) Most of the maps quite clearly portray two maxima in energy concentration, and the remainder point to the same dual distribution with sufficient definiteness to conclude that two maxima is the rule. One of the maxima roughly coincides with the somatic projection area in the anterior part of the cortex, while the other lies over most of the posterior half of the cortex, with its peak in the occipital pole. (4) The peaks of these maxima shift about, from situation to situation, thus only in a general way are the maps similar to each other. On the other hand, the pattern is unquestionably constant for constant sets of conditions. (5) The lowest area is a strip common to all 10 situations and corresponds to the histological region just anterior to the parietal as designated by Campbell in 1905. The significance he gives that area is not understood. (6) The auditory projection
area (the sylvian gyrus) was usually part of this low area, but three situations its level leaped to a maximum, or nearly so. Under these conditions (gross movements) the area constituted a part either of the anterior or the posterior maximum. It never stood out as a distinct third area of maximum concentration. For further information on the auditory area see the thesis of F. Theodore Perkins. It will be remembered that no auditory stimulation was administered the animals in the situations described, neither was strong visual stimulation given in all the cases; nevertheless, it seemed that whether the situation was or was not characterized by strong visual "stimulation", the visual pole of the cortex was the locus of a maximum of kinetic energy, the possible significance of which will be dealt with later in relation to the findings of Cutsforth.

V. Interpretation of Data
A. Logical Foundation of a Field Theory.

In expanding upon the summary of the energy distribution maps, and in showing their relation to contemporary work in psychology and allied fields, a theory has been sought that would avoid the obvious shortcomings of traditional concepts. The view must be judged on the basis of whether it avoids the obvious difficulties existent in current theory. Adherents of the views which are at the same time classical and current have unsuccessfully sought to avoid certain of the faults that will be mentioned, though there are yet other inconsistencies that have not hitherto been discovered.

Present hindrances toward the understanding of known cortical phenomena, as evidenced both by lack of prediction
and control and by self-contradictory logic, may be classified in the following ways. (1) The significance of relativity has neither been understood, nor has relativity been consistently employed as a principle dealing with problems of brain dynamics. (2) There has been no distinction between the phenomenological and the dynamic. In fact, much of science has been couched in static types of description, from which explanation has been expected to accrue. (3) It has not been recognized, except in a very few cases, that entities do not possess properties in their own right, but acquire them from the situation of which they are parts. (4) There has been no consistent and justifiable procedure of envisaging an entity at one time as a part and at other times as a whole. (5) The problem of unity has never been satisfactorily solved by current logic and cannot be solved so long as no attempt is made to conceive of all properties as dependent. Units then, have in recent times always been parts of the situations studied, and theorization has never progressed farther than the attempt to account for a derived unity or a derived organization. The concepts of integration, synthesis, co-ordination, association, and fusion have been the entire stock in trade, and have repeatedly been used as explanatory concepts without success. (6) Causation has repeatedly been conceived in terms of what some call 'one-line functionalism'. That is, one event is said to cause another. (7) It has always been assumed that when, during experimentation, one holds certain conditions constant he has eliminated them from the explanatory picture. Such a practice is scientifically invalid.

The present alternative is to construct a scheme which
will avoid the faults just mentioned. Moreover, the scheme should be broad enough to encompass all known phenomena; at the same time it should be capable of particularization. The old notion of homogeneous unity held by previous advocates of functional unity in the cerebrum failed to suggest experimental methods and problems. Nothing remained to be done after the faith had been stated because it was not subject to differentiation in actual situations. Accordingly a field theory presents itself alternative to the current viewpoints all of which logically fall into one category, atomism. A field theory denies atomism as an assumption, and consequently makes use of relativistic principles. With its assumption of unity and the basic laws of balance, it makes intelligible the relation of the part to the whole, a heretofore unsolved problem. In short, a field is a chosen continuum characterized by some form of energy structurization observed directly or by instrumental aid, or postulated by logical necessity, and described in terms of differences in interdependent energy potentials. The basic assumptions, therefore, take care of flux, relationships, and directionality of activity; it assigns a definite reason for each event within the field. The chosen field is the unit, and its size is dependent upon the scope of the problem. It is the situation actually dealt with.

When description necessitates terms other than 'differences in potential' and allied concepts, it is non explanatory and is called phenomenology. With the general statement of a field theory in mind, evidence aside from thesis is inspected; and finally, the theory presented in detail.
B. Relation of Present Study to Contemporary Work.

In the cortical maps that were made from the data of this study were found two areas of maximum concentration in energy, (1) the anterior common to various forms of behavior and fluctuating around the cortical projection areas for the somatic sense organs, and (2) a posterior maximum fluctuating over the visual projection area. None of the 10 situations brought out more than the two areas of concentration although there is an auditory projection area, anatomically speaking, which was found to be low in concentration in situations not intentionally involving hearing. In three situations this area exhibited a high level of kinetic energy but was a part either of the anterior or the posterior concentration. The olfactory and gustatory regions were not explored so that the manner in which they are related to the two areas of concentration cannot here be discussed from actual data. However, something may be said as to their expected behavior in light of existing facts.

It would appear that the visual and somatic parts of the field are primary 'differentiations' of the cortex. We may presume that as departure from homogeneity takes place in the growth of the cortex, the first and grossest differences to arise are regions of maxima just mentioned. This is in keeping with what Cutsforth found and described in his thesis, where he shows the rise of subjectivity and objectivity in terms of kinessthesis and vision, respectively. All external reference is in terms of vision, while bodily reference is in visual terms or kinesthetic, and by the latter is meant the 'somatic' as used in this thesis. The maps seem to show this bi-modality
in neurological terms, and demonstrate further that the part of the cortical field nearest the ear, namely the auditory area, is not concentrated as a third region but appears as a part either of the visual or the somatic concentrations. This, too, is in keeping with what has been found in actual experience, since sound, in order to be localized must evidently have either a visual or kinesthetic frame of reference. In addition, the various characteristics of sounds described in terms of body reference, such as 'rough', 'smooth', 'harsh', 'sharp', 'penetrating', etc. point to the dependence of the auditory upon the kinesthetic field, and terms like 'bright', 'dull', 'high', 'low' and other synesthetic adjectives reveal a dependence upon the visual field. What seems to be necessary, therefore, in the treatment both of experience and the cortical field is in the former an adequate description of the role played in experience by vision and kinesthesis and, in the latter, the taking account of the anterior and posterior maxima in the cortical field. It would seem, however, that there is possibly at one time the dominance of the somatic pole and under other conditions the dominance of the cortex by the visual pole. The maps reveal evidence that at one time there is a greater posterior than anterior concentration. A case of the latter is found when gross movements are made, for example, when the animal attempts to free himself from the harness and to look for a way of escape from the operating table. It was then that the visual field became for it more significantly structured. A case of kinesthetic dominance is found when the animal was resting passively upon the table. We may expect developments in the
phenomonology of experience to harmonize with this fact.

**Differentiation of the Somatic Area.**

The question arises of the further differentiation of the cortical field, some of which would necessarily take place within the two areas of high concentration. One would expect specific qualities, such as pain, cutaneous pressure, kines thesis, cold, and warmth to depend in part upon differentiations within the gyri in the anterior part of the cortex. This does not set this part of the cortex off as a functioning anatomy for the behavior that is described in the above qualitative terms. Rather, it means that structurization of energy with respect to somatic modes of stimulation takes place here more than in any other part of the system, because of the greater amount of energy reaching the cortex at this point from the somatic receptors. Similarly, the visual cortex represents a maximum structurization of energy with respect to incoming impulses from the retina. There is evidence throughout that the local differentiation at the poles depend upon each other as well as their respective peripheral organs. In addition, all parts of the periphery vary in their proximity to given parts of the cortical field in the amounts of energy they receive from the periphery and in the relative ease of transfer of energy from one place to another. Hence, differences in structurizations of the cortex should be expected.

All of the somatic qualities not only have a bodily but also a visual reference, as Cutsforth also points out. If one is touched he feels pressure somewhere upon his body, but the 'somewhere' is visual.
Pain, similarly to pressure, is referred to the body but located in a spaceframe in terms of vision. But there is another class of experiences indicative of the visuo-somatic duality. Warmth and cold as ordinarily experienced have a bodily reference but sometimes are visual and are described in visual terms, as in the case when we talk about warm and cold colors or when we say that the day looks warm. Visual projection of pressures to space beyond the body is another class of examples. From this, one can see the diversity in the role played at one time and another by the visual field and by somesthesia.

Pain as a Somatic Individuation. Among the sensory qualities that arise within the somatic field is pain, and in comparison with touch it is poorly localized. Nevertheless, investigations made in the localization of pain by cutaneous stimulation have led to the belief that the pain spots are more thickly distributed than touch spots. This appears to be a contradiction, for on this basis, one would suppose pain to be more definitely localized than touch. Pain is elicited from subcutaneous tissues that are not seen, and is localized definitely in proportion to its nearness to skin surface. This field is highly differentiated in terms of vision, which gives maximum localization point for point. Conversely, visceral pains are proverbially poorly localized, especially when coming from parts of the body where visualization is difficult.

The Visual Field in the Blind. Our demonstration of a cortical field in which the occipital pole seems always to play a part may add weight to the growing suspicion that the congenitally
blind possess an undifferentiated space field, one of whose potential aspects is visual.

Ordinarily, in stating that a person is blind, it is meant that there are retinal lesions which render visual stimulation. But it must be realized, nevertheless, that even in such cases, the greater part of the central nervous system is still intact and is functioning. We may suppose that one phenological consequence of this field as a whole is undifferentiated spatially. Although the various specific properties of a visual field depend upon visual differentiation, relative to retinal stimulation, the existence of an undifferentiated visual field is not dependent upon external stimulation. In this connection Tracy's experiment may be recalled. He found that undifferentiated motor activity did not at first depend upon the development of the sensory or peripheral nervous system in the toad-fish.

The Auditory Field. No one has found evidence of an undifferentiated auditory field in the congenitally deaf. This might be partly on account of the fact that no one has searched for such an experience. It would seem reasonable to question the existence of such a field, at least to suppose that it would be an extremely intangible thing, from the evidence of a 'borrowing' found in all descriptions of sound. Further evidence against a primary auditory field on a par with the visual or kinesthetic come from anatomical consideration. The cochlear projection areas are not so extended as the visual, and lie between the somatic and the visual. The auditory receptors are less numerous, and the auditory radiation is smaller than either the somatic or visual.
These facts lead to two hypotheses: (1) The auditory area fails to differentiate through relative lack of energy from the periphery. Thus the condition of the auditory field may be explained in terms of dynamics. (2) The auditory area is subordinate to either one of two trans-cortical gradients which dominate it. It would follow from (2) that the subservience of the auditory to the somatic and visual areas hinges upon the dynamics of polarity. Nowhere is nature does there seem to be activity between two poles which is not dependent upon the poles.

A plain example, although remote from the content of our discussion, is that of the tree, in which the trunk's activity is dependent upon the activity of the leaves and roots.

Pathology of Vision. We have said that the visual field arises out of structurization of energy made possible in the cortex by retinal stimulation. This differentiation occurs more at the occipital pole than elsewhere because of the greater amount of energy reaching the cortex, at that point, from the retina. Hence, visual disturbances follow from a lesser destruction of tissue here than in other cortical regions. All attributes of vision do not suffer equally, however. Those arising out of more highly structured patterns of energy will suffer the most distortion, or the first disappearance. Lesions will disturb the system in keeping with their location on account of the disturbance of a relationship between the various parts. The less highly structured the system the less difference the locus of a lesion makes, the very result that has been observed. The less highly structured the system, the less differentiated
or varied the behavior, so that the injury or removal of any part of the system, whether brain, sense organ, or cord, produces effects in keeping with the way the system is reduced in complexity of structurization of its energy.

With anterior injuries, vision is likely to suffer the least; while there is little disturbance elsewhere in the field and an intact posterior region, visualness exists, even though the eyes themselves have suffered damage.

The results of this thesis harmonize with the findings of Gelb and Goldstein in this connection, who investigated the vision of a war veteran with an occipital injury. Their subject lost form and movement. It was necessary for him to make head movements and follow the contour of the object before gaining appreciation of its shape. Provided these movements were prohibited by instruction, or prevented by excessive geometric complication of the figure, form was absent. Drawing several lines through a written word would serve to make it meaningless. It is reasonable to suppose that the necessary 'borrowing' from kinesthesia to supply awareness of form is consistent with the present discovery of cortical polarity, and with Cutsforth's results in which there seems to be complete agreement. Further, the dependence upon vision of localized touch in the Gelb case is added evidence for the present bipolar field conception.

v. De Barenne and the Strychnine Technique. The experiments of de Barenne, described in Section II of this thesis, have justified the growing suspicion that the so-called motor areas in the anterior half of the cortex are not merely motor in
function but sensory as well. Although the first experimenters made a sharp distinction between the motor and the sensory, later workers observed phenomena that could be interpreted either as sensory or motor. In de Barenne's work we find an experimental justification of the precise situation in the brain that a truly non-localization, or field theory, would require. His results clearly harmonize with the bi-polarity of the cortex discovered in this study, in which we find that the anterior pole is somatic rather than motor or sensory or a mosaic of the two.

V-B-vi. Lashley's experiments. Lashley's experiments have been so extensive and varied in character that, within the limits of the present discussion, they cannot be considered in detail. In his late monograph, he has reported upon the effect of cerebral injuries in rats on maze running, solving the problem of a platform box, and on simple brightness discrimination. More recently he has reported the discrimination of form.

Superficially, the three types of performances just mentioned suffered differently from the effects of cerebral lesions. Lashley concluded that there was some localization in case of the platform box and brightness discrimination, but not in the case of maze running. Accordingly, he still thinks in terms of simple sensory functions versus highly integrated performances, the former requiring localization. On the other hand, he believes that maze running is an example of intelligent behavior, and a function of the brain as a whole.
He bases his theory of brain functioning upon three principles; namely, equipotentiality, mass action, and dynamic equilibrium of brain parts. The first two concepts are so qualified that, in his own words, they merely apply to the association areas and not to regions where there is the possibility of some localization. Although he frankly shows that behavior disturbances are roughly proportional to loss of tissue, he continues to postulate localization of function in order to account for the fact that injury to the occipital pole was more critical for the brightness and form discrimination than injuries elsewhere. Likewise, in case of the platform box, the anterior pole was more important than any other area. Lashley did not make adequate use of the principle with which he starts; he commences at once to tear them down after accepting them as necessary. The present concept of the bi-polar distribution of energy takes care of his results in far more adequate fashion. Our knowledge of this fact of bipolarity of the animal's anatomy, and of the bi-modality of human perception, explains Lashley's results without recourse to the concept of localization, which he originally agreed should be abandoned. A given area derives its function from its relation to the field as a whole. When loss of the visual cortex destroys form vision, it is only that some of the energy necessary for this performance is lacking; hence the activity will not take place. But this does not mean that the activity depended on this area alone, or in principle, more upon this area than the brain as a whole. We need only to suppose that sufficient amounts of energy to carry on the form discrimination no longer exists at this pole. At the same time the visual function depending on this pole, also depends on the other pole.
in fact, upon the transcortical gradient.

vii. Pavlov and the Reflex School. The following quotation represents the conditioned reflex theory of the constitution and behavior of the cerebral cortex with reference to the rest of the organism: "It becomes obvious....that through the medium of the cerebral cortex a great number of environmental changes establish now positive, now negative, conditioned reflexes and determine in this manner the different effector activities of the animal organism and its everyday behavior. All of these conditioned reflexes must have a definite representation in the cerebral cortex in one or another definite group of cells. One such group of cells must be connected with one definite activity of the organism, another group with another activity: one group may determine a positive activity, while another may inhibit an activity. The cerebral cortex can accordingly be represented as an exceedingly rich mosaic, or as an extremely complicated 'switchboard'. However, in spite of its extreme complexity as a switchboard, there are always large spaces reserved for the development of new connections. Moreover, points which are already involved in a definite conditioned activity frequently change their physiological role and become connected with some other activity of the animal."

"The idea of the cerebral cortex as a mosaic of functions is in part indicated in the current anatomical and physiological teaching". "The rather rough localization of function which has been achieved during the last century of experimental physiology is no less in accord with such a conception."
"The existence of localization of function in the cortex is in some cases sufficiently proven by the evidence of structure alone, definite receptor elements having been shown to stand in connection with definite cortical cells. The study of conditioned reflexes has shown, however, that a conditioned reflex appears at first in a generalized form, i.e. that excitation irradiates from its point of initiation to embrace also cells belonging to other receptor elements beyond the boundary of the area of the cortex primarily connected with the stimulated receptor; the problem becomes still more complicated when we take into account also the subsequent concentration of excitation upon its point of initiation." (Pavlòv, I. P. Conditioned Reflexes. London, 1927. pp. 219-220.)

The atomism in such quotations as these, from Pavlov, is appalling. These quotations are intended to interpret the findings of his last thirty years of work. It is obvious that they are no different in type from the postulations of 100 years ago! Except in the matter of certain details, he has not progressed from the thinking of that time.

All of his experiments have been made under the most rigidly controlled conditions. The behavior of the animals has been simplified artificially. He recognizes this simplification, and sets out deliberately to obtain it, but has forgotten that what he observes the animal to be doing is a function of the whole organism, in fact more than that, a function of the whole behavior situation. He is blinded by his original atomistic assumptions. Were he to discover this fact, he could no longer employ simple phenomenological
units upon which to build phenomenological complexity. He
would no longer say that the observed acts were reflexes,
in the sense that they are the parts out of which observed
complex behavior is built. He would treat any performance
of an intact dog as accruing from the whole dog, and would
not reserve, as he does, part of the animal for the development
of future conditioned reflexes. Actually he has not observed
a single phenomenon, in all these years, that would necessitate
the assumption that any less of the dog was involved in his
experiments than if the animal were out of the laboratory
pursuing a rabbit or trailing a criminal, or arousing his
master in case of fire. It is true that if the stimulus
conditions are simplified and thus made less variable than
usual, responses will in proportion be simplified. Less is
demanded of the animal and the animal satisfies the demand.
This is just the same as saying that a slot machine will
dispense chewing gum, but not command an army. This, however,
does not say that if the army commander were to dispense
chewing gum, he would not use his eyes, smile, speak, gesticu-
late, and show courtesy in doing so. A system always behaves
in terms of its total structurization, so that the argument
that it could be simpler and still do what might be required
of it does not tell how it functions in the first place. Our
maps of energy distribution, and our bi-polar findings, make
predictable the kind of reductions in simplicity that can occur
for various types of behavior required, under laboratory con-
ditions prescribed by Pavlov, whereas Pavlov cannot predict.
from mosaics anything that will occur in the future. It is curious that, although he admits the generality of reflexes, in the first stages of their developments, he does not accept the significance of this fact, but entertains a logic contradictory to it. There are many facts that, as stated by Pavlov, actually demand a field theory, such as the one just mentioned—initial mass character of reflexes. Others are the dependence of the salivary reflex on the cortex, and the so-called phenomenon of inhibition and facilitation, for, how could one obtain these phenomena if the parts were not already in relation to each other; and if they are clearly in relation to each other, how could they have acquired their relation other than under the laws of dynamics or balance, which presupposes a unitary field.
VI Summary

(1) The dog's cortex is active when the animal is apparently passive and under no particular intended stimulation. It is possible, however, that the experimental situation, including pain from the wound, accounts for the records in situation 1. Nevertheless, our records lead to the conclusion that the so-called passive animal exhibits a pattern of cortical activity essentially the same character as exhibited by the active animal. In other words, there seems to be a basic pattern operating under all conditions of behavior and that any experimental stimulation of the animal under controlled conditions does no more than modify this pattern. In other words, there is a basic pattern which pictures the adjustment of the cortex as a whole to the total stimulus situation. This pattern is characterized chiefly by a concentration of energy extending from the anterior to the posterior pole through the auditory area with maxima at the poles.

(2) Under brightness stimulation, dog passive, the level of concentration rises in the occipital pole and at the anterior pole, shifts toward the median aspect of the hemisphere.

(3) From it follows that the cortex, at least when intact, is involved in responses to brightness. This finding is contrary to the suppositions of Lashley and certain neurologists.

(4) When the dog is stimulated over proprioceptive channels by artificially moving its head from side to side (dog passive) the level of the anterior maximum rises strikingly and also increases in area, perhaps because moving the head caused pain. But the posterior maximum rises with the corresponding
increase in the anterior pole.

(5) The cortical pattern is modified to a less extent by artificially moving the dog's limbs. Neither the anterior nor the posterior maxima undergo so much of a change toward greater extent and magnitude. On the contrary, the anterior becomes more restricted and suffers a loss in magnitude of disturbance, as compared with the consequences of head movement.

(6) In this situation, however, the peak of the anterior concentration shifts medio-anteriorly; that is, from the coronal to the anterior sigmoid gyrus. Curiously, the sigmoid gyrus is supposed to be a motor area. However, the animal was not actively resisting the stimulation. It would seem therefore that activity in this region represents a sensory function as much as it represents a motor function. This is the region that showed almost no activity with the dog passive and under no particular stimulation (Situation I). The maximum at the posterior pole spreads lateral and anterior almost as far as the auditory area and is higher in the region of the middle lateral gyrus than in the case of brightness stimulation, dog passive. The total picture suggests again, mutual dependence upon activity in the two poles regardless of the mode of experimental stimulation.

(7) Since the cortical pattern under pain stimulation from the tail, with the dog passive, is similar to the pattern in situation I where the dog was passive undergoing no particular experimental stimulation, one of two conclusions seems inevitable. In spite of the local anesthetic, the animal might have suffered pain from the wound or it might not have felt the pain
stimulation from the tail. We are inclined to accept the latter interpretation and that the experimental situation raised the dog's threshold to pain stimulation.

(8) In situation 6 (pain stimulation and slight wincing of the dog) there is evidence that the anterior concentration rises to a maximum far exceeding that of situation 5 where the dog is passive under pain stimulation from the tail and as compared with other situations spreads lateral and posterior encompassing the auditory area. The posterior concentration is at a lower maximum but higher than under brightness stimulation, with dog passive. This latter observation along with many others of a similar kind points undeniably to the multiple functioning of given points on the cortex.

(9) In situation 8 in which limb movements occurred in response to artificial pulling of the dog's leg, records are incomplete on the whole gradient; however, the anterior pole exhibits a pattern similar to situation 3 where the dog was passive under artificial head movements and of a higher maximum than when passive under artificial limb stimulation. Thus the anterior maximum is apparently conditioned both by sensory and motor modes of activity. In this behavior situation we find a maximum which extends into the anterior ectolateral gyrus where under conditions of passivity, with no particular stimulation, and passivity with brightness stimulation, the level is at a minimum. At this point in two other situations medium concentration was found; namely, wincing with pain stimulation and gross movement with pain stimulation. This suggests that the anterior ectolateral gyrus plays an important part in the voluntary initiation of movement along with activity nearer
the extremes of the poles. Again, the indications are that the extreme visual pole is more active when the dog moves even with no particular stimulation than when brightness stimulation is given.

(10) In situation 10 (gross movements to pain stimulation) both poles are at maximum, the posterior concentration reaches a maximum throughout and extends from the posterior lateral gyrus all the way to the sylvian region, taking in the so-called auditory area. In this pattern the auditory area seems to be an integral part of the posterior concentration; whereas, in situation 11, as will become evident, this region belongs to the anterior concentration. The pattern in situation 10 suggests that visual activities are at a maximum under ordinary conditions of illumination when the dog is highly active and harmonizes with the thesis that more energy in this area is necessary for form discrimination than for mere brightness discrimination. When the dog is struggling to free himself from the apparatus in the presence of two or more experimenters, it is presumably safe to conclude that form discrimination is at a maximum.

(11) In situation 11 (gross movements to motion of the body) the posterior concentration seems greatly reduced, and the anterior pole raised to a maximum throughout, extending from the median line to the sylvian gyrus, thus including the auditory area. This pattern proves again that both the stimulus and behavior situations must be taken into consideration before the pattern will become intelligible. Any effort to find a simple one-to-one correlation between behavior and stimulation situations
separately and the pattern is futile and misleading. For example, the dog is making gross movements to artificial movement of the body, and the so-called auditory area of the cortex is highly active; yet there was no more auditory stimulation than in situations where concentration in the auditory area was at a minimum.

(12) In situation 14, where head movements were made to pain stimulation, both concentrations are reduced and the points of maxima confined to middle lateral region.

(13) Maximum concentration in the so-called visual area (posterior ectolateral and posterior lateral gyri) is found for gross movement to pain. Medium concentration is found apparently when the dog is passive to artificial movement of the limbs and when he is making limb movements to motor stimulation; low degrees of concentration appear with the dog passive to brightness stimulation, passive to no particular experimental stimulation, passive to pain stimulation and head movements to pain stimulation. In all of these situations, of course, the visual stimulation has not been eliminated; nevertheless, the fact remains that under gross movement to pain stimulation, there was more activity at the occipital pole than when the dog was deliberately subjected to brightness stimulation by dazzling light while passive.

(14) The so-called parietal region of the dog's cortex reveals no measurable concentration with the dog passive under brightness stimulation; some activity with the animal passive with artificial movement of the limbs, and with the dog making slight limb movements to motor stimulation; moderate concentration when the dog winces to pain; maximum concentration is shown
when the dog is passive to movements of the head, and when he makes gross movements to pain and head movements to pain.

(15) Within the limits of our records, the auditory area, so-called, shows slight activity with the dog passive to brightness stimulation, passive to head movements, passive to limb movements, and when the dog is making head movements to pain. A high degree of concentration occurs in this region when the dog winces to pain and when it makes gross movements of the body to pain or to artificial movements of the body.

(16) The area to which tradition assigns facial and muzzle sensitivity, shows slight concentration with dog passive, and moderate activity in gross movements to pain; maximum activity occurs with head movements to pain, wincing, and gross body movements to pain.

(17) The somesthetic area reveals slight or moderate concentration with the dog passive to brightness stimulation, passive to limb movements, passive to pain, gross movements to pain, while it exhibits maximum or nearly maximum concentration under the following conditions; passive to head movements, wincing to pain, gross movements to pain and to motion of the body.

(18) The median extremity of the supposed somesthetic area, said to be the seat of sensibility of the hind limbs shows slight disturbance with the dog passive to artificial movement of the limbs, moderate activity with dog passive to brightness stimulation, and with head movements to pain stimulation; maximum concentration appears with the dog passive to head movements, wincing to pain, and presumably when making gross movements to pain, when making gross movements to rolling of the body, and artificial movements of the limbs. The point
to be emphasized here is the fact that maximum concentration in this region not only may occur when the hind limbs are being stimulated excessively by voluntary movement of the limbs but also when the dog's head is moved and the animal is passive. This would look as if the significance of the dog's behavior whether sensory or motor in function must be considered in understanding the activity of the cortex, for there is no reason to suppose that with the dog passive there should be excessive stimulation of the hind limbs.

(19) The so-called motor area of the dog's cortex exhibits moderate concentration in most situations in which the dog is supposedly passive, the lateral region of this area often associated with head movements shows slightly increased activity under brightness stimulation. All records from this area reveal maximum activity when the dog is making gross movements. Curiously, it exhibited nearly maximum activity with dog passive both to motor stimulation of the head and limbs, and less activity when the dog was wincing slightly to pain stimulation from the tail.

(20) Our results support the older findings in general in so far it was evident that these different areas were involved in the reception of stimuli and in the initiation of movement, however, they demand a different interpretation, namely, that the activity of a specific area depends not only upon the proximity of the area in question to the incoming and outgoing nerve roots but upon the amount of energy necessary to execute a given performance. With gross and intensive activity, higher energy concentrations extend over larger areas of the cortex, but all of the cortex is involved at all times in whatever
activity the animal is pursuing. The significance of activity at any one point of the cortex then can be understood only in terms of the laws of dynamics and not by [having] recourse to purely anatomical considerations. 

(21) Our results have been brought into relation with the studies of Cutsforth and Gelb and Goldstein in the belief that it furnishes the neurological principle which explains their results. We find that whenever the animal presumably compelled to perceive pain and movement, activity in the visual cortex rises. This may be interpreted to mean that whatever contribution the anterior pole makes to this performance depends upon a corresponding contribution from the posterior pole, moreover, the subordination of the auditory area to the anterior and posterior poles of the cortex point to a similar conclusion regarding the dependence of audition upon vision and bodily movement, a fact stressed by Cutsforth in all of his work on auditory perception. Results obtained by Mr. Perkins substantiate this interpretation. He finds that activity in the auditory region under sound stimulation never rises and falls without corresponding fluctuations at the poles. If tactual and auditory perceptions depend upon the existence of space frames or fields of a visual or somatic character, we should expect to find a general cortical pattern dominated by the anterior and posterior poles and this is what we actually do find. This dominance would furnish the neurological basis for the ground upon which the tactual or auditory experience is figured. In addition, we have discussed possible reasons why there cannot be a basic ground or frame of simply a tactual or auditory character. The dynamics of the cortex prevent it.
The larger amount of incoming energy from the visual and somatic receptors other than tactual, sets up the two poles and induces a greater amount of neural differentiation with respect to vision and movement than in case of other modalities. These both dominate the entire field, because an adjustment of these greater concentrations to each other commands the total activity of the cortex and the smaller concentrations elsewhere must, to exist at all, become subordinate to this adjustment.

(22) Our results have been brought into relation to those of Lashley and his interpretations (inconsistent with his data) have been revised by an appeal to the principles of dynamics.

(23) The conditioned reflex experiments of Pavlov have been criticized briefly both for their logical and factual inconsistencies.

(24) The results of this investigation can as yet be interpreted only in the most general way, since the difficulties of obtaining records were so great and the numbers of records for each behavior situation necessarily so limited. Many refinements and elaborations of our suggestions are to be expected. As for the more refined measurements that could be made from our records, relating to frequency and pattern formation of the impulses, little can be said until large masses of data have been obtained under more restricted conditions. Certain general facts however, stand out in this connection. No significant deviations in frequency and pattern have appeared in the records from different areas of the cortex whether sensory or motor.

(25) It is quite evident that level and extent of the energy concentrations are not independent or separate factors in brain economy. Whenever a given performance requires increased vigor
of action a more complex and widespread concentration is required. This is obviously seen in the extension of maxima to the so-called auditory areas whether or not auditory stimulation changed.

(26) It seems beyond doubt that a given area of the cortex may play a multitude of roles in accordance with the character of the total cortical pattern, that is in accordance with what is happening in other parts of the cortex. We must abandon, therefore, any theory of cortical activity that rests upon any notion of localization of function. It is no more legitimate to speak of localization of function in the cortex than it is to speak of the localization of weight within a stone. The weight is a function not of the stone as an isolated thing but of the position it occupies in a gravitational field, together with its density. Likewise, a given area of the cortex plays a certain part in the economy of the total nervous system in virtue of its position in the system, namely, its anatomical proximity to the receptors of the body and to other specific parts of the cortex. This specificity of function is a matter of dynamic relation, not a property inherent in the structure of the part. This does not mean in any sense localization of function, because the function depends upon the entire system. To destroy a part, therefore, and to find a loss in function as a result means that the capacity of the total system to condition the performance has been lost, owing to the destruction of vital parts. The loss must be explained by the fact that sufficient energy to continue the function no longer exists. In this connection, we have pointed out that the more complex function, as, for example, form vision versus brightness vision is destroyed
by a loss of a proportionately lesser amount of energy. This energy is found in the visual area not because this area has a visual function and other areas do not but because the total cortical pattern responsible for vision is more highly differentiated in the visual than any other area in terms of the greater amount of incoming energy in that area than at any other point.

What would we expect the retina and visual area to accomplish if hypothetically dissected out with its normal blood supply, laid upon the table and stimulated? Would this 'organism' see color and form? If the reader is not willing to answer this question in the affirmative, he certainly cannot consistently subscribe to a localization theory.

(27) It seems necessary to abandon [unreservedly] a distinction between sensory and motor functions. The anatomical [criterion] of the position of parts and direction of conduction have led to errors of interpretation. In place of this view, we must consider the consciousness of the organism to depend upon the neural field as a whole. It is not referable to incoming any more than to outgoing impulses or to 'sensory' any more than to 'motor' impulses. In fact, these terms lose practically all of their significance except in an anatomical sense. This conclusion is demanded by the facts as well as by logical considerations. Heightened activity in the so-called sensory areas is quite as likely to appear without increased peripheral stimulations as with it. Conversely, heightened activity in the so-called motor areas is as likely to appear without movement as with it, under the right conditions, as when the main consequence of cortical activity is the perception of movement, intense sensory stimulation, and [we may presume, also] form.
In accordance with the facts and suggestions that have preceded, a field theory of the nervous system is demanded if its activities are to become intelligible. A field theory supposes: (1) that the nervous system always functions as a whole, (2) that the activity of any part depends upon the activity of the whole, (3) that the activity of the part is not fixed by its internal structure alone, by its position with respect to the periphery, but by a vast number of dynamic relations with the total field, (4) that the activities of any part of the cortex come about through processes of growth and differentiation which determine the functioning of the sense organs as well as the functioning of the cortex, (5) that any mechanical, mosaic, or synthetic theory of nervous activity is futile, neither fitting the facts nor resting upon sound logic; (6) that the concept of reflex action must be supplanted by the concept of configurational response, (7) that further progress in research upon the nervous system, if adequate, must be undertaken in the light of field hypotheses.

There are numerous evidences for the fluid character of the central nervous system.

A. Historical.

a. As we have pointed out in our historical introduction, many of the discoveries of early investigators demanded a field theory for explanation, especially is this true of the results of Flourens, Bechterew, Goltz. The significance of these earlier findings was submerged in a deluge of experimental data obtained observed out of relation to the conditions upon which they depended. Such were the data collected by such men as Fritsch, Hitzig, Broca,
Wernicke, Sherrington and many others, on the so-called motor and sensory areas. Only recently has this blind alley been adequately exposed. Among those whose work on the nervous system and allied problems are the logical antecedents of this study are Magnus, de Barenne, Lashley, Coghill, and Tracy.

Magnus found definite evidence that posture was conditioned by vast stimulus situations involving the functioning of distance, as well as body receptors, further that posture, as such, is a dynamic field in which the functioning of the parts depends upon the pattern of the whole. These facts point directly to the unitary character of the total central nervous system and if it is a unit its functioning must be of a field character rather than the cooperate functioning of independent parts having discrete functions.

b. The unitary character of the central nervous system is indicated by de Barenne's experiments in which his animals showed evidence of sensory activity when motor areas were stimulated by strychnine. If the same areas have both sensory and motor functions, the conclusion is inevitable that the functioning of the parts depend upon their relation to the whole. This principle is demanded also by the fact, observed many times even by earlier investigators, that motor phenomena could be elicited from sensory areas. Theories of cortical activity since the time of Flourens, until the time of Lashley have practically ignored these facts.

c. The facts of Lashley's experiments together with his lack of success in using in part, the principle of
localization in accounting for his results is a point in favor of a field theory.

d. We have not referred specifically to recent discoveries in neurology beyond the mention of Tracy's work, the elaborate discoveries of Coghill, Child, and others concerning the development of the nervous system in the embryo reducing the problems of neural growth to field laws of dynamics.

e. The architecture of the cerebrum is such that a field theory should be expected. No where are there any evidences of compartmentalization of function, no sharp lines of demarcation from area to area, or internal differences in structure that justify a prediction from structure to function.

f. In investigations so atomistic and mechanistic as those of Pavlov there are numerous evidences that his highly categorical assertion concerning the mosaic and switchboard character of the cortex breaks down under the weight of his own experimental contributions. Where we should expect him to fall back ultimately upon his original assumptions as a last resort, he forsakes them and admits principles which presuppose opposite assumptions.

B. Evidences from this study.

a. The existence of active energy in widely separated portions of the cortex no matter what the behavior or what the stimulus situation, points to a field theory.

b. The existence of a transcortical gradient no matter what the behavior or stimulus situation is an undeniable sign of the unitary field.
This gradient is attested by the existence of kinetic energy concentrations along the medial lateral aspect of the cortex from the somatic to the visual poles through the so-called auditory area. The relationships of this pattern to the behavior and stimulus situation show that the pattern is a functional one, not an anatomical mosaic.

c. The fluctuations in this gradient in terms of different behavior and stimulus situations took place in every instance without a disappearance of the main characteristics of the gradient, for example, the relative concentrations of energy in the anterior, central and posterior portions of the cortex might vary relative to each other but only within limits; always the gradient as a whole was found to exist.

d. The subordination of the auditory to the somatic and visual regions of the cortex is consistent with a field theory. This means that no isolation exists at different points in the cortex.

e. Since no high energy concentration was found in the so-called association areas it cannot be concluded that cortical activity reduces to an association of diverse independent functions localized at various places in the cortex and brought together by the agency of the association areas.

f. It is evident from this investigation that neither the level nor the area of energy concentration in the cortex can be treated as a discrete entity for the purpose of explaining the dog's behavior, but of necessity must be considered in their mutual relations. This is true not only for single parts of the gradient but for the parts in
their relation to each other. On any other basis than that of a field theory, one should be able to predict from isolated aspects of cortical functioning to discrete aspects of the animal's behavior and vice versa. (30) And finally, the specific contributions of this investigation are (1) a fairly clear-cut demonstration by the action current technique of the fluid and field character of the dog's cortex, (2) the discovery of a bi-polarity in the cortical field in which the anterior and posterior poles dominate the total pattern, (3) the conclusion, based on various suggestive data that the distinction between motor, sensory, and association areas is false, (4) the bringing into relation facts pertaining to the dynamics of the cortex with the new phenomenology of perception demanded by the discoveries of Cutsforth, Gelb and Golstein and others.
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