PRELIMINARY STUDIES ON THE SUPPRESSOR AREAS OF THE CEREBRAL CORTEX OF THE DOG

by

DONALD E. OLSON

A THESIS

Presented to the Department of Anatomy
and the Graduate Division of the University of Oregon Medical School
in partial fulfillment
of the requirements for the degree of
Master of Science

June, 1947

APPROVED:

[redacted]

(Professor in Charge of Thesis)

[redacted]

(Chairman, Graduate Council)

ACKNOWLEDGMENT

I wish to express my sincere appreciation to Dr. Archie Tunturi for his invaluable assistance in directing the course of this study, his continuous encouragement in the face of many difficulties, and his numerous contributions to the consideration and pursuit of this investigation.

I also wish to thank Urick Krasnopolsky for his excellent translation of the Russian article by D. Gedevanishvili.

TABLE OF CONTENTS

		Page
I.	Introduction	1
II.	Methods	1
III.	Results	5
IV.	Discussion	15
V.	Summary	18
VI.	Bibliography	21
VII.	Figures and Tables	

LIST OF FIGURES

1. A diagram of the cerebral hemisphere of the dog showing the points of application of the strychnine and the effects obtained.

2. An electroencephalogram showing suppression of cortical, electrical activity following a strychninisation.

3. An electroencephalogram showing suppression of cortical, electrical activity 2 hours after a strychninisation.

4. A diagram indicating the cortical areas from which movement could be induced by electrical stimulation.

5. A diagram of the cortical areas explored on dog #14 and the results obtained using electrical techniques.

6. A diagram of the cortical areas explored on dog #15 and the results obtained using electrical techniques.

7. A diagram of the cortical areas explored on dog #16 and the results obtained using electrical techniques.

8. A diagram of the cortical areas explored on dog #17 and the results obtained using electrical techniques.

9. Kymograms of the left foreleg extensor twitch.

INTRODUCTION

The existence of so-called "suppressor" areas or "strip" areas of the cerebral cortex has been shown by Dusser de Barenne and McCulloch, Bailey, Hines, and Garol (2,6,8,10,11,12,14,15,17). These investigators have located these areas in the monkey, chimpanzee, and cat. In each of these species four separate "strip" areas or "suppressor" bands, all of which apparently have the same function, have been discovered. In the monkey and chimpanzee the four areas are 8s, 4s, 2s, and 19s. In the cat the "suppressor" bands are 8s, 2s, 3s, and 19s. Garol (15) describes the location of these areas in the cat as follows: (1) 8s lies near the sulcus between the anterior sigmoid gyrus and the frontal gyrus; (2) 2s extends from the rostral portion of the postcruciate sulcus to the caudal portion of the coronal sulcus; (3) 3s extends from the junction of the suprasylvian and anterior suprasylvian to the junction of the lateral and ansate sulci; and (4) 19s lies in the posterior margin of the posterior suprasylvian gyrus.

The anatomical connections of these "suppressor" bands and other inhibitory areas in the central nervous system of various animals have been shown for electrical activity, motor activity and respiratory movements by Allen, Dusser de Barenne and McCulloch, Glees, etc. (1,7,11,16, 18,19,20).

This investigation was undertaken in an effort to locate the "suppressor" areas in the cerebral cortex of the dog.

METHODS

Eighteen dogs were used in these experiments, and each dog was maintained for periods of 16 to 24 hours. The dogs were anesthetized

with either Dial or Delvinal (0.5 cc./kg. of body weight), which was given slowly intravenously or the dose was divided and one half injected intramuscularly and one half intraperitonealy. In several animals the depth of anesthesia was increased by small supplemental intraperitoneal injections of either Dial, Delvinal or Nembutal. To facilitate the operative procedure local infiltration of the operative sites with about 10 cc. of Novocaine was carried out on approximately 1/3 of the dogs.

The operation consisted of cannulating the trachea, clamping the dog's jaws in a brace which prevented any movement of the head, doing an extensive craniotomy on the right side, and excising the orbital contents in about 1/2 of the animals so as to provide adequate exposure of the frontal and anterior sigmoid gyri. All of the margins of the craniotomy were then packed off with cotton soaked in warm Ringer's solution.

In the early part of this work a Grass four channel electroencephalograph was available for recording the exploration of the cerebral cortex with the strychnine technique used by Dusser de Barenne and McCulloch, Bailey, and Garol (2,6,8,12,15,16). Nine animals were used in this part of the investigation, but one of them died after only one hour and fifteen minutes. Pieces of filter paper 2 to 4 sq. mm. in area were saturated with a solution of 3% strychnine sulfate colored with Toluidine blue and applied to the dog's cortex. The filter paper was removed in from 1/2 to 4 minutes; in most instances, however, the application lasted only one minute. The area of strychninization was always then dried with absorbent cotton so as to remove any excess solution. Fifty-two applications of strychnine were made. Bipolar silver electrodes were used to pick up the electrical activity from the strychninized area, and the impulses were fed into one channel of the electroencephalograph. Either

four or five monopolar electrodes were used with the indifferent electrode buried in the saturated cotton around the craniotomy. In the first four animals cotton electrodes tied to heavy silver wires and saturated with Ringer's solution were used, but these proved inefficient in that slight drying of the cotton changed the resistance in the circuit, and thus decreased the amplitude of the activity recorded on the electroencephalograms. In order to avoid this artefact the electrodes had to be moistened every 20 to 30 minutes. For this and other reasons plain silver electrodes with a ball tip were substituted; the ball being applied directly to the cortex. The recording monopolar electrodes were arranged either vertically or horizontally over the cerebral cortex. Generally the electrodes were on a horizontal plane with one electrode on the anterior sigmoid gyrus, one on the posterior sigmoid, one on the caudal portion of the coronal or caudal portion of the anterior ectosylvian gyrus and one on the suprasylvian gyrus. Control records were taken which lasted from approximately four minutes to two hours, strychnine was applied, and then records taken for 45 minutes to 2 hours before another strychninization was done. The records were not taken continuously but were run for 2 to 4 minute intervals and then shut off for 1 to 4 minutes so as to conserve paper. The procedure was not invariably followed as on occasion when significant changes were appearing records were taken for 20 minute periods without interruption.

When the electroencephalograph became unavailable, electrical pulse techniques were employed in the exploration. The "motor" cortex was stimulated principally with rectangular pulses of a duration of approximately 20 msec. at a frequency of once per second. When a constant response at a frequency of once per second had been obtained in

the left foreleg for about 15 minutes, an exploration for "suppressor" areas was then commenced. The exploration was done using a 60 cycle a.c. stimulator set to deliver a current between one and five ma. Bipolar silver or stainless steel electrodes with an interelectrode distance of 2 to 3 mm. were used for delivering the pulses of both stimulators. The a.c. stimulus was generally applied for a period of 5 to 10 seconds, but occasionally this period of stimulation was increased to 30 seconds. An interval of at least 30 seconds to 1 minute was allowed to elapse before a second stimulus was applied. Each point was tested with at least two different currents-one at 2 to 3 ma. and one at 5 ma.. At each point at least two stimuli of the same strength were applied. The effects of the "suppressor" stimulus were determined principally by visual observation and palpation of the muscles and extremities. Five dogs were utilized in this part of the work, and 207 points were explored moving the electrodes in 2 mm. steps. Each dog's body was suspended across a large hole in an animal board by means of four straps which were so arranged that the animal's four legs were allowed to hang perfectly free. Thus more careful observations of any movement in the extremities could be made. The head was again held immobile by clamping the jaws in the brace mentioned above. Attempts were made to increase cerebral blood flow by elevating the foot of the table six inches. An attempt was also made to conserve the animal's body heat by keeping the room temperature at about 85°F. and by burning a 60 watt lamp immediately over the body of the animal or by placing an electric heating pad under the animal.

The remaining four animals were used for supplementary investigation which was felt would be of aid in the interpretation of the procedures indicated above.

RESULTS

A: Strychninization

In the exploration of nine dogs with 52 strychnine applications sharp, large, irregularly appearing, voltage deflections, or so-called strychnine "spikes", appeared at the strychninized point generally within two minutes; sometimes, however, appearing within 30 seconds, while on occasion the appearance of the spikes was delayed for as long as 10 or 12 minutes. (The term, "firing", has been used by Dusser de Barenne for the appearance of these strychnine spikes in any area.) Spiking or firing then persisted in the strychninized area from 10 to 150 minutes. The firing generally disappeared, however, in from 40 to 60 minutes. The exceedingly long duration of strychnine spiking occurred in the second dog at only one point where the strychnine had been applied for 4 minutes, and the firing did not start for 12 minutes. On the other hand the short, 10 minute duration of firing occurred in another animal at two points where the strychnine had been applied for only one minute, and the onset of strychnine spikes did not appear for 10 minutes. The remainder of the points in both of these animals had an average interval of 2 minutes between the application of the strychnine and the onset of the firing and an average duration of spiking of 30 minutes.

Fifteen applications of strychnine were made in the region of the posterior suprasylvian gyrus, postero-lateral gyrus and the posterior portion of the suprasylvian gyrus (Fig. 1). Evidence of a moderate to marked decrease in the amplitude of voltage fluctuations or, in other words, of electrical activity occurred in one of these animals from three points located near the sulcus between the postero-lateral gyrus

and the junction between the posterior supracylvian and supracylvian gyri. The suppression of electrical activity was further characterized by the absence of 6 to 10 persecond high voltage fluctuations of a duration of 2 to 4 seconds over the sigmoid gyri. The decrease in electrical activity appeared almost simultaneously in the anterior sigmoid gyrus, the anterior portions of the coronal and anterior ectosylvian gyri and in the inferior portion of the anterior composite gyrus. Electrodes were not present on other gyri. From these three single strychninizations there were six individual periods of suppression. Each period of suppression had a duration of approximately 10 to 14 minutes before the electrical activity resumed its normal amplitude. There was no constant time of onset of the suppression period following the application of the strychnine; this onset varied from 7 to 35 minutes. However, the last five suppressor periods obtained from B-3 & B-4 (Fig. 1) were each spaced 40 to 50 minutes apart irrespective of the time of actual application of the strychnine. Firing was present from the strychninized point during all suppressor periods except one as indicated in Table 1.

In the region of the posterior portion of the coronal gyrus, the posterior cruciate gyrus and the anterior portion of the supracylvian gyrus 10 strychninizations were preformed on three dogs (Fig. 1). Six of the points yielded evidence of suppression. Two of the points were on opposite sides of the coronal sulcus--one being at the inferior margin of the post-cruciate sulcus and the other being almost directly opposite along the superior margin of the coronal gyrus. The remaining four points formed a somewhat curved band near the inferior border of the posterior portion of the coronal gyrus. From point F-5 two periods

of suppression, each lasting 5 to 7 minutes, were obtained. The first suppression appeared within two minutes after treating the point with strychnine and was characterized by a marked decrease in voltage fluctuations and absence of spikes from the strychninized area. The suppression quickly spread into the anterior and posterior sigmoid gyri, the posterior portion of the coronal gyrus and into the anterior portion of the lateral gyrus. In the second period of suppression the decreased voltage appeared first over the anterior and posterior sigmoid gyri, then 5 minutes later was present in the strychninized area with an associated absence of spikes, and 8 minutes later was seen in the posterior portion of the coronal gyrus. The suppression from I-1 (Fig. 1) appeared 25 minutes after strychninization and spread from the posterior sigmoid to the anterior sigmoid gyrus. About 3 minutes later it spread to the posterior portion of the anterior ectosylvian and later still into the suprasylvian. The suppression lasted about 10 minutes and at no time affected the spiking or the normal amplitude of voltage fluctuation at I-1.

From the four points along the inferior margin of the posterior portion of the coronal gyrus the suppression appeared from 2 to 40 minutes after applying the strychnine and returned to normal in from 1 to 15 minutes. Two periods of suppression, which were separated by an interval of only 5 minutes, were found from a single strychninization of point E-7. In point E-7 the wave of suppression was first noticed over the sigmoid gryi and then appeared in the strychninized point whereas in F-3 and I-3 the suppression was first noticed in the strychninized areas where the voltage fluctuations were reduced markedly and the spikes disappeared. However, repetition of strychninization of point I-3 one

hour and thirty minutes after the first application failed to produce results similar to those on the first trial. There was only suggestive evidence of suppression and never any absence of spiking or loss of amplitude from point I-3 with the second strychninization. Point I-7 produced only very questionable evidence of firing and repetition of the strychninization produced entirely different results than the first application of strychnine.

Nine points were explored in three animals from the posterior sigmoid gyrus, anterior sigmoid gyrus, anterior portion of the coronal and anterior ectosylvian gyri, and from the anterior composite gyrus. There was no evidence suggestive of suppression from any of these points, although in one of the animals a point in another area— posterior portion of the coronal gyrus (E-7) did give evidence of suppression.

Fourteen points were explored on the frontal gyrus in three animals (Fig. 1). From five points (F-2, F-1, G-3, G-4, & H-9) there was fair evidence of suppression of electrical activity, and there were nine period of suppression from the five strychninizations. Again it was difficult to find any constant pattern of suppression from any of these points. The onset of the various suppressor periods varied from 15 minutes to 2 hours and 15 minutes after the application of strychnine, and the periods of suppression had a duration varying from 1 to 10 minutes. (For illustrations of suppression see Figs. 2 & 3).

When strychnine was applied to 12 of the points explored, there were sharp, voltage deflections or spikes which appeared in areas of the cortex other than the point being strychninized. These distant spikes occurred almost synchronously with the spikes from the strychninized region, although the exact latency of the secondary or distant spikes was never actually determined.

Strychninization of two points in one animal (A-1 & A-2) on the superior portion of the posterior suprasylvian gyrus and posterior portion of the suprasylvian gyri did produce typical strychnine spikes not only at their location but also in the mid-portion of the suprasylvian gyrus. No spikes were found in records obtained from the posterior portion the coronal gyrus, the inferior portion of the posterior cruciate gyrus and from the inferior portion of the posterior sigmoid gyrus.

Strychninization of two points (C-1 & C-4) on the posterior part of the suprasylvian gyrus near the location of points A-1 & A-2 produced spikes in the inferior portions of the anterior and posterior sigmoid gyri and the anterior portions of the coronal and anterior ectosylvian gyri. No records were taken from the mid-part of the suprasylvian gyrus.

Two applications of strychnine to one point (I-3) in the mid-portion of the coronal gyrus resulted in strychnine spikes in the posterior superior part of the anterior ectosylvian gyrus after both strychninizations. No spiking resulted in the suprasylvian gyrus, the mid-portions of the anterior sigmoid gyrus or the posterior sigmoid gyrus. Strychninization of point E-7, which was slightly more posterior on the coronal than the previous point, I-3, produced strychnine spikes in the inferior parts of the anterior and posterior sigmoid and posterior cruciate gyri, and in the posterior portion of the coronal gyrus. No electrode was on the anterior ectosylvian gyrus.

Strychninization of six points (E-1 to 6) all in the same animal from the anterior portion of the coronal and anterior ectosylvian gyri and the anterior composite gyrus produced strychnine spikes in the posterior portion of the coronal gyrus and the inferior parts of the

posterior cruciate, posterior sigmoid and anterior sigmoid gyri. However, when records were taken from the strychninized point with a monopolar electrode the secondary strychnine spikes could not be found, although spikes continued to be present from the strychninized points.

Strychninization of the middle part of the posterior sigmoid gyrus (I-5) produced spikes in an area approximately 1 mm. away on the same gyrus. Strychninization of the superior portion of the anterior sigmoid gyrus (H-5) did not produce spikes in the inferior portion of the anterior sigmoid gyrus, whereas strychninization of a point (H-d) about 1 mm. away from the recording monopolar electrode near the inferior portion of the anterior sigmoid gyrus did produce strychnine spikes under the monopolar electrode.

Usually the distant strychnine spikes appeared 1 to 2 minutes after spikes had been demonstrated from the strychninized point. Occasionally, however, the two sets of spikes made a simultaneous appearance; while at other times the distant spikes did not appear until 10 to 12 minutes after spikes had first appeared at the strychninized point.

B: Electrical stimulation

As a second part of this study an attempt was made to stop electrically induced cortical movement of the left foreleg by stimulating other areas of the brain with another electrical stimulus.

When rectangular pulses of a duration of approximately 20 msec. at a frequency of once per second were applied to the cortical surface from which foreleg responses on the contralateral side could be obtained, a single, brief twitch of one muscle or group of muscles with a common action resulted (Fig. 9). This twitch could be repeated at one second intervals without significant variation in the type of muscular response

for as long as ten hours. During this ten hour interval the threshold of response slowly rose so that the current delivered by the rectangular pulser had to be increased. Usually after 1 to 2 hours of continuous stimulation at a rate of once per second small holes, which penetrated the cortex to a depth of 1 to 2 mm, could be found under the stimulating electrodes. The single twitch response for one muscle or muscular group could be obtained only from a very discrete or localised area of the cortex. Moving the bipolar electrodes as little as 1 mm. in any direction resulted in failure of the response to appear even with increased current.

No attempt was made to map the cortex from which movement of the various parts or muscles of the body could be found, but it was noted in three dogs that extensor movements at the scapulo-humeral and occasionally at the humero-ulnar joint could be induced from the most inferior portion of the posterior sigmoid gyrus, near the coronal sulcus. In another dog a similar area in the anterior sigmoid gyrus produced a flexor movement of the scapulo-humeral joint.

In one animal the electrodes were applied to the cortex in the area giving an extensor twitch at the left scapulo-humeral joint. The response was not visible but could be felt by palpation of the muscles through the skin. Then the electrodes were withdrawn, the blood vessels within 1 cm. of the previously stimulated cortex coagulated, the cortex removed over about an area of 2 sq. cm. to a depth of about 6 to 8 mm., and then the electrodes reapplied directly to the white matter of the cortex. The left foreleg extensor muscles at the scapulo-humeral joint immediately began to respond with similar twitches at a rate of once per second. The responses were readily visible and recordable on a kymograph (Fig. 9).

On one animal condensor discharges delivered through a thyratron unit were used to roughly explore the area of the cortex from which movement could be induced. It was found that single, condensor discharges at a frequency of once per second and with a current roughly equivalent to that delivered by the rectangular pulser also produced single, rapid twitches of one muscle or group of muscles with a common action. With these condensor discharges contralateral hind leg movements were obtained from the superior portions of the adjacent parts of the sigmoid gyri (Fig. 4). Immediately inferior to this area contralateral trunk movements were obtained. At the inferior margins of the posterior and anterior sigmoid gyri along the coronal sulcus contralateral foreleg movements resulted from stimulation. Immediately below the cruciate sulcus on the coronal and anterior ectosylvian gyri ipsilateral neck muscle responses were observed during stimulation. Further posteriorly on both the coronal and anterior ectosylvian gyri contralateral ear movements resulted from stimulation. Contralateral neck responses were observed from stimulation of both the superior and inferior portions of the anterior sigmoid gyrus.

When repetitive condensor discharges at a rate of 40 to 60 per second were maintained for 5 to 10 seconds and the current was reduced, the resulting cortically induced movement was the gradual contraction of a number of groups of muscles which was quickly followed at the height of contraction by rapid clonic movements. Similar results were obtained when an a.c. 60 cycle current was used as the stimulus.

An exploration of the coronal, inferior margins of the posterior sigmoid and posterior cruciate, superior margin of the anterior ectosylvian and the superior part of the anterior composite gyri was carried out on five dogs. In four of the five dogs the exploration was done in

2 ma. steps using a 60 cycle a.c. stimulus. The details of the effect of this a.c. stimulus upon the left foreleg extensor twitch produced by the once per second rectangular pulse was variable as shown in Figs. 5, 6,7,&8, but the result from stimulation of any one point on a particular animal were fairly constant.

When the a.c. current was at 5 ma. and was allowed to flow for 5 to 10 seconds, the extensor twitch of the left foreleg was stopped within 1 to 3 seconds, or at least was reduced markedly in amplitude, and remained absent or decreased during the remainder of the stimulation of most but not all of the points explored in the coronal and inferior margins of the posterior cruciate and posterior sigmoid gyri. One per second twitches usually returned promptly after withdrawl of the a.c. stimulus, but this was not invariably true as the response occasionally did not return for 1 to 2 minutes. The extensor twitch response following removal of the a.c. stimulus often would return with a much greater amplitude of contraction than had been present prior to stimulation of the explored area. Occasionally, as indicated by the Figs. 5,6,7,&8, the extensor twitch would first be increased in amplitude by the a.c. stimulus before a decrease in the amplitude would result. Very frequently when the "suppressor" or a.c. stimulus had been applied, there would be marked resistance to passive motion at the joints of the left foreleg or, in other words, increased tone in the muscles acting upon the joints. Unfortunately this phenomenon was not tested at each point. This phase of increased tone then was followed very often by rapid clonic movements in the extremity. From numerous explored points the clonic phase would follow the tonic phase only after removing the a.c. stimulus. The extensor twitch from a small number of the points explored would first stop

for a few seconds and then gradually return while the a.c. stimulus was still being applied. During the period of absence of the extensor twitch at the left shoulder joint from stimulation of many points on the coronal gyrus an extensor twitch of the left forepaw at the rate of once per second would occur. Frequently movements of the face or of the left hind leg could be detected initially, during, or after the application of the a.c. stimulus to various points.

In the superior portion of the anterior composite gyrus respiratory movements often ceased completely during the stimulation period; however, if the stimulus were applied for as long as 30 seconds, respiratory movements would begin to reappear after 20 to 25 seconds.

When the stimulating current was reduced to 2 to 3 ma., the same phenomena occurred as were described above, but the number of responsive points was greatly reduced, especially from the inferior parts of the explored area.

During the course of the electrical stimulation experiments it was noted that when, over a long period of time, the amplitude of the left extensor foreleg twitch had spontaneously decreased, passive rapid flexion and extension for 3 or 4 seconds of either the right or left foreleg, and occasionally of either hind leg, produced a prompt return in the amplitude of the extensor twitch which occasionally persisted for a number of minutes. During the suppression of the extensor twitch by an a.c. stimulus rapidly flexing and extending the left foreleg for 3 or 4 seconds on two occasions produced a return in the extensor twitch even though the a.c. stimulus was maintained. Forceful, passive extension of the right foreleg in one animal reduced the amplitude of the extensor twitch, whereas in another animal this same procedure increased the amplitude of contraction. The

application of a hemostat to a foot pad on the left forepaw resulted in a marked increase in the amplitude of the extensor twitch of that leg which persisted for 3 to 5 minutes. When the hemostat was applied during a period of suppression of the extensor response or when the twitch was of a very small amplitude, the extensor twitch immediately reappeared at a greatly increased amplitude which persisted for 3 or 4 minutes even though the hemostat and a.c. stimulus were removed (Fig. 9). Application of the hemostat to a claw of the left forepaw resulted in no change in the extensor twitch. Application of the hemostat to footpads of the other extremities produced no results on the extensor twitch of the left foreleg of one animal, but it did cause twitches at the rate of once per second in the left hind leg when the instrument was applied to a footpad of that extremity. Pinching the skin of the left hind leg or the abdomen in one animal resulted in no change in the extensor twitch; while in another animal pinching the skin of the abdomen resulted in one large extensor twitch in the foreleg, but pinching the skin of the foreleg in this same animal produced no change in the extensor twitch.

DISCUSSION

The results obtained using the strychnine technique on the cerebral cortex of the dog are somewhat in variance with the results reported for other animals by Dusser de Barenne, McCulloch, Garol, etc. (2,6,12,415). From the 52 applications of strychnine made on dogs suppression of cerebral electrical activity was definitely found from a number of points; however, this suppression differed from the suppression described by the above authors in these ways: (1) The onset of the suppression of electrical activity instead of occurring in 4 to 20 minutes, occurred from 2 minutes

to 2 hours and 15 minutes after applying the strychnine. (2) The wave of suppression sometimes spread across the cortex in 2 to 3 minutes whereas at other times 8 to 10 minutes were required for the spread. Other authors describe the suppressor wave as crossing the cortex in 15 to 20 minutes. (3) Frequently 2 or 3 periods of suppression would result from a single strychninization instead of one period as described for other animals. (4) Suppressor periods in the dog would often occur after the detectable electrical effects of the strychnine had subsided at the strychninized area. (5) Frequently decreased electrical activity and absence of spiking occurred in the strychninized areas as well as in the other parts of the cortex during the course of the suppression. This has been described by Bailey, et. al. (2) as occurring from one band in the chimpanzee. The remainder of the papers do not describe it. (6) The wave of suppression sometimes commenced in distant areas and then spread to the strychninized area, whereas the reverse also occurred. The spread of suppression has been found to always move from the strychninized point towards distant areas in other animals.

No isolated, discrete, suppressor bands could be definitely located from the strychninizations on the dog; however, an adequate number of strychninizations have not been carried out so their possible existence can not be disproved.

Insufficient records were taken to precisely subdivide the "sensory cortex" of the dog into its various areas on the basis of the strychnine spike distribution. Moreover, if this were to be properly done many more recording monopolar electrodes should be used on the cortex of each dog and the findings should be correlated with cytological studies of the cortex explored.

The facts that the rectangular pulses at a frequency of once per second produced single, sharp twitches of one muscle or group of muscles with a common action; the electrodes usually had penetrated the substance of the white matter in the course of an experiment; and the same type of response, except for the lower threshold, was obtainable upon directly stimulating the white matter all point to the probable conclusion that in the course of the electrical explorations the motor response was the result of direct stimulation of the Betz cells or their axons and not the result of stimulation of superficial cortical layers.

Dusser de Barenne, McCulloch, Garol, etc. (10,11,&14) have shown that electrically induced cortical movement can be "suppressed" by stimulation of any of the four suppressor bands in the monkey, cat, etc. True "suppression" of motor response, as defined by Dusser de Barenne and McCulloch (11), can only be induced from one of these bands, has a latency of 2 to 12 minutes, and a duration of 6 to 30 minutes. Thus "suppression" differs from extinction, which also produces an inhibition of motor response, in several ways. Extinction can only be produced by antecedent stimulation of the same focus in the motor cortex or by antecedent stimulation in other areas if the electrical disturbance is transmitted to the site of the first stimulus in the "motor" cortex. Also the latency of extinction is of the magnitude of but a few seconds, and extinction has a duration of not more than one or two minutes.

None of the electrically explored areas in the dog showed evidence indicating the presence of a "suppressor" band. Movement was very often stopped but evidence of either facilitation extinction, or both, or spread of current was usually present. This is to be expected in these experiments as the known parameters of stimulation for facilitation and extinction

were not rigidly controlled (4,5,29). Neither were the results similar to those reported by Gedevanishvili and Baritoff (3&13).

The abolition of respiratory movements over a 20 to 25 second period and their gradual return with longer stimulation in the region of the anterior composite gyrus is in accord with the findings of Smith (21).

SUMMARY

A partial exploration of the cerebral cortex of the dog for suppressor areas has been preformed using both the strychnine and electrical pulse techniques with the following results:

(1) No isolated, suppressor bands have been established by either procedure.

(2) Suppression of electrical activity has been observed from several points in the frontal gyrus, the posterior portion of the coronal gyrus and in a small area around the posterior portion of the lateral sulcus.

(3) No suppression of electrical activity was found from the region of the anterior portions of the coronal and anterior ectosylvian gyri and from the anterior composite gyrus.

(4) The onset of electrical suppression varied from 2 minutes to 2 hours and 15 minutes after applying the strychnine.

(5) The electrical suppression had a duration of about 3 to 15 minutes.

(6) The electrical suppression spread over the cortex, but it did not always commence near the strychninized area.

(7) During the period of suppression the electrical activity decreased, and the strychnine spikes often, but not always, disappeared from the strychninized point.

(8) Strychnine spikes were observed in distant areas of the cerebral cortex following strychninization of some of the other points on the cortex. Insufficient experiments were done to accurately map the cortex on the basis of the distribution of the spikes.

(9) Stimulation of the "motor" cortex with single, rectangular pulses of a duration of about 20 msec. at a frequency of once per second produced single, sharp contractions of one muscle or group of muscles with a common action.

(10) An exactly similar type of twitch as described above could be produced by stimulating the white matter of the cortex directly, except that the threshold was lower.

(11) The extensor twitch of the left foreleg at the scapulo-humeral joint produced by the rectangular pulses could be stopped or greatly decreased during the application of a 60 cycle a.c. stimulus of 5 ma. to numerous points in the region of the coronal gyrus and the inferior portions of the posterucciate and sigmoid gyri, and the twitch usually, but not always, returned promptly following the withdrawal of the a.c. stimulus.

(12) The inhibition of the extensor twitch was frequently accompanied by any or all of the following: (a) tonic and clonic movements in the left foreleg, (b) extensor twitches of the left forepaw, (c) movements of the face or the left hind leg, and (d) a marked increase in the amplitude of the twitch following cessation of the a.c. stimulus.

(13) Respiratory movements often ceased during the application of the a.c. stimulus to the anterior composite gyrus, but returned if the stimulus were prolonged beyond approximately 25 seconds.

(14) Rapid, passive flexion and extension of either foreleg and occasionally of either hind leg resulted in the return of the extensor

twitch to its original amplitude when it had become reduced spontaneously. The use of this same procedure during a period of inhibition from the a.c. stimulus also caused the return of the extensor twitch.

(15) Clamping a footpad of the left forepaw with a hemostat caused a marked increase in the amplitude of the extensor twitch of that leg which persisted for 3 to 5 minutes after removal of the hemostat. Clamping a claw on the same extremity resulted in no change of the extensor twitch.

(16) Clamping a footpad of the left hind leg resulted in one per second twitches in that extremity but had no effect on the extensor twitch of the left foreleg.

BIBLIOGRAPHY

1. Allen, W.F. Location in the spinal cord of the pathways which conduct impulses from the cerebrum and superior colliculus, affecting respiration. Jour. Comp. Neur., vol. 43, pp. 451-511, 1927.

2. Bailey, P., Dusser de Barenne, J.G., Garol, H.W., and McCulloch, W.S. Sensory cortex of chimpanzee. J. Neurophysiol., vol. 3, pp. 469-485, 1940.

3. Beritoff, J., and Bakuradze, A. On the afferent paths of the vegetative nervous system. Transactions of J. Beritashvili Physiological Institute, vol. 5, pp. 157-159, 1943.

4. Brown, T.G. Studies in the physiology of the nervous system. XXII: On the phenomenon of facilitation. 1: Its occurrence in reactions induced by stimulation of the "motor" cortex of the cerebrum in monkeys. Quart. J. Exp. Physiol., vol. 9, pp. 81-99, 1915.

5. Dusser de Barenne, J.G., and McCulloch, W.S. Local stimulatory inactivation within the cerebral cortex, the factor for extinction. Amer. J. Physiol., vol. 118, pp. 510-524, 1937.

6. Dusser de Barenne, J.G., and McCulloch, W.S. Functional organization in the sensory cortex of the monkey (Macaca mulatta). J. Neurophysiol., vol. 1, pp. 69-85, 1938.

7. Dusser de Barenne, J.G., and McCulloch, W.S. Sensorimotor cortex, nucleus caudatus and thalamus opticus. J. Neurophysiol., vol. 1, pp. 364-377, 1938.

8. Dusser de Barenne, J.G., McCulloch, W.S., and Ogawa, T. Functional organization in the face-subdivision of the sensory cortex of the sensory cortex of the monkey (Macaca mulatta). J. Neurophysiol., vol. 1, pp. 436-441, 1938.

9. Dusser de Barenne, J.G., and McCulloch, W.S. Factors for facilitation and extinction in the central nervous system. J. Neurophysiol., vol. 2, pp. 319-355, 1939.

10. Dusser de Barenne, J.G., Garol, H.W., and McCulloch, W.S. The "motor" cortex of the chimpanzee. J. Neurophysiol., vol. 4, pp. 287-303, 1941.

11. Dusser de Barenne, J.G., and McCulloch, W.S. Suppression of motor response obtained from area 4 by stimulation of area 4s. J. Neurophysiol., vol. 4, pp. 311-323, 1941.

12. Dusser de Barenne, J.G., Garol, H.W., and McCulloch, W.S. Functional organization of sensory and adjacent cortex of the monkey. J. Neurophysiol., vol. 4, pp. 324-330, 1941.

13. Gelevanishvili, D. Investigations in the field of cortical inhibition. Transactions of J. Beritashvili Physiological Institute, vol. 5, pp. 40-97, 1943.

14. Garol, H.W. The "motor" cortex of the cat. J. Neuropath. Exp. Neurol., vol. 1, pp. 139-145, 1942.

15. Garol, H.W. The functional organization of the sensory cortex of the cat, II. J. Neuropath. Exp. Neurol., vol. 1, pp. 320-329, 1942.

16. Glees, P. The anatomical basis of cortico-striate connections. J. Anat., Lond., vol. 78, pp. 47-51, 1944.

17. Hines, M. The "motor" cortex. Johns Hopk. Hosp. Bull., vol. 60, pp. 313-336, 1937.

18. McCulloch, W.S., Graf, C., and Magoun, H.W. A cortico-bulbo-reticular pathway from area 4s. J. Neurophysiol., vol. 9, pp. 127-132, 1946.

19. Nettler, F.A., Ades, H.W., Lipman, E., and Culler, E. A. The extrapyramidal system. An experimental demonstration of function. Arch. Neurol. & Psychiat., vol. 41, pp. 984-995, 1939.

20. Tower, S.S. Extrapyramidal action from the cat's cerebral cortex: motor and inhibitory. Brain, vol. 59, pp. 403-444, 1936.

21. Smith, W.K. The representation of respiratory movements in the cerebral cortex. J. Neurophysiol., vol. 1, pp. 55-68, 1938.

TABLE 1

Dog & no. of strychninization	Period of application of strychnine	Onset of strychnine spikes after application	Duration of strychnine spikes	Onset of suppression after strychninization	Duration of suppression
A-1	1.5 min.	50 sec.	40 min.	—	—
2	?	40 sec.	37 + min.	—	—
3	?	?	36 + min.	—	—
B-1	4 min.	2 min.	57 + min.	35 min.	10-14 min.
2	4 min.	2 min.	60 + min.	—	—
3	2.5 min.	3.5 min.	35 min.	7 min.	11 min.
				52 min.	?
4	4 min.	12 min.	150 min.	22 min.	12 min.
				73 min.	10 min.
				112 min.	?
5	2 min.	5 min.	70 + min.	—	—
C-1	1 min.	2 - min.	53 min.	—	—
2	2 min.	40 sec.	35 min.	—	—
3	1 min.	1 - min.	30 min.	—	—
4	1 min.	2 - min.	40 min.	—	—
5	1 min.	10 min.	10 - min.	—	—
6	1 min.	10 min.	10 - min.	—	—
7	1 min.	2 - min.	40 min.	—	—
D-1	1 min.	Dog died in 1 hour & 15 minutes.			
E-1	1.5 min.	30 sec.	70 min.	—	—
2	1 min.	1 - min.	30 min.	—	—
3	1 min.	2 - min.	40 min.	—	—

TABLE 1 (Cont.)

Dog & no. of strychninization	Period of application of strychnine	Onset of strychnine spikes after application	Duration of strychnine spikes	Onset of suppression after strychninization	Duration of suppression
R-4	1 min.	2 - min.	50 min.	—	—
5	1 min.	2 - min.	42 + min.	—	—
6	1 min.	2 - min.	30 min.	—	—
7	1 min.	4 min.	40 + min.	5 min.	2-3 min.
				10 min.	1-3 min.
F-1	2 min.	2 min.	40 min.	123 min.	5-6 min.
2	1 min.	3 min.	40 min.	46 min.	4-7 min.
3	1 min.	2 - min.	33 min.	38 min.	7-10 min.
4	1.5 min.	1 - min.	40 min.	—	—
5	1 min.	5 min.	55 min.	2 min.	5-7 min.
				31 min.	5-7 min.
G-1	1 min.	50 sec.	20? min.	—	—
2	1 min.	2 - min.	40 min.	—	—
3	1 min.	2 - min.	20 min.	20 min.	6-10 min.
4	1 min.	2 - min.	45 min.	20 min.	5 min.
4a	1 min.	40 sec.	40 min.	30 min.	5-10 min.
R-1	1 min.	2 min.	45 min.	—	—
2	2 min.	1 min.	40 min.	—	—
3	1 min.	3 min.	60 min.	—	—
4	1 min.	10 min.	30 min.	—	—
5	1 min.	2 - min.	30? min.	—	—
6	1 min.	?	?	—	—
7	1 min.	2 - min.	45 min.	—	—
8	1 min.	3 min.	30 min.	—	—

TABLE 1 (Cont.)

Dog & no. of strychninization	Period of application of strychnine	Onset of strychnine spikes after application	Duration of strychnine spikes	Onset of suppression after strychninization	Duration of suppression
H-9	1 min.	5 - min.	30 min.	—	—
10	1 min.	3 min.	20 + min.	—	—
I-1	1 min.	1 min.	65 min.	25 min.	9-10 min.
2	1 min.	1 min.	65 min.	—	—
3	.5 min.	1 min.	65 min.	20 min.	9 min.
3[1]	.5 min.	1 min.	70 min.	?	—
4	.5 min.	1 min.	45 min.	—	—
5	.5 min.	2 - min.	75 min.	—	—
6	.5 min.	1.5 min.	40 min.	—	—
7	.5 min.	6 min.	15 min.	?	—
7[1]	.5 min.	2.5 min.	40 min.	—	—

FIGURE 1

A composite diagram of the lateral surface of the right, cerebral hemisphere of 9 dogs. The rectangles indicate the approximate points of application of strychnine to the cortex. The "S" within the rectangle signifies that suppression of electrical activity was produced by strychninization of that point, and the "F" within the rectangle indicates that distant strychnine spikes appeared upon strychninization of that point. The capital letters outside the rectangular blocks represent the particular animal that was used, and the Arabic numerals stand for the particular strychninization on that animal.

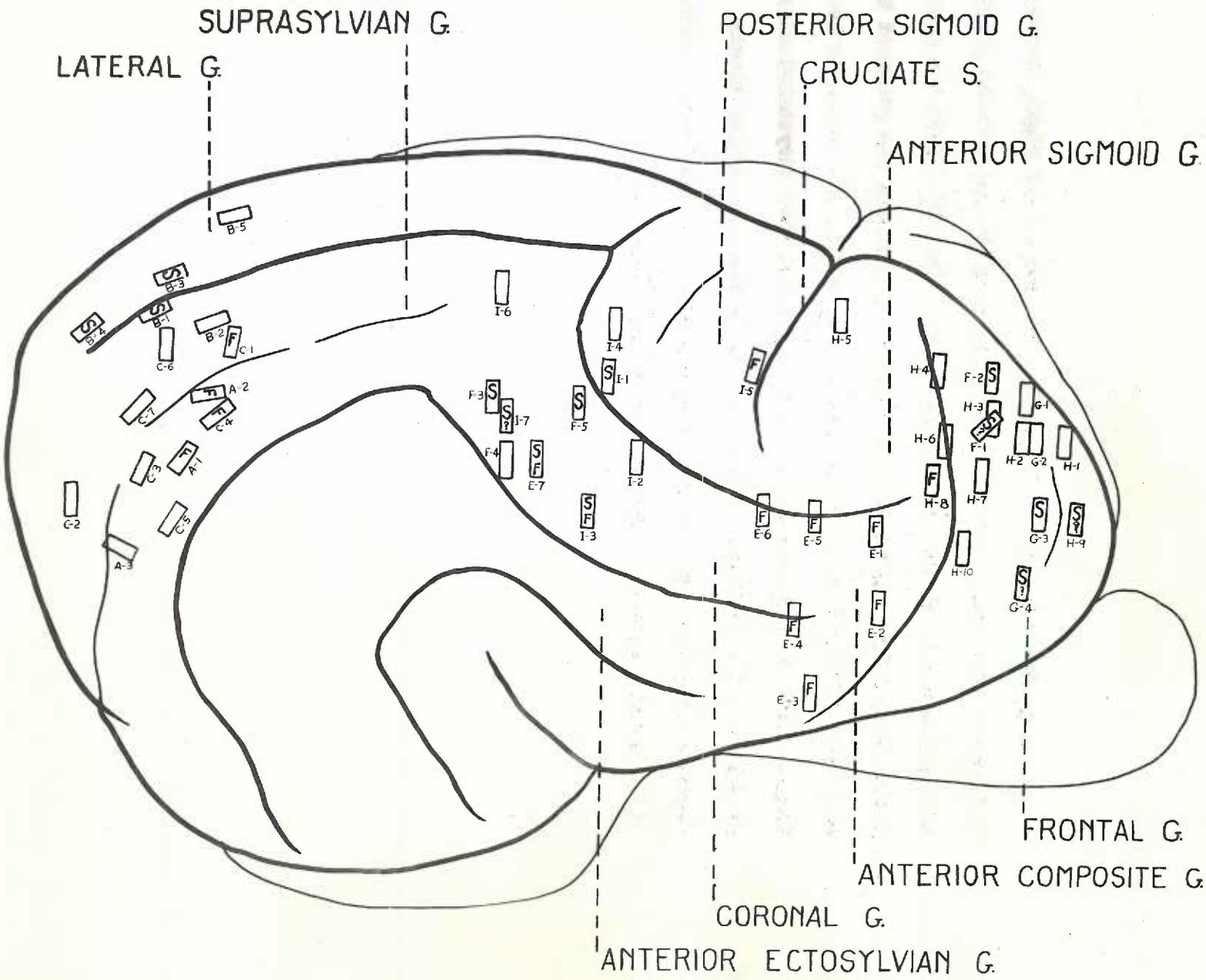

SUPRASYLVIAN G.
LATERAL G.
POSTERIOR SIGMOID G.
CRUCIATE S.
ANTERIOR SIGMOID G.
FRONTAL G.
ANTERIOR COMPOSITE G.
CORONAL G.
ANTERIOR ECTOSYLVIAN G.

FIGURE 2

Representative portions of an electroencephalogram obtained by strychninization of dog #8 (F-3; see Fig. 1) showing suppression of electrical activity. The suppression appeared 38 minutes after the application of the strychnine, and it had a duration of 5 to 7 minutes. The position of the monopolar electrodes was as follows: 1-5 on the anterior portion of the suprasylvian gyrus, 2-5 on the posterior portion of the coronal gyrus, 3-5 on the posterior sigmoid gyrus, and 4-5 on the anterior sigmoid gyrus. 7-8 stand for the bipolar electrodes around the strychninized point. Notice that strychnine spikes also appear in the posterior portion of the coronal gyrus.

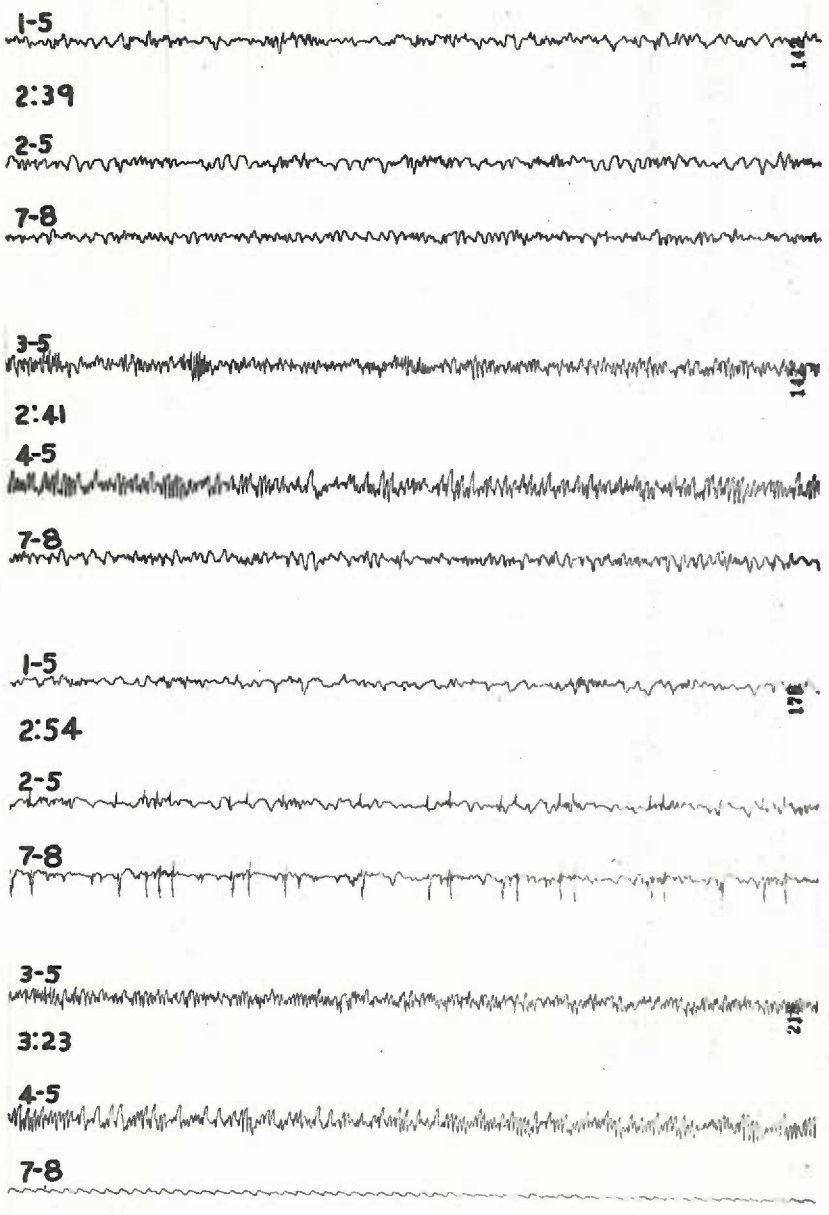

1-5
2:39
2-5
7-8
3-5
2:41
4-5
7-8
1-5
2:54
2-5
7-8
3-5
3:23
4-5
7-8
1-5
3:24
2-5
7-8
3-5
3:30
4-5
7-8
3-5
3:36
4-5
7-8
1-5
3:41
2-5
7-8

FIGURE 3

Portions of an electroencephalogram obtained from dog #6 (F-2; see Fig. 1). The suppression appeared 2 hours and 3 minutes following strychninization of point F-1. No strychnine had been applied to point F-2. The position of the monopolar electrodes is the same as that described in Figure 2.

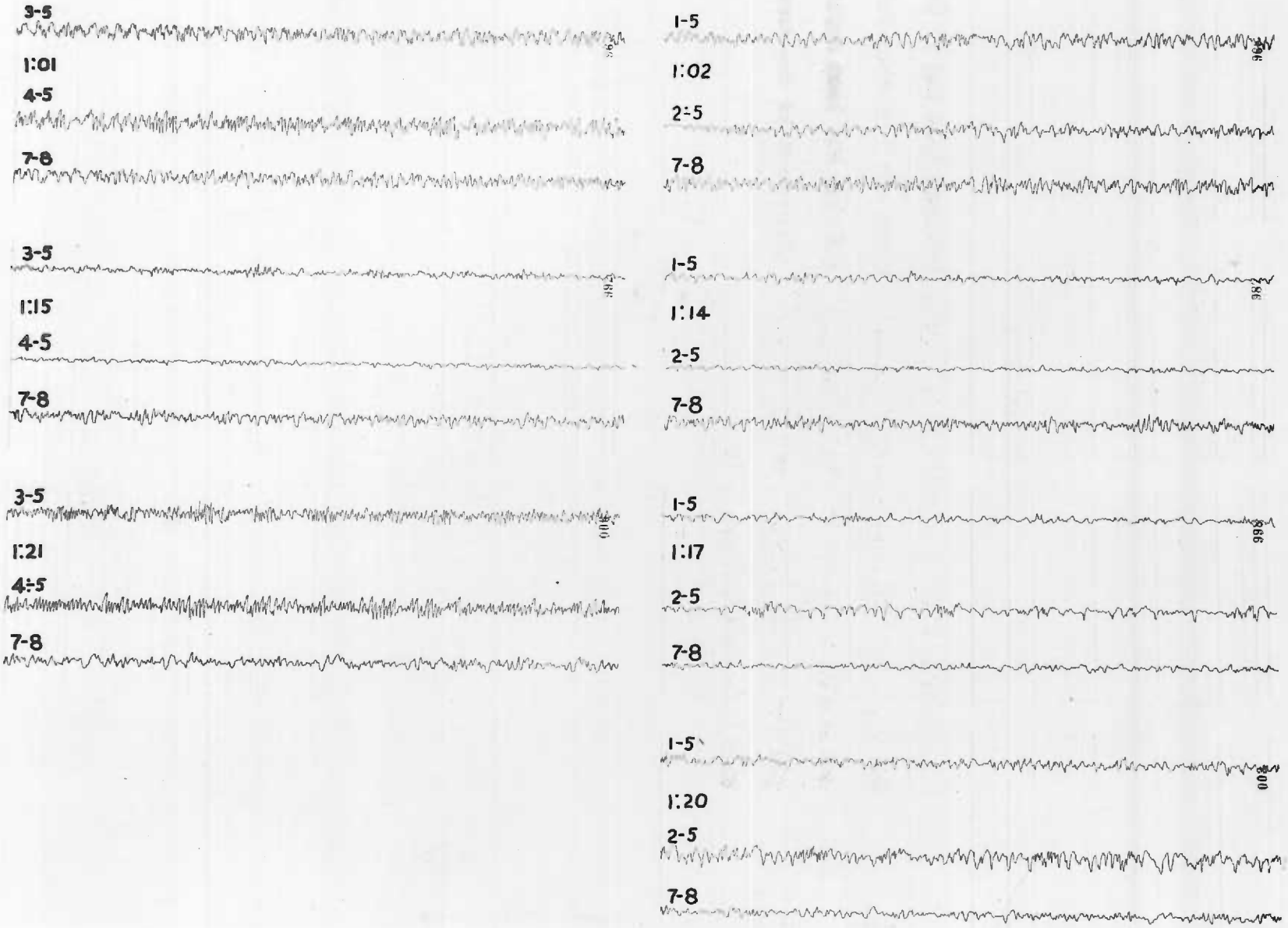

3-5
1:01
4-5
7-8
3-5
1:15
4-5
7-8
3-5
1:21
4-5
7-8
1-5
1:02
2-5
7-8
1-5
1:14
2-5
7-8
1-5
1:17
2-5
7-8
1-5
1:20
2-5
7-8

FIGURE 4

A diagram of the fore part of the right, cerebral hemisphere of dog #6. The symbols are indicative of the areas explored and the region of the body in which movement was obtained by stimulation of the cortex with single, condenser discharges at a frequency of once per second.

Left hind leg

Trunk

Left foreleg

Left side of neck

Left ear

Right side of neck

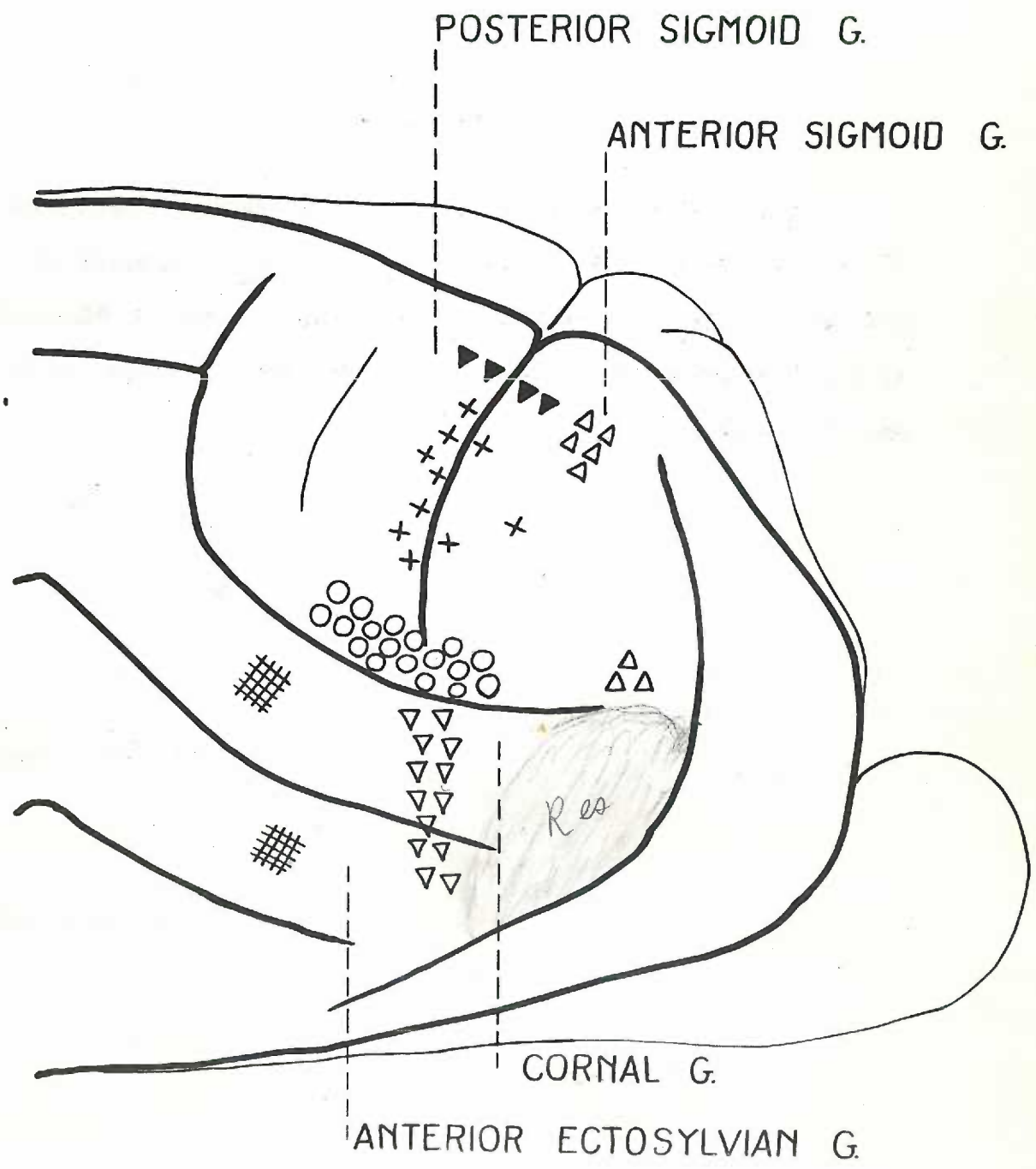

POSTERIOR SIGMOID G.
ANTERIOR SIGMOID G.
CORNAL G.
ANTERIOR ECTOSYLVIAN G.

FIGURE 5

A diagram of the cortical areas explored on dog #14 using a 5 ma. 60 cycle a.c. stimulus with a duration of 5 to 10 seconds. The effects produced by this stimulus on the left, foreleg, extensor twitch at the scapulo-humeral joint are shown by means of the symbols listed below. The two, large black dots on the posterior sigmoid gyrus represent the region from which the extensor twitch was induced by an electrical, rectangular pulse of a duration of 20 msec. at a frequency of once per second.

Complete suppression of the extensor twitch at the left, shoulder joint.

Increased tonus in the left foreleg.

Clonic movements of the left foreleg.

Facilitation of the extensor twitch at the left, shoulder joint.

Suppression of respiratory movement.

Decreased amplitude of the extensor twitch at the left, shoulder joint.

Increased amplitude of the extensor twitch at the left shoulder joint after withdrawl of the a.c. stimulus.

Face movements.

Extensor twitches of the left forepaw.

Neck movements.

Hind leg movements.

Return of suppressed extensor twitch of the left, shoulder joint prior to removal of the a.c. stimulus.

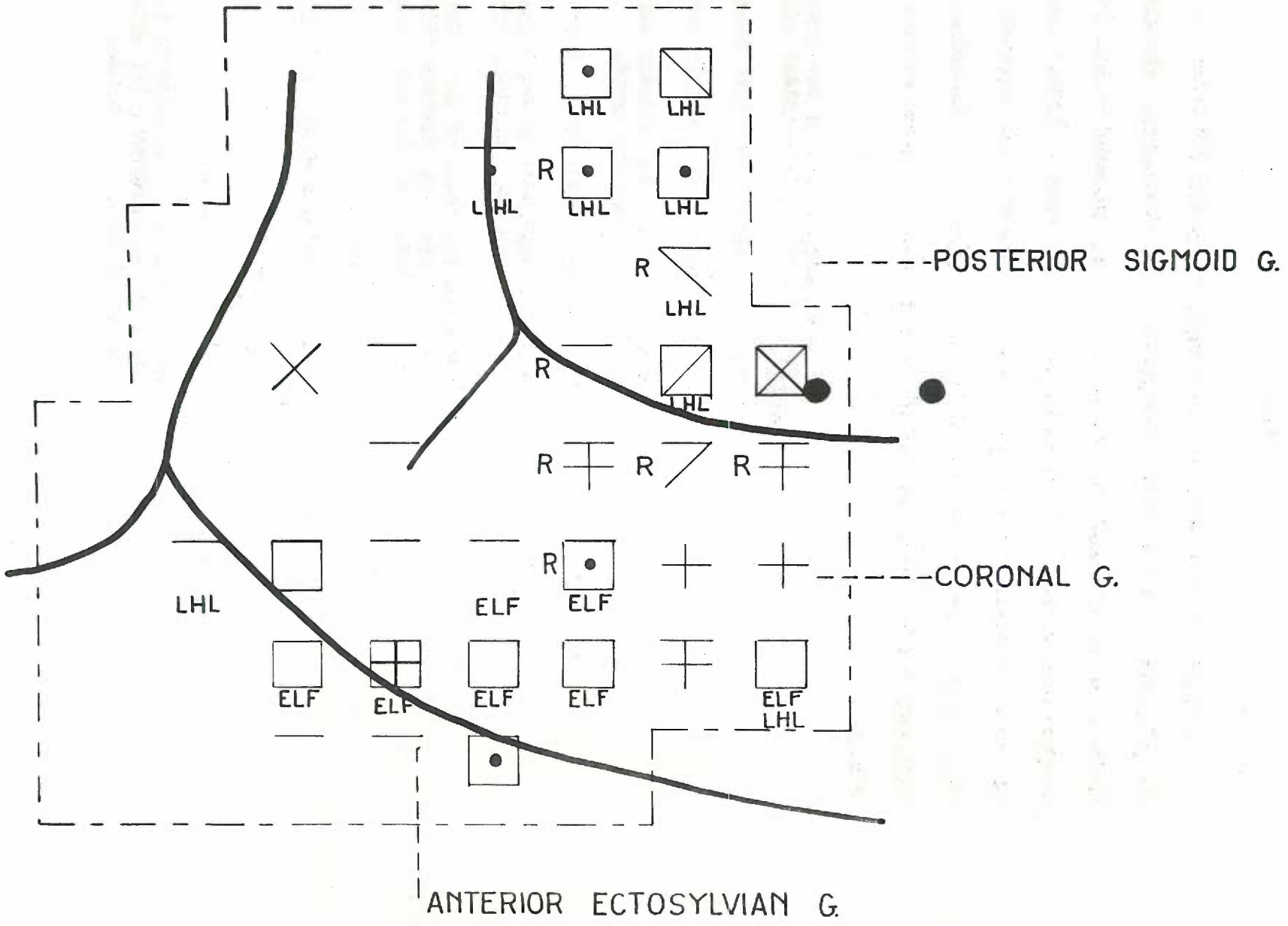

LHL
LHL
R
LHL
LHL
LHL
R
LHL
POSTERIOR SIGMOID G.
R
LHL
R
R
R
R
LHL
ELF
ELF
CORONAL G.
ELF
ELF
ELF
ELF
ELF
LHL
ANTERIOR ECTOSYLVIAN G.

FIGURE 6

A diagram of the cortical areas explored on dog #15 using a 5 ma. 60 cycle a.c. stimulus with a duration of 5 to 10 seconds. The effects produced by this stimulus on the left, foreleg, extensor twitch at the scapulo-humeral joint are shown by symbols, which are the same as those used in Fig. 5.

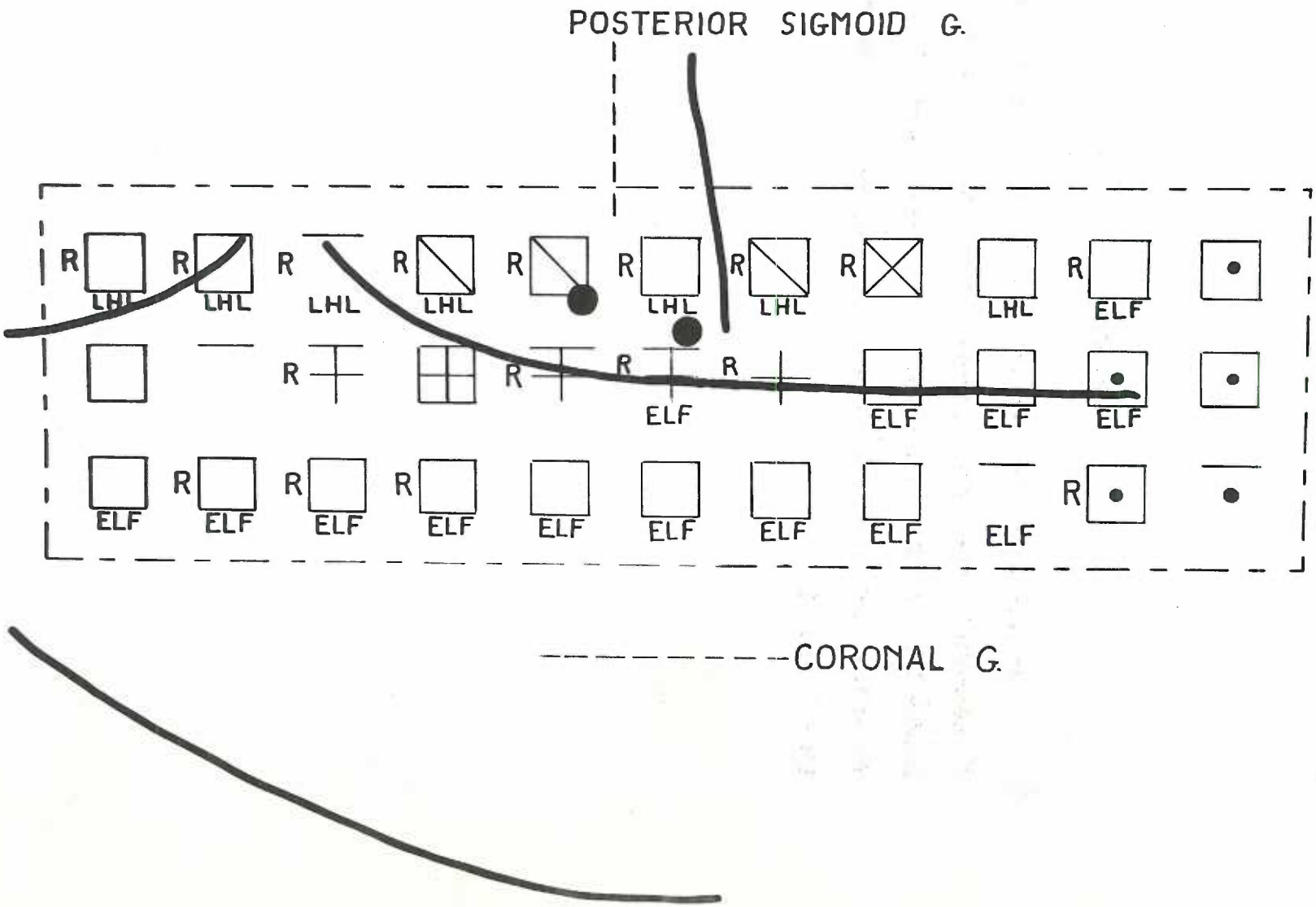

POSTERIOR SIGMOID G.
R
LHL
ELF
CORONAL G.

FIGURE 7

A diagram of the cortical areas explored on dog #16 using a 3 ma. or 5 ma. 60 cycle a.c. stimulus with a duration of 5 to 10 seconds. The effects produced by this stimulus on the left, foreleg, extensor twitch at the scapulo-humeral joint are shown by symbols, which are the same as those used in Fig. 5.

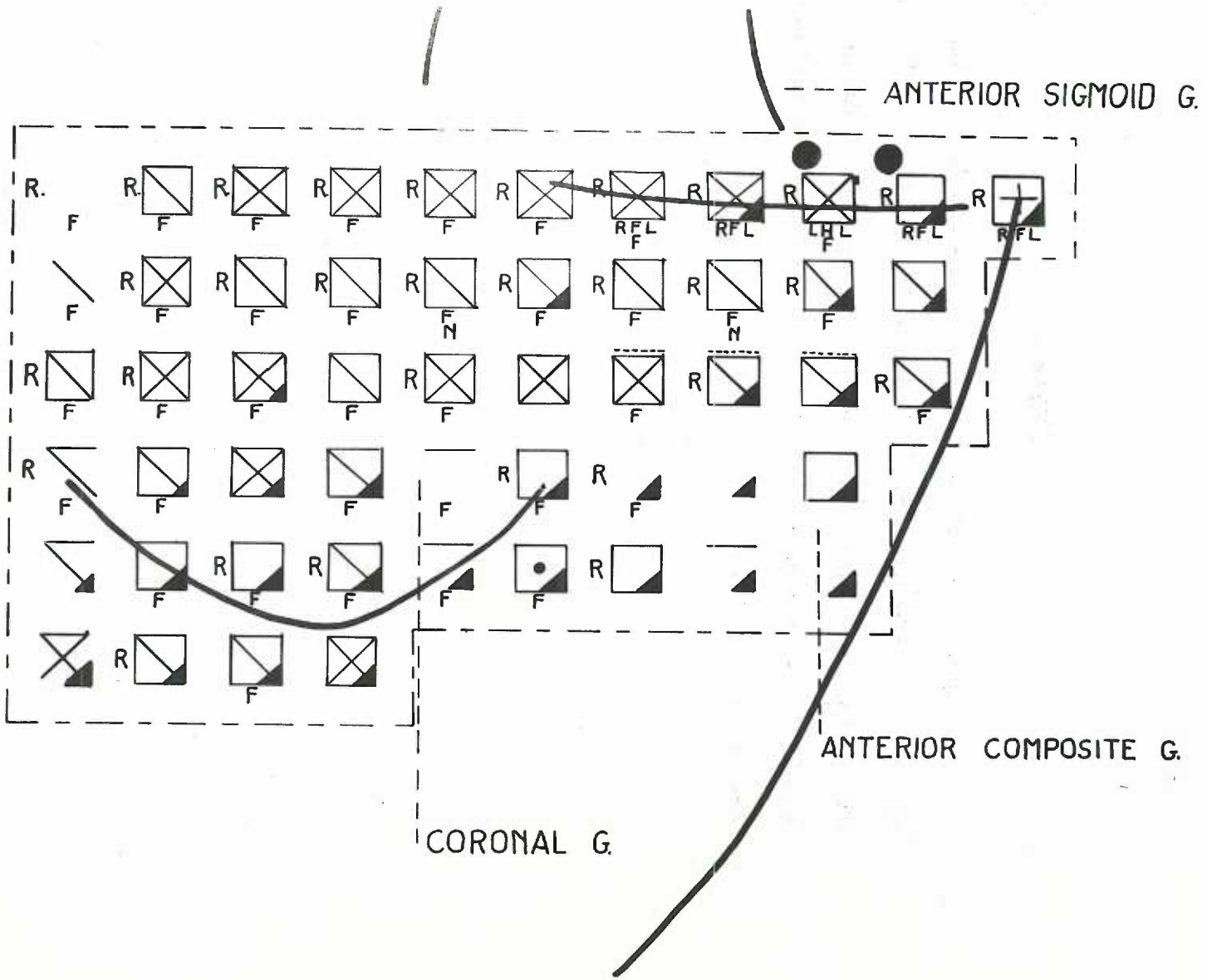

ANTERIOR SIGMOID G.
ANTERIOR COMPOSITE G.
CORONAL G.

FIGURE 8

A diagram of the cortical areas explored on dog #17 using a 5 ms. 60 cycle s.c. stimulus with a duration of 5 to 10 seconds. The effects produced by this stimulus on the left, forelag, extensor twitch at the scapulo-humeral joint are shown by symbols, which are the same as those used in Fig. 5.

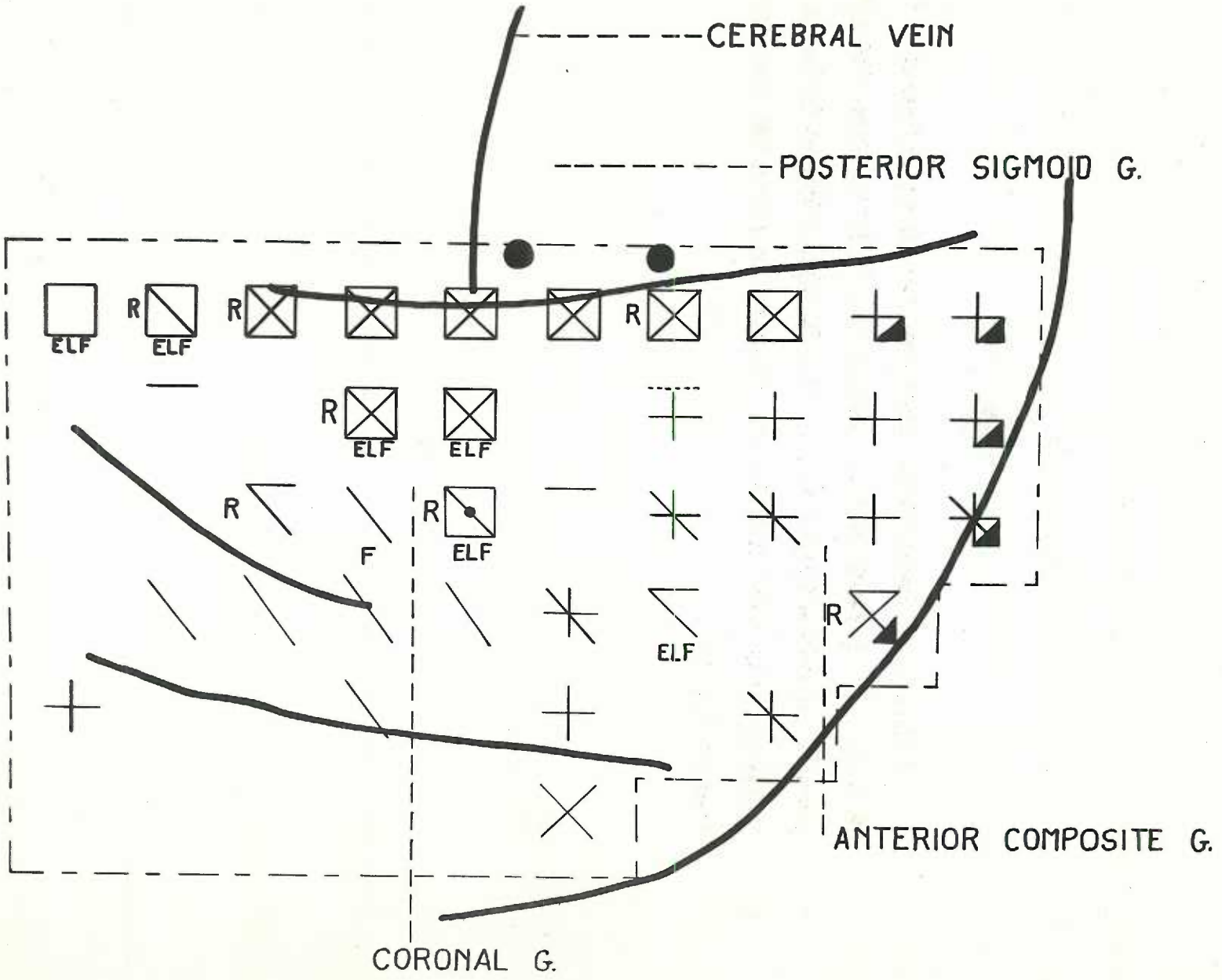

CEREBRAL VEIN
POSTERIOR SIGMOID G.
ELF
R
F
ANTERIOR COMPOSITE G.
CORONAL G.

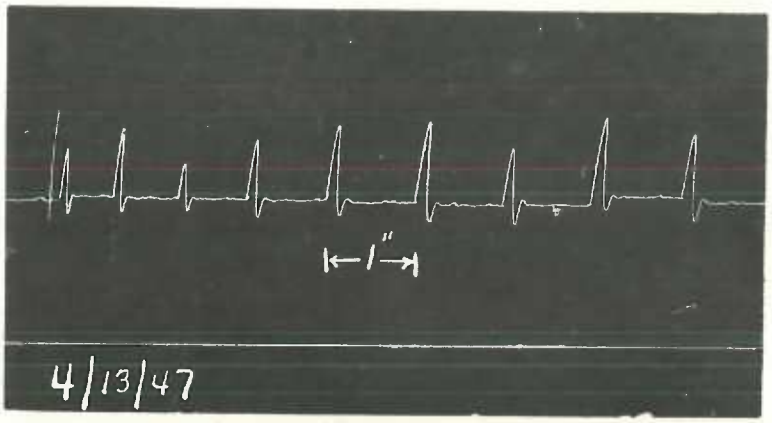
FIGURE 9

A. A kymogram of the left, extensor twitch at the scapulo-humeral joint produced by stimulating the inferior portion of the posterior sigmoid gyrus with rectangular pulses of a duration of 20 msec. at a frequency of once per second. The interval between each contraction is one second. The variation in amplitude of the contractions is partially due to friction in the recording apparatus.

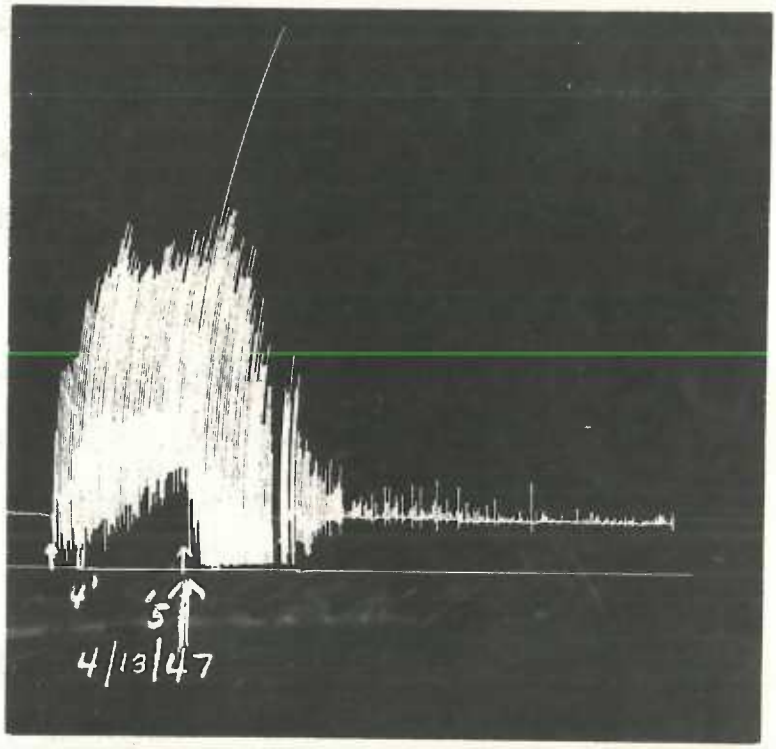
B. At the beginning of this record the extensor twitch at the left scapulo-humeral joint was not recordable but could be palpated. At the arrow opposite no. 4 a hemostat was clamped on a footpad of the left foreleg, and at the arrow opposite no. 5 the hemostat was removed.

C. Prior to taking this record the cortex, which was stimulated in B, was removed to a depth of 6 to 8 mm. The electrodes were then applied directly to the white matter underlying the point stimulated in B. Notice that the extensor twitch was recordable immediately without increasing the strength of the stimulus. At 7' a hemostat was clamped to a footpad of the left foreleg, and at 8' it was removed.

A



B



C