

ON THE RELATION OF THE OPTIC THALAMUS TO
RESPIRATION, CIRCULATION, TEMPERATURE,
AND THE SPLEEN.*

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PLATES 38-43.

SYNOPSIS

HISTORICAL.

1. Circulation.
2. Respiration.
3. Spleen.
4. Temperature.

DESIGN OF RESEARCH.

METHOD AND TECHNIQUE.

STIMULATION EXPERIMENTS ON THALAMUS AND ADJACENT REGIONS.

- Group I. Circulation.
Respiration.
Spleen.

- Group II. Temperature.

DISCUSSION AND CONCLUSIONS.

In the year 1909, I published in *Brain*¹⁰¹ an article recording the results of a series of experiments on the optic thalamus in which its anatomy and some of its functions were considered. That investigation was carried on by a more accurate method than had hitherto been employed; namely, with Clarke's stereotaxic instrument. This method proved so useful that a further study of certain functions of the thalamus was undertaken. In the present paper, I have considered four points which have been under discussion for some time; namely, the relation of the thalamus to circulation, respiration, spleen, and temperature.

*Received for publication, June 30, 1911.

HISTORICAL.

Since my previous communication, a few contributions have been made to the subject. D'Abundo's² experimental study has not added anything very new to the subject. His lesions were large and yielded for the most part the same results as Roussy⁸⁸ obtained. He has made no observations on the questions that interest us here. The valuable paper of Malone¹⁴ on the nuclei of the thalamus divides the thalamus, by the Nissl method, into such a large series of nuclei that we cannot use his classification for our studies. The papers of Aisenstat,³ Sinelnikow,¹⁰⁷ and Streerath,¹¹⁰ on the heat centers in the thalamus and corpus striatum, we shall speak of under the heading of temperature.

(1) *Circulation*.—Since Danilewsky²⁰ first claimed that certain regions of the thalamus and caudate nucleus were concerned with changes in blood pressure and pulse rate, a number of other observers have directed their investigations towards this subject. Simbriger,¹⁰⁶ Hitzig,⁸⁸ Balogh,⁹ 10 Howell and Austin,⁸⁵ Prus,⁸² and Bechterew and Mislawsky,¹² 13 all found such changes, a rise of blood pressure and at times a change in rate. Carville and Duret,²⁴ Beevor and Horsley,¹⁵ and some others obtained absolutely negative results.

The most careful work on the positive side was that of Prus, whose table shows different effects on the thalamus according to the point stimulated. However, no observer, not even Prus,⁸² has attempted to correlate the points of stimulation with the various anatomical regions of the thalamus. This is due to the large lesions and inaccurate methods used. Opinions also vary somewhat as to the cause of these phenomena. Thus Bechterew and his school claim that these points stimulated are circulatory centers. Such a conclusion is not warranted, for we shall see later on that these changes are very similar to those observed when a peripheral sensory nerve is stimulated. The view advanced by Howell and Austin in their brief communication seems more nearly in accordance with the facts. Tigerstedt¹¹³ and Boruttau²⁰ hold a very similar point of view; namely, that such phenomena may be simply reflex.

(2) *Respiration*.—Few chapters in physiology have a more extensive or confusing literature, and as recently as 1909, Boruttau²⁴ declared that the views on the nervous control of respiration were so varied that many experiments were still necessary to clear it up. A general survey of the subject leads inevitably to the conclusion that investigators have been but too ready to claim the existence of a respiratory center in any region from which, upon stimulation, respiratory phenomena were elicited. Marckwald,⁷⁵ Rosenthal,⁸⁶ Christiani,²⁵ 26 Martin and Booker,⁷⁷ Asher and Lüscher,⁷ and Lewandowsky⁶⁶ are some of those who have found respiratory changes upon thalamic stimulation. Martin and Booker⁷⁷ described four kinds of changes: inspiratory and expiratory inhibition, rapid respiration, and inspiratory tetanus.

The mechanism involved in these changes has received innumerable explanations which cannot, for lack of space, be considered here. Boruttau has reviewed the subject clearly and objectively. The experiments were carried on sometimes by stimulation of the basal ganglia after extirpation of the cortex, and then again by introducing electrodes or other instruments directly into the regions to be studied. Besides considering the region stimulated, a number of factors have been mentioned from time to time that were supposed to influence

respiratory movements. The most important of these were the type of stimulus, whether chemical, mechanical, or electrical (Eckhard,³² Budge, Bernard,¹⁷ Rosenthal⁹⁷), the sex of the animal (Meltzer),⁷⁸ and other even more unusual factors. Subsequently the views of von Helmholtz⁴⁷ and a few other investigators gained ground; namely, that the character and strength of the stimulus were the important factors. Lewandowsky⁶⁰ went so far as to claim that weak tetanizing currents produced inhibition of respiration, stronger currents rapid respirations, and spreading currents inspiratory tetanus, and that this latter stimulus was comparable to the painful stimulus of a sensory nerve. Boruttau²¹ claims that the length of stimulus determines whether there shall be acceleration or inhibition of respiration. This has been strenuously denied by others, and the present investigation, as may be seen from a glance at the records, does not support such a view. From our records it is evident that acceleration or inhibition starts at the moment the stimulus begins, regardless of its length. Spencer,¹⁰⁹ after repeating Christiani's experiments, does not see why, if respiratory centers are assumed, as such, excitation experiments are better explained by attributing their results to stimulation of fibers rather than to stimulation of central mechanisms. In summing up this chapter, Boruttau²¹ says: "It seems most probable that all cerebral and spinal tracts of general sensibility, particularly those of the respiratory paths and respiratory muscles, are connected directly with the respiratory center tentatively assumed to lie in the region of the corpora quadrigemina."

(3) *Spleen*.—Erikson, working in Bechterew's laboratory, as reported in Bechterew's book on the nervous system, maintained that there was a center in the thalamus controlling movements of the spleen. In Bechterew's book (vol. 2, pp. 1166 and 1167) are some of the kymograph records. These are so inaccurate and show such mediocre work that that alone makes us doubt his results. Furthermore, one single experiment, in which when there was a movement of the spleen the animal also urinated, is cited as proving that the bladder and splenic centers lie near each other in the thalamus. Then, too, we find no mention in his text of the normal splenic wave (figures 1, 3, and 6) first described by Roy,⁹⁹ and later more exhaustively studied by Schäfer and Moore.¹⁰³ Some of Bechterew's records look strikingly like these normal splenic waves. These observations of Erikson on the relation of the thalamus to the spleen have never been confirmed. Roy⁹⁹ says that the drop in the specific rhythm synchronous with the rise in blood pressure is a vaso-constrictor action arising in the medulla.

(4) *Temperature*.—It has been claimed that the thalamus and corpus striatum control temperature. Lesions of these regions are said to cause a rise of temperature. Aronsohn and Sachs,⁶ Ott,⁸⁷⁻⁹⁰ White,¹¹³ Richet,⁹³ Tangl,¹¹² Ito,⁵⁶ and many others have made such observations. Most of these studies have been on rabbits, some on dogs, and Tangl's four experiments were on horses. White,¹¹³ though first inclined to think that the thalamus was concerned with these changes in temperature, in a later publication ascribes them all to the corpus striatum. He also observed clinically marked rises of temperature, and such observations are not uncommon in apoplexies with ventricular hemorrhage. Mosso⁵⁰⁻⁵³ is the chief opponent to this view and in a series of investigations has pointed out many of the errors in connection with it. Thus he found that the temperature of rabbits

varies greatly (1° to 2° C.) under normal conditions without any operative procedure at all. Some of the possible causes postulated by him for the rise of temperature are hemorrhage and excitement. Muscular contractions may cause a rise, which some investigators have excluded by the use of curare. Under such conditions Aronsohn⁵ found no rise of temperature. Such experiments as the four of Tangl on horses are quite inconclusive, for only two showed a post-operative rise, and in these the author does not say how much hemorrhage occurred. A large experience in surgical wards has shown me repeated examples of post-operative rises of temperature in cases where there was no hemorrhage, no traumatism of tissues, and in which the wounds healed *per primum* without any reaction. This makes one very skeptical as to the cause of any particular post-operative rise of temperature. These criticisms hold also in regard to the three researches published in the past year by Aisenstat,⁸ Sinelnikow,¹⁰⁷ and Streerath.¹¹⁰ The latter, though he says that the rabbit's temperature may vary 1.3° C., always makes his calculations from the minimum temperature.

Tigerstedt¹¹⁸ sums up the subject well when he says that there is little evidence of a temperature center in the brain, though there is some evidence that there may be one in the corpus striatum.

DESIGN OF THE PRESENT RESEARCH.

From this brief review, it is apparent that it has not been established what, if any, is the relation of the thalamus to circulation, respiration, the spleen, and temperature. The more accurate method at my disposal has enabled me to throw some further light on these questions and to place the true functions of the thalamus on a firmer basis. In the course of this work, I have made some observations on other portions of the brain and these will also be reported.

METHOD AND TECHNIQUE.

In the present investigation, ninety-two cats were used. Only sixty of these are made use of in the present report. The thirty-two not incorporated were discarded either because they died before the termination of the experiment—usually from an overdose of ether—or because the records were not clear enough to study. With the exception of one or two, all of these were animals employed in the earlier experiments, when we were perfecting the methods of procedure. The experiments will be reported in two groups.

- I. Electrical stimulation of the thalamus and neighborhood with reference to circulation, respiration, and the spleen.

II. Electrical stimulation of the thalamus, caudate nucleus, and lenticular nucleus with regard to temperature.

The animals were all operated upon under ether anesthesia. Aseptic methods were not used, as each animal was killed at the end of the experiment, before recovering from the anesthetic. The head with the brain *in situ* was hardened in 10 per cent. formalin, and after several days the brain was removed, cut on a macrotome to show the lines of stimulation, photographed (figures 8 to 12), and then cut in serial sections and stained with polychrome methylene blue in order to identify more accurately the region that had been stimulated.

The Clarke instrument is fully described by Horsley and Clarke⁵⁴ in their account of experiments on the cerebellum. Bipolar stimulation was used throughout with needles measuring 1 to 1.5 millimeters in diameter. The needles, as seen from the course of the needle track in the photographs, were introduced through the vertex (figures 8 to 12). Bipolar stimulation was used, as the unipolar method with one electrode in the brain substance and the other on the surface yields unreliable results, as pointed out in Horsley and Clarke's⁵⁴ article and in my own.¹⁰¹ The current was obtained from an induction coil which was supplied by one dry cell. A minimal current was used at all times. At no time was this current more than would yield a moderate response if applied to the motor cortex. If at any time such a current was too powerful, it was reduced until a point was reached where the weakest possible current yielded a result. During the experiments the brain was kept warm by constant irrigation with warm solution, and only as long as the animal showed no fatigue was an experiment continued.

Circulation was studied by means of a cannula in the carotid, connected with a mercury manometer. For recording the respiration, a cannula with three arms was inserted into the trachea; one of these arms was connected with an ether bottle, one was a safety opening to admit air rapidly in case of a collapse, and the third was connected with a large bottle which in turn was connected with a modified Brodie receiving tambour made of a large, thin-walled ice-bag. By this device the upstroke on the records represents

expiration, and the downstroke, inspiration. The large bottle was inserted to lessen the depth of excursion of the lever. The arm leading to the ether bottle had a three-way stopcock so that pure air, pure ether, or a mixture of the two could be given. When a kymograph record was taken, all connection with the outer air was excluded, and for this purpose the large bottle was also useful, as it contained enough air to prevent asphyxial symptoms. Between each two stimulations the animal was given fresh air.

Splenic records were obtained with an oncometer of the type described by Schäfer and Moore,¹⁰³ with air transmission. The receiving tambour was a modified Brodie tambour made of part of a small finger cot. In these records the upstroke represents expansion of the spleen body. In the temperature experiments, the animal was kept on a warm stage. The temperature was taken per rectum with a Heidenhain thermometer made by Koehler and Martini in Berlin.

In localizing any point in the brain when using the Clarke instrument, the brain is conceived as divided by three planes: (1) The sagittal plane passes longitudinally between the two hemispheres. The plane sections parallel to it are spoken of as lamellae 1, 2, 3, according to their distance in millimeters from the sagittal (zero) plane. (2) The basal plane has its four points determined by the inferior margin of the bony orbits and the centers of the bony auditory meati. The horizontal plane employed for convenience, as zero, is parallel to this and ten millimeters higher in the average cat. The height above or below this is designated in letters thus: A=one millimeter above the plane; -A=one millimeter below the plane; B=two millimeters above, etc. (3) The frontal or interaural plane, perpendicular to the horizontal plane, passes through the centers of the two meati. The numbers 1, 2, 3, etc., designate the distance in millimeters in front of or behind this plane.

In the kymograph records, each point of stimulation has been lettered according to this nomenclature. This, however, need not concern the reader, since he is only concerned in knowing what anatomical region was stimulated, and as animals' heads vary somewhat. Lamella 2, B 10, for example, would not correspond to the same point in every brain; but knowing that a certain result was

obtained there, one could readily identify the spot on the brain sections as it would be two millimeters from the median line, two millimeters above the horizontal plane, and ten millimeters in front of the interaural plane. In each experiment, stimulation was carried on in but one lamella, but not every point in the thalamus in that lamella was stimulated in each experiment. Therefore I have selected type photographs of each lamella. These show what points were stimulated during the various experiments. From these and the tables which record the regions stimulated in each experiment, it will be seen that the thalamic nuclei were repeatedly stimulated as well as certain neighboring regions. In these experiments I have adopted the same classification of the thalamic nuclei which I used in my previous paper,¹⁰¹ as it is most practical for recording these experiments, as follows: nucleus anterior, nucleus medius, nucleus reuniens, nucleus lateralis, nucleus ventralis, center median and nucleus arcuatus, and pulvinar.

The results can best be stated by taking up each nucleus separately and then the adjacent regions.

GROUP I.

Nucleus anterior.—(Table II.) In seventeen cats the anterior nucleus was stimulated. In all but four instances there was a respiratory change, usually of an expiratory inhibitory character. These inhibitory phenomena usually consisted of a moderate slowing of the rate. There were four instances of inspiratory inhibition, —a very unusual phenomenon in the thalamus. So unusual is this occurrence, and so rarely was it observed in any other region (see experiments 141, 145, 191, 193, table I) of the thalamus, that we consider it the exception.

A rise of blood pressure was the rule, and in proportion as the blood pressure rose the spleen changed in volume; that is, where there was a slight rise no change occurred, but when there was a rise of more than five millimeters the spleen showed a change in volume, and this at times was an increase, at other times a decrease. There seemed no way of predicting what the nature of this change would be; sometimes the pressor effect predominated, and then

again the depressor. The volume changes in the spleen are influenced entirely by the blood pressure changes. We have never observed a change in the spleen without an associated change in the blood pressure. No change of impulse rate was observed at any time. In our previous communication, we pointed out a close relation between the anterior nucleus and the nucleus caudatus. The anterior nucleus was as unresponsive as regards motor phenomena as was the caudate, and, furthermore, we traced degenerations running from it along the stratum subcaudatum. The present facts clearly show that though neither is concerned with motor phenomena, stimulation of the anterior nucleus affects respiration and blood pressure, while the caudate is inert to stimulation.

Nucleus medius.—(Tables I and II, figure 3, C 10, O 10.) In thirteen experiments the results were uniform. No respiratory or circulatory changes were observed. This nucleus is then as inert in respect to these functions as it is in respect to the motor phenomena. It is of particular interest to note that this applies only to the dorsal part of the nucleus and that in this region there are no fibers from the superior cerebellar peduncle, while in the ventral portion, occupied by the nucleus reuniens, the fibers of the superior cerebellar peduncle are found (Horsley and Clarke).

Nucleus reuniens.—(Table II, figure 3, —B 10; figure 4, —B 8.) In ten experiments the marked difference between the dorsal and ventral portions of the nucleus medius was apparent. This consisted of total inspiratory inhibition following stimulation, with a condition of inspiratory tetany (Martin and Booker),⁷⁷ and this was associated with forced inspiration. The blood pressure rose markedly, though the pulse rate remained the same. The changes in the spleen were only observed when the blood pressure rose a great deal, and at such times the progression movements, so characteristic of the superior cerebellar peduncle, contributed to the apparent volume increase of the spleen. This accounts for the very unusual rise in figure 3, —B 10. That the nucleus reuniens, which was first described by Ziehen¹²² in the marsupials, should always have been considered a part of the nucleus medius, is amply accounted for by the physiology of the former, as well as by its anatomy.

Malone⁷⁴ has but recently pointed out how very different its structure is from the rest of the nucleus medius.*

The type of respiration here observed is similar to that seen on stimulation of a more posterior part of the thalamus and of the region about the corpora quadrigemina. The posterior region is the one in which Christiani^{25, 26} placed his respiratory center, yet here we observe the same phenomena in connection with a region much more anterior.

Nucleus lateralis.—(Table I, figure 1, C 12, O 12.) The twenty observations all show a respiratory change which is more marked in connection with the ventral and posterior portions of the nucleus. The excitation phenomena increase in intensity in proportion as there are more fibers from the superior cerebellar peduncle and median fillet. In my previous paper, already referred to, it is pointed out that the largest number of fibers from these tracts end in the ventral and posterior portions, while they become fewer in the anterior and dorsal portions. About half of the observations show a change in blood pressure, while the others show none. In those in which the change occurred, the region stimulated was this same more ventral, more sensitive portion. The pulse rate remained the same throughout and the spleen was unaffected.

Nucleus lateralis ventralis.—(Tables I and II, figure 1, —B 12.) Here in fifteen observations the same conditions were observed as were noted in connection with the nucleus lateralis, but here they occurred with more intensity. The anatomic connections of the nucleus lateralis ventralis with the sensory paths, superior peduncle, and fillet, are the same as those of the nucleus lateralis. It is of interest to note that as we approach the base of the nucleus lateralis ventralis,—the hypothalamic region (figure 4, —B 8),—the respiratory phenomena change and inspiration is differently affected, which we shall see later is characteristic of the globus pallidus of the nucleus lenticularis.

Pulvinar.—(Tables I and II.) Seventeen observations indicate greater excitability of the median portion than the lateral portion, and this becomes more marked as the posterior commissure is

* Edinger⁸⁸ pointed this out some years ago in the invertebrates, and I⁸⁹ identified it as a separate structure in the vertebrate series.

approached. The respiration on stimulation of this region shows at times expiratory inhibition or some acceleration, and in this respect it is of the same type as in the rest of the thalamus. The blood pressure changes are less marked, but still present. The median portion of the pulvinar is evidently more sensitive on account of its more intimate connection with the fillet (Probst) and with the central grey and nucleus fasciculis longitudinalis posterior (Edinger).³³

Posterior Commissure.—(Tables I and II.) Nine observations were made. In this region, as already stated under the last heading, the excitability is greater, and shows itself by inspiratory tetanus, and by a rise of blood pressure which at times is so marked that the spleen volume changes. The character of the respiratory change is identical with that observed upon stimulation of the nucleus reuniens (figure 3, B 10—B 10).

Ganglion Habenulae and Meynert's Bundle.—(Table II.) The ten observations are uniform in their results and practically identical with the findings in the active parts of the thalamus. This, the epithalamus, Edinger³³ claims is connected through the taenia thalami with the general olfactory system. That this should be so very excitable is not surprising since this system is highly developed in the carnivora.

Fornix.—(Tables I and II, figure 5, C 4.) Thirteen observations were made. This region has invariably proved inert to stimulation even with strong currents. In the record shown, the cornu ammonis of the fornix was stimulated, but the same negative result was also obtained from stimulation in other parts of the fornix, as is shown in the photographs.

Fibers of Lancisi.—(Table II, figure 1, G 12.) Nine observations were recorded. This region invariably yielded no result on stimulation. It is of interest and perhaps somewhat surprising that such marked effects should be obtained from one part of the olfactory system—the ganglion habenulae—while the fornix and fibers of Lancisi were inert. This, however, seems readily enough explained by the fact that the latter two belong to a higher system of neurones and do not take part in a lower reflex mechanism.

Fillet.—(Table I, figure 5, O 4.) Six observations were made.

Here, too, we observe the same respiratory phenomena and inspiratory tetanus, which we have observed both in the nucleus reuniens and the ventral portion of the lateral nucleus. This was to be expected, for here we have but stimulated in their course the fibers whose terminations we stimulated in the nucleus reuniens, nucleus lateralis, and nucleus lateralis ventralis.

Central Grey.—(Tables I and II, figure 6, O 3, —A 3, —B 3.) Twenty observations were made. This region yields on stimulation very marked results; it seems that of all the regions stimulated, respiratory changes are most pronounced in this region. The results on stimulation were always very rapid respiration and what Martin and Booker⁷⁷ have described as inspiratory tetanus. Together with this the blood pressure rose, and at times, when marked blood pressure change occurred, the volume of the spleen was affected. The pulse rate never changed. This region is unquestionably the one that Christiani²⁵ described as a respiratory center. The central grey substance, however, as pointed out by Edinger,³³ and Meynert and Obersteiner, runs from the thalamus down to the fourth ventricle and contains fibers which connect all the cranial nerves with the thalamic region. The chief one of these tracts and the one that concerns us especially here is the dorsal longitudinal bundle of Schütz,¹⁰⁵ which would carry any impulse directly to the vagus nucleus.

A few isolated observations recorded on tables I and II of stimulation of the anterior and posterior corpora quadrigemina (figure 7, O 4, —A 4, —B 4), Türck's bundle, and descending root of the fifth nerve, only serve to show that from these regions also respiratory and blood pressure changes may be obtained.

Nucleus caudatus.—(Tables I and II.) Of twelve observations made in this region all were negative, and even with strong currents no result was obtained. This confirms what the most careful observers have repeatedly maintained, that the nucleus caudatus is inert to stimulation as regards any changes in respiration or circulation.

Nucleus lenticularis (Globus pallidus).—(Tables I and II, figure 2, C 15, O 15.) Eleven observations. By stimulation here we invariably obtained inspiratory inhibition with slowing of respira-

tion, but at no time was there any similarity to the inspiratory phenomena noted on stimulation of the central grey. In the latter case there was forced inspiration followed by tetanus, while in stimulation of the globus pallidus complete inspiration was stopped and the lungs were never filled to their full normal capacity. In some of these observations, blood pressure changes were also noted, but we are inclined to think that pure globus pallidus excitations are unaccompanied by blood pressure changes, since in those cases in which the blood pressure was affected, our electrodes were at the innermost edge of the globus pallidus, next to the internal capsule and nucleus lateralis ventralis.

GROUP II.

Temperature.—The experiments on this important phase of the subject number eight, of which one is a control.

They were carried on differently from those generally reported in the literature, which we have reviewed in the beginning of this paper. Before a final verdict can be rendered, other experiments must be performed. We feel, however, that these observations clear up one phase of the subject absolutely.

If a certain region of the brain is a true temperature center, and if the nerve paths which pass out of it have that specific function, stimulation with a faradic current ought to yield some change in temperature. Furthermore, such a change ought to occur as promptly as the result following any excitation of a nerve or nerve center. If the lesions made in the various experiments of other observers are to be construed as destructive ones, electrical stimulation of such a center ought to produce the opposite effects. If those lesions act as mechanical stimuli, faradic excitation ought to produce the same result. By not allowing the animals to live for several days, as previous investigators have done, we have excluded a large number of possible sources of error which were enumerated in the historical review. I wish to emphasize here once more that with the most painstaking surgical technique, where no blood has been lost, and where no infection and no traumatism of tissues have occurred the day following operation, a post-operative temperature rise of several degrees occurs. In reviewing the experiments in the

literature, I have attempted to discover whether in those experiments in which excessive rises in temperature occur there was much bleeding from the diploic vessels, and whether the experimenters used bone wax, the quickest and most effectual method of stopping such hemorrhage. This is of particular importance in experiments on carnivora, as their diploic vessels are very well developed. The experiments reported, however, throw no light on this question at all.

From the appended tables it is evident that all parts of the thalamus, nucleus caudatus, and nucleus lenticularis were repeatedly stimulated. Never was the slightest effect noticed upon the temperature. All the animals, like control cat 105, showed a gradual progressive fall of temperature which in the course of an hour amounted to from 1° to 2° C. This gradual fall was independent of the stimulation, for in every instance the temperature recorded in the tables was the same before and after each stimulation. The gradual fall occurred between stimulations.

Cat 97. April 16, 1910. Lamella 2.

Temperature before operation, 37.6° C.

Temperature after operation, 37° C.

Each stimulation lasted 30 seconds unless specially indicated.

Point of stimulation.	Temperature.	Region.
* J 15	36.5	Cingulum
E 15	36.5	Fornix
O 15	36.45	} Nucleus anterior
C 15	36.45	
1 min.—B 15	36.5	Nucleus lateralis (muscular movements)
J 10	36.4	Fibers of Lancisi
E 10	36.4	Fornix
C 10	36.35	Ganglion habenulae
1 min. O 10	36.4	Meynert's bundle (respirations violent, current strong)
—B 10	36.3	Nucleus reuniens
E 6	36.25	Corpus callosum
C 6	36.2	Anterior corpus quadrigeminum
1 min. O 6	36.2	} Central grey
1 min.—B 6	36.15	
E 3	36.2	Ventricle
C 3	36.1	} Central grey
2 min. O 3	36.1	
1 min.—B 3	35.95-35.8	Posterior longitudinal bundle

* For my abbreviations, see under "Method and Technique."

Cat 101. April 20, 1910. Lamella 4.

Temperature before operation, 37.45° C.

Temperature after operation, 37.15° to 36.6° C.

Each stimulation lasted one minute unless otherwise indicated.

Time.	Point of stimulation.	Temperature.	Region.	
30 seconds	E 14	36.5	Anterior nucleus	
30 seconds	C 14	36.4	Lateral nucleus	
	O 14	36.4	Lateral nucleus	
	—B 14	36.35	Globus pallidus	
	E 10	36.3 to 36.2	Lateral nucleus	
	C 10	36.2	Median nucleus	
	O 10	36.15 to 36.1	Median nucleus	
	E 6	36.0	Ventricle	
	C 6	35.95	Anterior corpus quadrigeminum	
30 seconds	O 6	35.9	Central grey	Respirations stopped
10 seconds	—B 6	35.65	Central grey	Respirations stopped
	E 3	35.5	Ventricle	
	C 3	35.45	Posterior corpus quadrigeminum	
	O 3	35.45	Central grey	
	—B 3	35.4	Central grey	Violent muscular contractions

Cat 103. April 22, 1910. Lamella 6.

Temperature before operation, 37.75° C.

Temperature after operation, 37.2° C.

Each stimulation lasted one minute.

	Point of stimulation.	Temperature.	Region.	
	E 14	37.1	Nucleus caudatus	
	C 14	37.05	Nucleus caudatus	
	O 14	36.75	Internal capsule	
	—B 14	36.7	Globus pallidus	
	E 10	36.65	Nucleus lateralis	
	C 10	36.6	Nucleus lateralis	
	O 10	36.55	} Nucleus lateralis ventralis	Violent muscular movements
	—B 10	36.5		
	E 6	36.5 to 36.4	Ventricle	
	C 6	36.35	Pulvinar	
	O 6	36.3	Pulvinar	
	—B 6	36.25	Median fillet	
	E 3	36.2	Ventricle	
	C 3	36.1	Posterior corpus quadrigeminum	
	O 3	36.05	Fillet	
	—B 3	36.0	Fillet	} Muscular movements
	—D 3	36.0	Türk's bundle	

Cat 105. April 25, 1910. Control Experiment.

Temperature before operation, 37.7° C.

12.20. Temperature after operation, 37.4° C.

This animal was operated upon, as were all the others, by a craniotomy with opening of the dura. It was kept alive as long as the duration of the average experiment on the thalamus. No lesions were made, but every other step was taken.

Time.	Temperature.
12.25	37.35° C.
12.30	37.1° C.
12.40	36.85° C.
12.45	36.6° C.
12.50	36.4° C.
12.58	36.15° C. Experiment stopped

Cat 107. May 4, 1910. Lamella 8.

Temperature before operation, 37.95° C.

Temperature immediately after operation, 37.65° C.

Temperature 20 minutes later, 37° C.

Each stimulation lasted one minute.

Point of stimulation.	Temperature.	Region.
E 14	36.9° C.	} Internal capsule
C 14	36.8° C.	
O 14	36.75° C.	} Putamen
—B 14	36.7° C.	
E 12	36.6° C.	} Nucleus lateralis
C 12	36.6° C.	
O 12	36.5° C.	} Nucleus lateralis ventralis
—B 12	36.45° C.	
E 10	36.4° C.	} Nucleus lateralis
C 10	36.3° C.	
O 10	36.2° C.	} Nucleus lateralis ventralis
—B 10	36.1° C.	
E 8	36.05° C.	} Fornix
C 8	36° C.	
O 8	35.95° C.	} Corpus geniculatum exterior
—B 8	35.9° C.	
E 6	35.75° C.	} Pulvinar
C 6	35.7° C.	
O 6	35.65° C.	} Corpus geniculatum exterior
—B 6	35.6° C.	
E 3	35.5° C.	} Ventricle
C 3	35.5° C.	
O 3	35.4° C.	} Corpus quadrigeminum and pulvinar
—B 3	35.3° C.	

Cat 199. May 12, 1911. Lamella 9.

1.30 P. M. Temperature before operation, 38.9° C.

1.40 P. M. Temperature after operation, 38.27° C.

Each stimulation lasted one minute.

Point of stimulation.	Temperature.	Region.
E 16	38.7° C.	} Internal capsule
C 16	38.65° C.	
A 16	38.6° C.	
—A 16	38.6° C.	} Putamen
E 13	38.6° C.	
C 13	38.6° C.	} Internal capsule
A 13	38.55° C.	
—A 13	38.55° C.	} Putamen
E 10	38.55° C.	
C 10	38.5° C.	} Pulvinar
A 10	38.45° C.	
—A 10	38.45° C.	} Geniculate lateral
E 7	38.4° C.	
C 7	38.4° C.	} Pulvinar
A 7	38.4° C.	
—A 7	38.35° C.	} Cornu ammonis
—C 7	38.3° C.	

Experiment ended at 2.45 P. M. (same day).

Cat 201. May 26, 1911. Lamella 7.

10.40 A. M. Temperature before operation, 37.7° C.

10.50 A. M. Temperature after operation, 37.6° C.

11.00 A. M. Temperature after operation, 37.8° C.

Each stimulation lasted one minute.

	Point of stimulation.	Temperature.	Region.
	E 15	37.6° C.	} Nucleus caudatus
	C 15	37.5° C.	
	A 15	37.5° C.	
	—A 15	37.5° C.	} Internal capsule
11.20	E 12	37.4° C.	
	C 12	37.35° C.	} Internal capsule
	A 12	37.3° C.	
	—A 12	37.25° C.	} Lateral nucleus
	E 9	37.2° C.	
	C 9	37.15° C.	} Lateral nucleus
	A 9	37.1° C.	
	—A 9	37.05° C.	} Lateral ventral nucleus
	E 5	37.0° C.	
	C 5	37.0° C.	} Cornu ammonis
	A 5	36.95° C.	
	—A 5	36.925° C.	} Pulvinar
11.45		36.8° C.	
12.05	Experiment ended	36.3° C.	

Cat 203. June 1, 1911. Lamella 5.

10.50 A. M. Temperature before operation, 37.8° C.

11.00 A. M. Temperature after operation, 38.0° C.

11.15 A. M. Temperature after operation, 37.2° C.

Each stimulation one minute unless otherwise mentioned.

Point of stimulation.	Temperature.	Region.		
30 seconds	E 15	37.05° C.	} Nucleus caudatus	
	C 15	37.0° C.		
	A 15	37.0° C.	} Internal capsule	
	-A 15	37.0° C.		
	E 12	36.95° C.	} Nucleus anterior	
	C 12	36.85° C.		
	A 12	36.75° C.	} Median nucleus	
	-A 12	36.7° C.		
	E 8	36.65° C.	} Pulvinar	
	C 8	36.6° C.		
	30 seconds	A 8	36.65° C.	} Nucleus lateralis (violent muscular movements)
		-A 8	36.65° C.	
E 4		36.5° C.	} Anterior corpus quadrigeminum	
C 4		36.4° C.		
A 4		36.4° C.	} Commissure of anterior corpus quadrigeminum (violent muscular movements)	
-A 4		36.3° C.		

Experiment lasted about one hour.

DISCUSSION AND SUMMARY.

From what has already been said, it is apparent that changes in respiration and blood pressure may be produced by stimulation of a very large portion of the optic thalamus; that no one region controls these phenomena; that the spleen shows variations in volume only when marked blood pressure changes occur, and that such a change has been observed on stimulation of many places in the thalamus. Furthermore, the regions in the thalamus from which such effects are obtained are those in which the large afferent paths end; namely, the fillet and superior cerebellar peduncle, and a region directly connected with the vagus nucleus. The portions of the thalamus which proved inert to stimulation were those which in our previous investigation also were inactive; namely, the median nucleus, and the upper anterior end of the lateral—the region through which the fibers of the median nucleus pass.

These phenomena are similar in every respect to those observed when an afferent nerve is stimulated. In what has gone before, it has been shown that the respiratory and circulatory changes occurred when one of the sensory paths, or a path running directly to the medullary nuclei governing these functions was stimulated. In explaining these phenomena, therefore, there is no necessity for invoking the existence of special centers.

CONCLUSIONS.

1. There is no center controlling respiration in the optic thalamus, but any changes in respiration observed on stimulation are reflex effects.
2. The blood pressure is not governed by any special center in the thalamus; the changes observed are, as a rule, pressor effects.
3. Changes in pulse rate do not occur from moderate thalamic excitation.
4. There is no center controlling movements of the spleen; all changes are secondary to blood pressure changes.
5. The difference in respiratory effects noted on the stimulation of the thalamus and central grey are in all probability due to the stimulation of different paths going to the medullary centers.
6. The globus pallidus has an entirely different effect on the respiration from the thalamus and hence is connected with a different part of the medullary center.
7. The nucleus caudatus has no connection with the respiratory or circulatory mechanism.
8. The optic thalamus, nucleus caudatus, and nucleus lenticularis contain no centers which on direct stimulation produce changes in temperature.

In conclusion, I wish to express my thanks to Prof. C. G. L. Wolf for his valuable advice and helpful suggestions in the course of this investigation.

KEY TO FIGURES 1-6.

- ST = make and break of current.
- T = time marker.
- C = Blood pressure.
- R = Respiration.
- S = Splenic curve.

Figures 8-11 are furnished to show the sections of brains that have been stimulated in the various lamellae.

KEY TO FIGURES 8-12.

- ACQ = Anterior corpus quadrigeminum.
 CG = Central grey.
 F = Fillet.
 FL = Fibers of Lancisi.
 Fo = Fornix.
 GH = Ganglion habenulae.
 GP = Globus pallidus.
 IC = Internal capsule.
 My = Meynert's bundle.
 NA = Nucleus anterior.
 NC = Nucleus caudatus.
 NL = Nucleus lateralis.
 NLV = Nucleus lateralis ventralis.
 NM = Nucleus medius.
 NR = Nucleus reuniens.
 PC = Posterior commissure.

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EXPLANATION OF PLATES.

PLATE 38.

FIG. 1. Normal splenic curve. The lack of response upon stimulation of the fibers of Lancisi (G 12). The increase in respiratory change as the nucleus lateralis ventralis is approached (—B 12).

FIG. 2. Inspiratory inhibition upon globus pallidus stimulation. The circulation and spleen are unaffected.

PLATE 39.

FIG. 3. Normal splenic curve. Inert nucleus medius (C 10, O 10). Inspiratory inhibition from nucleus reuniens stimulation (—B 10). The same result is observed upon stimulation of the posterior commissure.

FIG. 4. Resemblance between hypothalamic stimulation (—B 8) and the globus pallidus (figure 2).

FIG. 5. Fornix (C 4), negative on stimulation. Fillet (O 4), great sensitiveness of this region; note the difference of the respiratory effect here and in figure 2.

PLATE 40.

FIG. 6. Great sensitiveness of the central grey (O 3, —A 3, —B 3). The first and third —A 3 show the result of subminimal current. Good normal spleen curve.

FIG. 7. Respiratory and circulatory changes from corpora quadrigemina, Türk's bundle, and the descending fifth root.

PLATES 41 TO 43.

FIGS. 8-12. Photographs showing the course of the needle track and the various anatomical points stimulated.

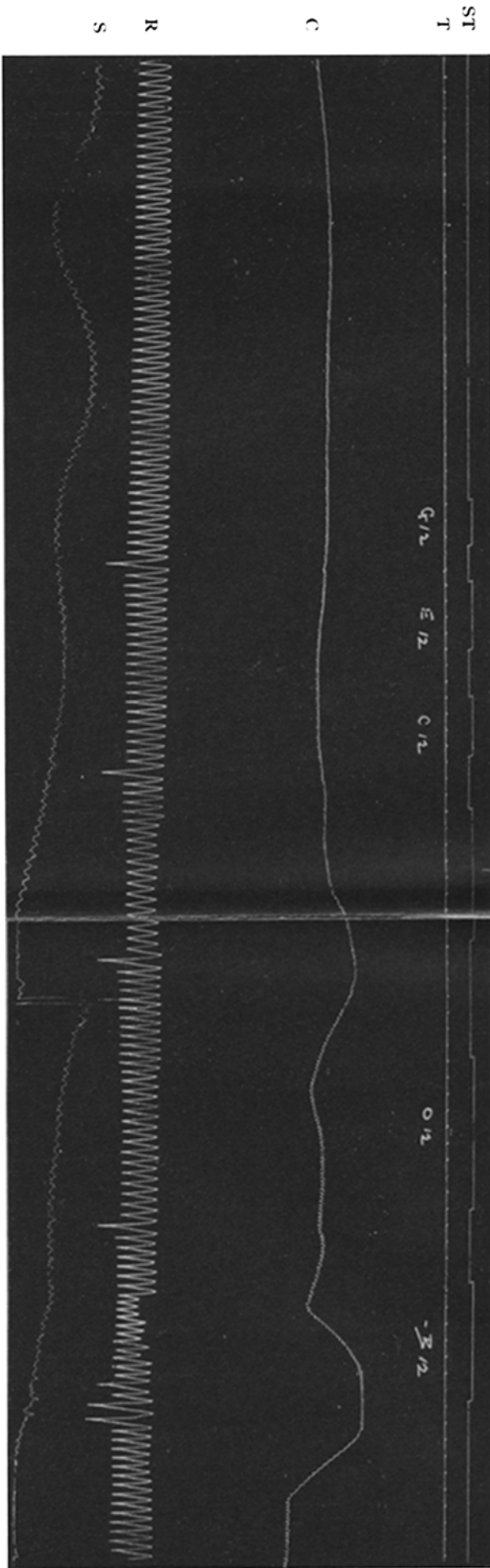


FIG. 1.

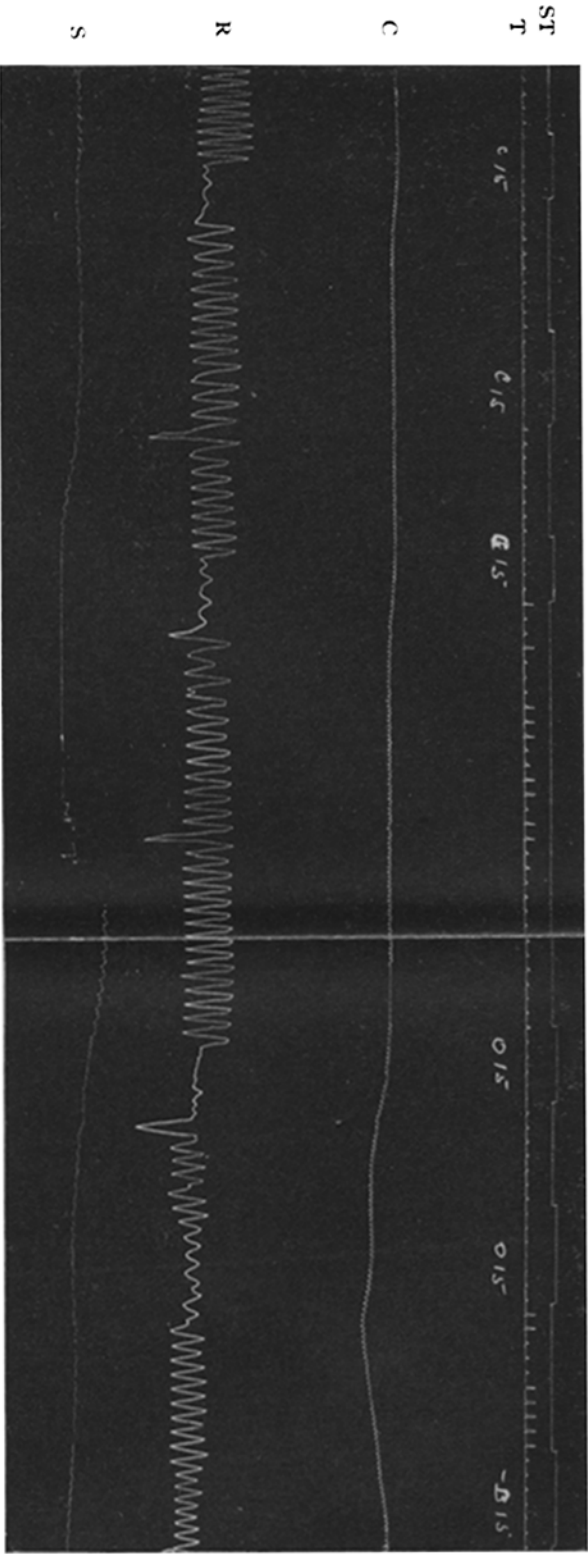


FIG. 2.

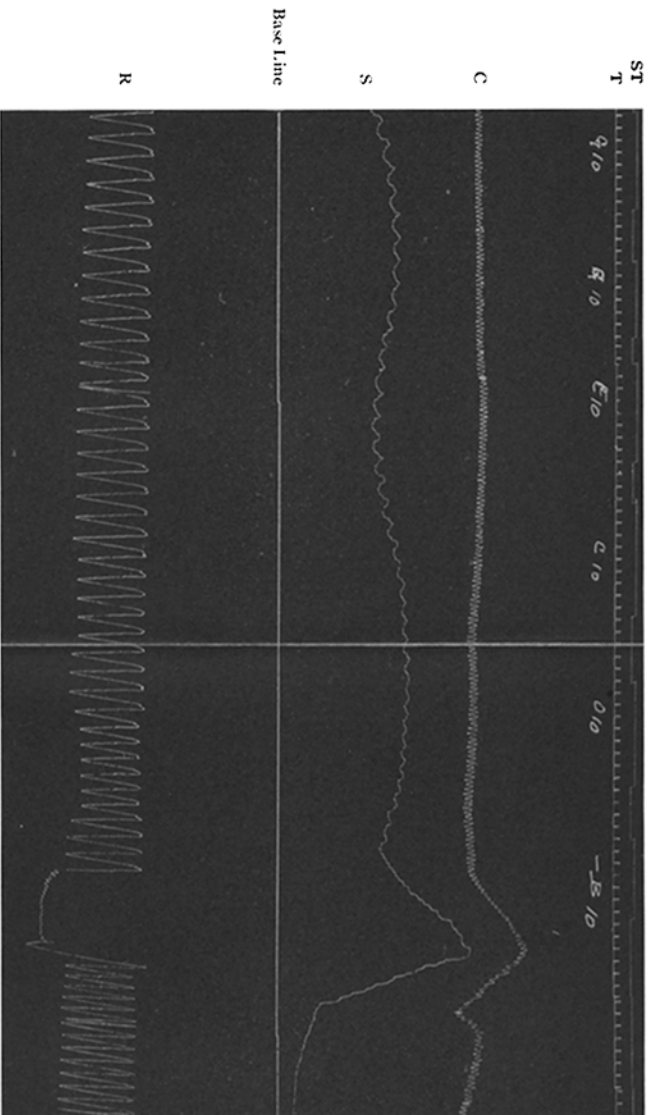


FIG. 3.

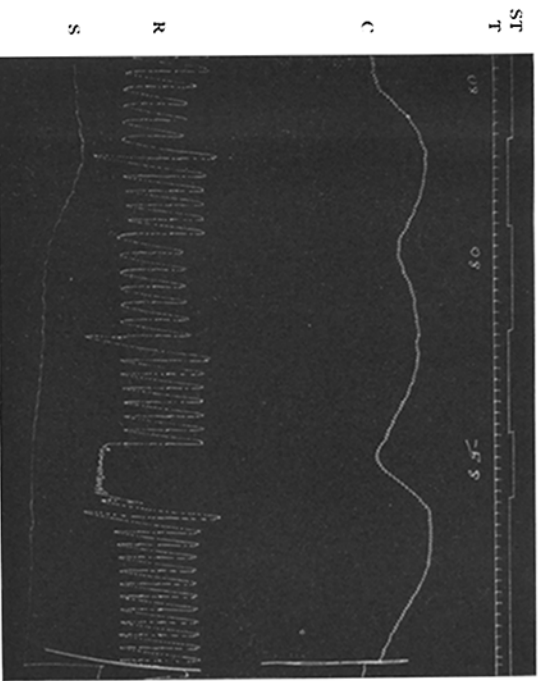


FIG. 4.

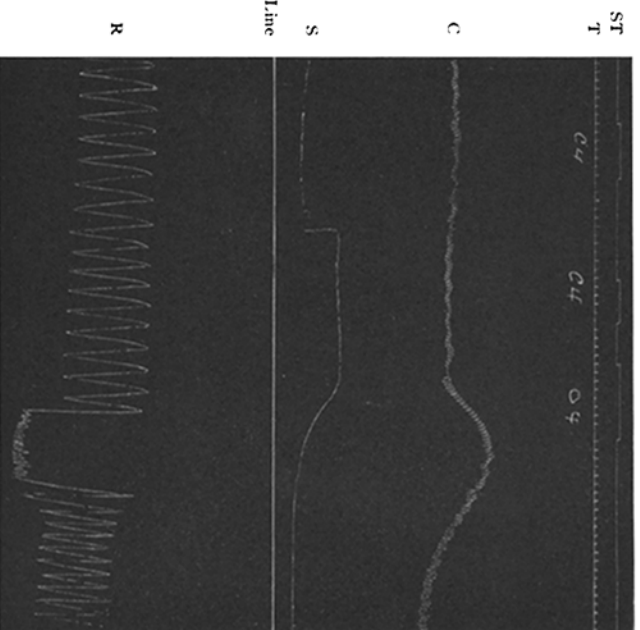


FIG. 5.

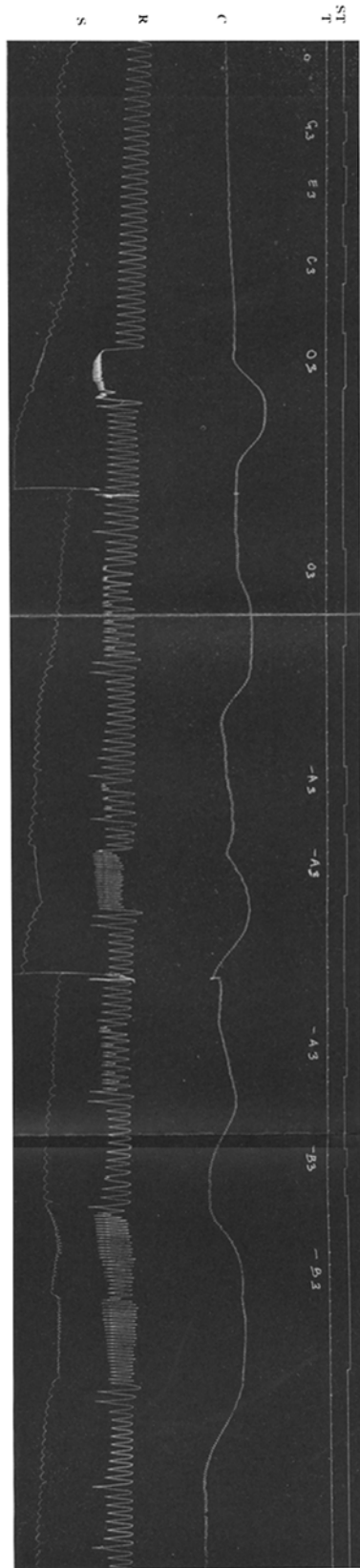


FIG. 6.

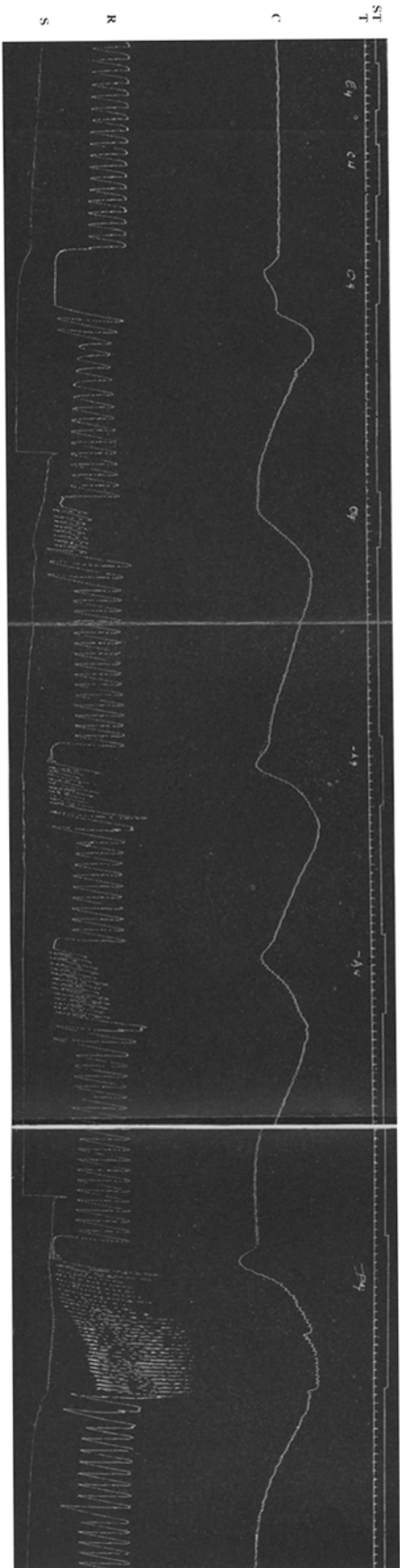


FIG. 7.

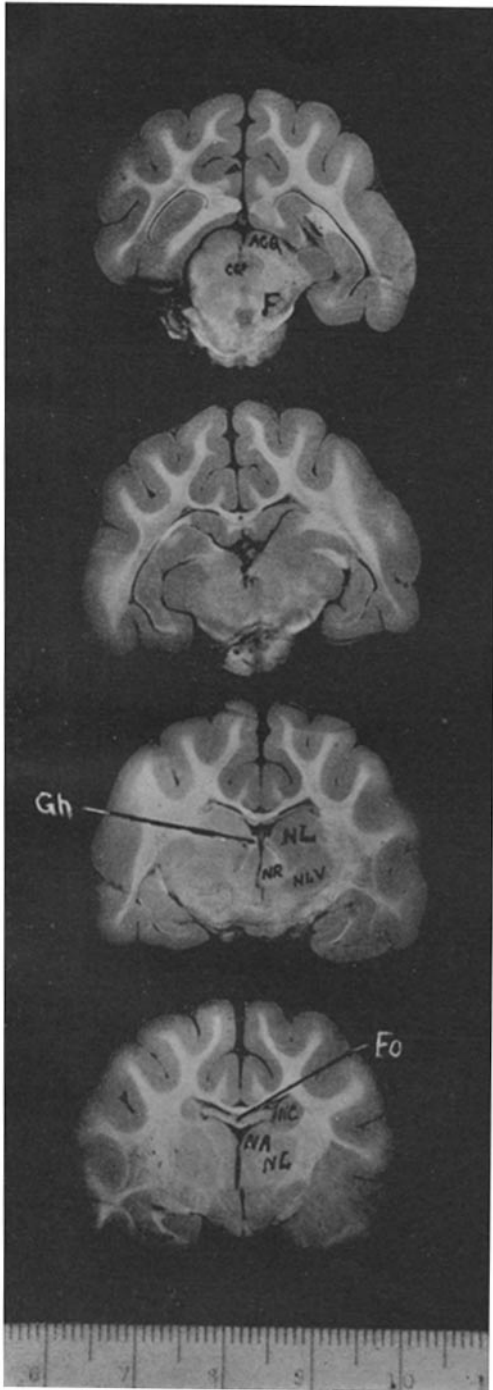


FIG. 8.

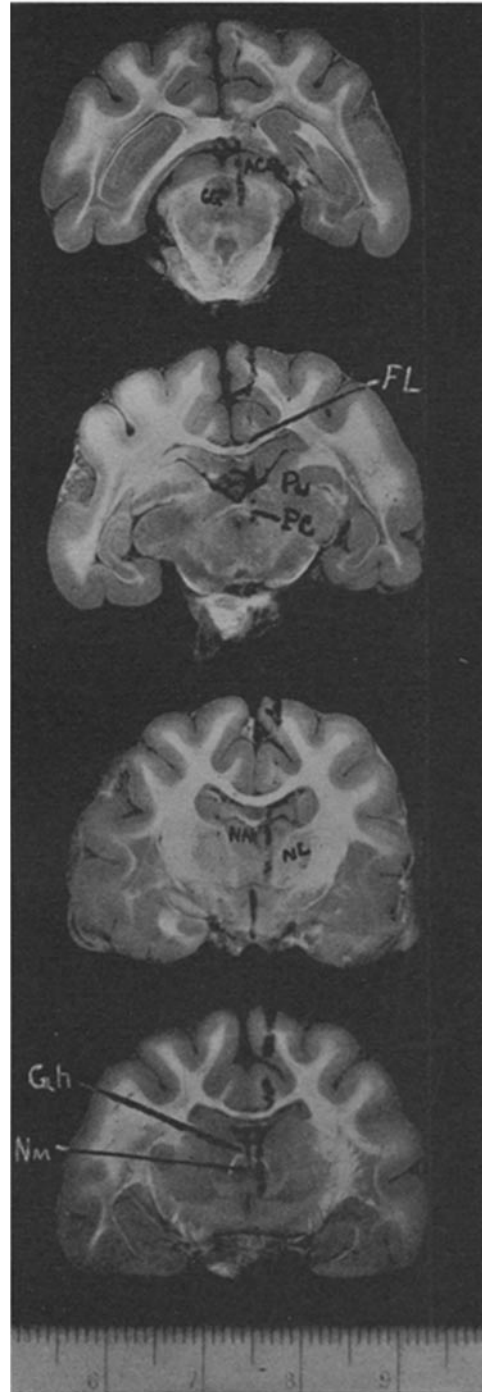


FIG. 9.

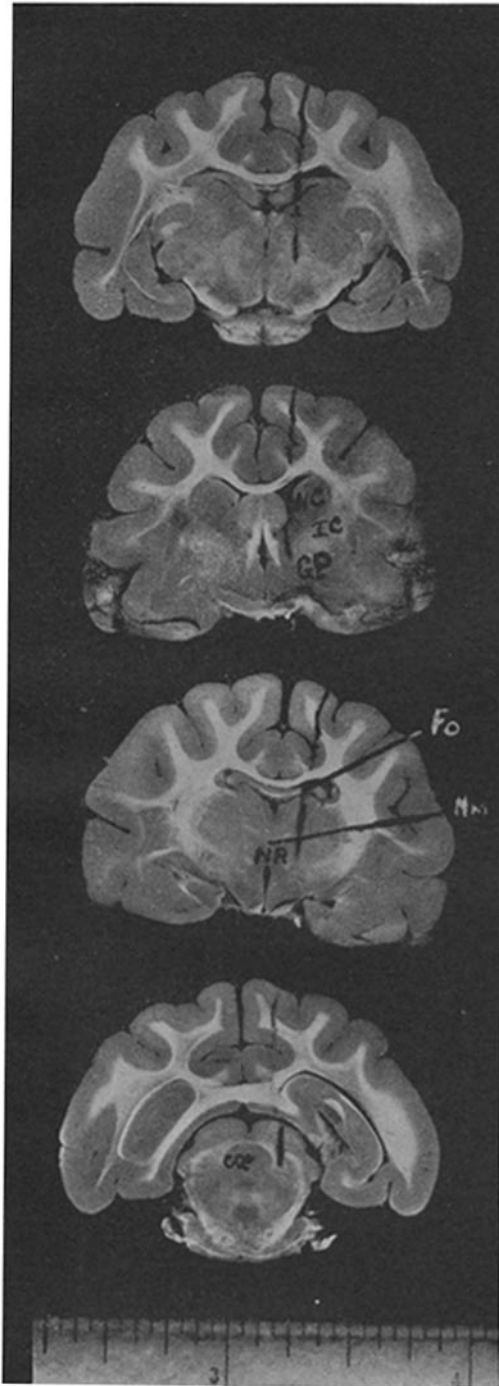


FIG. 10.

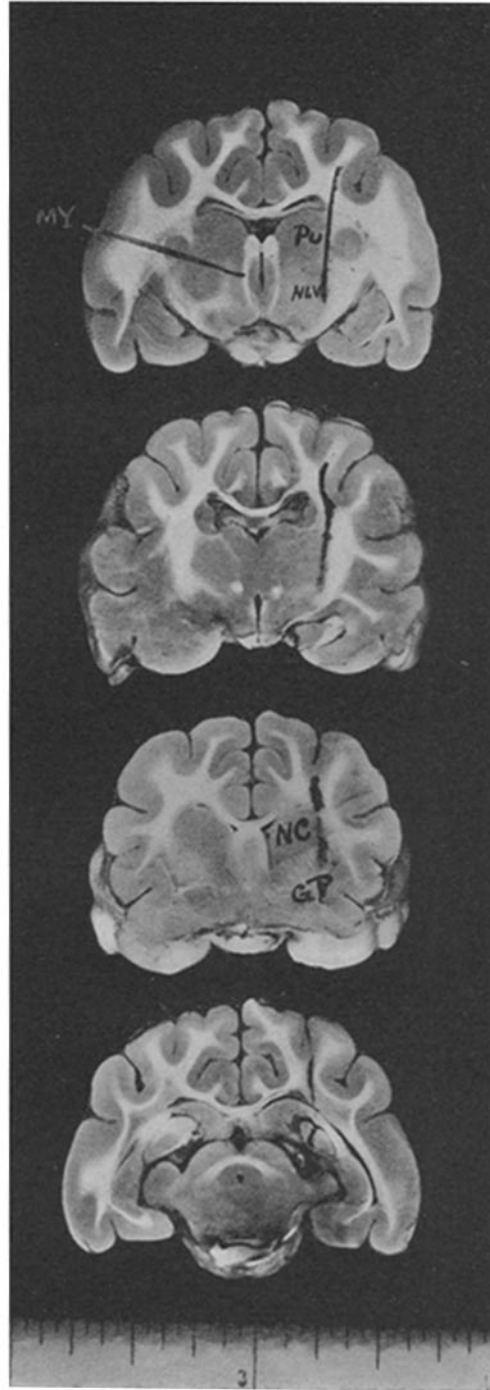


FIG. 11.

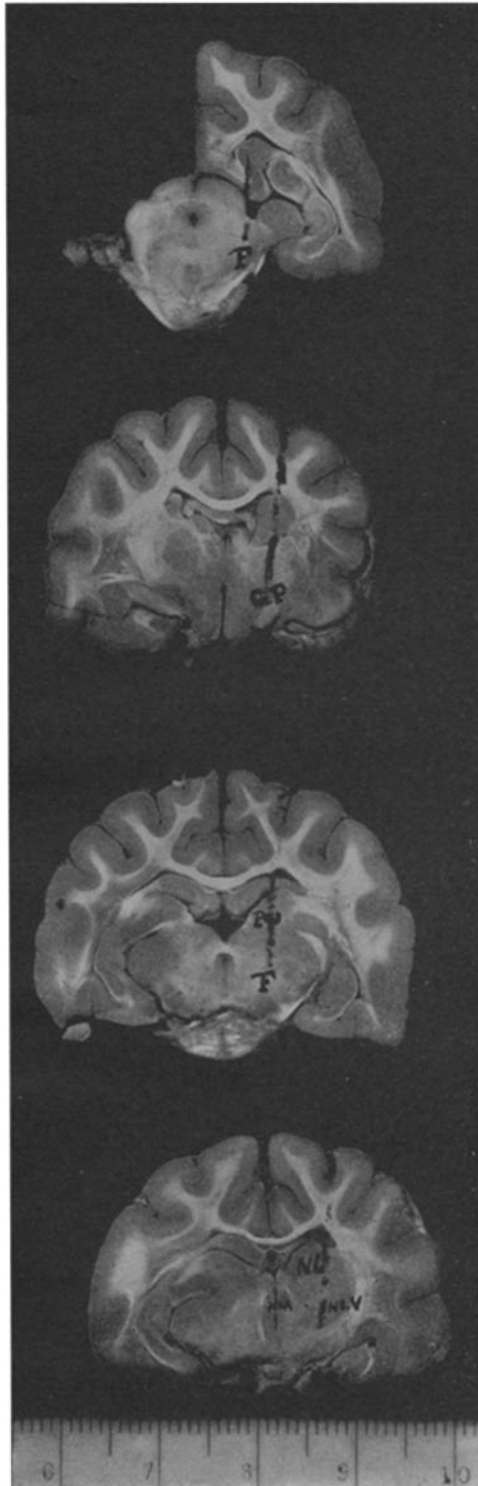


FIG. 12.