THE DIRECT STIMULATION OF THE RED NUCLEUS IN CATS.*

By

W. R. INGRAM, S. W. RANSON AND F. I. HANNETT, CHICAGO.

THE results obtained by direct stimulation of the mesencephalic tegmentum as described by a number of workers have been remarkably uniform. Stimulation with faradic current gives rise to a typical, though peculiar, reaction pattern whose salient features are turning of the head and curvature of the spinal column so that the concavity is toward the side stimulated, together with tonic flexion of the ipsilateral fore-limb and extension of the contralateral fore-limb. The hind-limbs may offer varying responses: flexion of both, or flexion of the contralateral and extension of the ipsilateral; they may also be swung toward the stimulated side. The reaction is essentially a homolateral one, in contrast with that obtained by stimulating the pyramidal tracts in the basis pedunculi, where the response is contralateral and marked by the absence of after-discharge.

The older workers obtained their results by applying electrodes to the cut surface of the brain-stem in decerebrate animals, attempting visually to locate the various foci from which this tegmental response could be elicited. Although the literature has been reviewed in previous communications (Hinsey, Ranson and Dixon¹, Ingram, Ranson, Hannett, Zeiss and Terwilliger²), it may be pointed out that Thiele³ located such a focal point ventrolateral to the medial longitudinal fasciculus and Brown⁴ attributed the response at first to the medial longitudinal fasciculus, then to the red nucleus, although his figure would indicate that his red nucleus area was really the region of the central tegmental fasciculus. Hinsey, Ranson and Dixon¹ marked the focal point by inserting a bristle into the substance of the brain-stem and decided after microscopic examination that the red nucleus was the spot in question. Such experiments have been performed by several workers under varying conditions, their main common feature being that in every case decerebrate animals were used, in which a definite localization of stimulated points was necessarily difficult. The present writers therefore initiated a series of investigations using methods whereby the interior of the intact brain could be stimulated, and by which the points at which the stimuli were applied could be determined microscopically. The results of the first series of these experiments have already been reported². The interior of the tegmentum was explored millimetre by millimetre from points

* From the Institute of Neurology, Northwestern University Medical School, Chicago.

well forward in the subthalamus to as far posterior as the trapezoid body, and the responses to stimulation carefully noted. It was concluded that the so-called typical tegmental response can be obtained 'from the caudal part of the subthalamus in the region of the anterior capsule of the red nucleus, from the reticular formation of the tegmentum dorsal and lateral to the red nucleus, including the central tegmental fasciculus, and caudal to the red nucleus from almost anywhere in the reticular formation back to the caudal part of the pons, where its foci seem to shift laterally until at the level of the trapezoid body they appear to lie ventrally and laterally in the neighbourhood of the rubrospinal tracts.' The red nucleus apparently did not give the response in these animals. However, since the number of cases in which the electrodes reached this cell group was relatively small, it was decided to gather more data in a special effort to determine finally whether or not the red nucleus was directly concerned in the reaction.

METHOD.

The general details of the means of approach used in these investigations have been described in another paper. The importance of using the proper sort of electrodes, however, must be emphasized, since one must confine the stimulation to a definite small area, eliminate any possibility of spread of current, and accomplish this with a minimum of trauma. The needle electrodes used were constructed of enamelled nichrome wires of 22 and 28 gauge (U.S. standard), drawn out so as to be perfectly straight, and cemented together and reinsulated with chlorinated rubber solution. The tips of these were ground to a point suitable for facilitating penetration, the needle being sufficiently stiff to pass through the dura without significant deviation from its pathway. Its diameter was less than one millimetre, and when the tips of the wires were properly adjusted the points of this bipolar electrode were within a millimetre of one another. These needles were oriented and directed by use of the Horsley-Clarke stereotaxic instrument, a complete description of which may be found in these authors' paper⁵ of 1908. Essentially, this apparatus is a device which, when fastened to the head of an experimental animal, makes possible the placing of electrodes at points in the interior of the brain at any desired distance and direction from a fixed central zero point, eliminating the use of external structures for orientation. A needle so fixed is held firmly and cannot be dislodged by any movement of the animal which may result from stimulation. The stimulating current was supplied through a Harvard inductorium connected with a dry cell furnishing about 1.5 ampères. A minimal stimulus for the response under consideration was secured with a coil separation of 13 cm. and obliquity of 45 degrees, this setting being retained in all the experiments.

The anæsthetic used was ether, which permits a greater control of the depth of anæsthesia than the non-volatile narcotics now in common use.

Following anæsthetization of the cat the calvarium was quickly opened, without cutting the dura, and the stereotaxic instrument adjusted. The animal was then placed in a hammock through which the legs protuded and the instrument suspended in such a way as to permit free swinging of the head from side to side. The needle electrode could now be inserted, through the dura, at any point and to any depth into the brain-stem. In earlier experiments, as reported, a large area was explored with stimuli applied at one-millimetre intervals, this area extending usually from 2 millimetres to the right of the mid-line as far as 5 millimetres laterally, and for varying distances rostro-caudally. In this way the greater part of the tegmentum was covered, but in the majority of cases the mesial boundary of this region was just at the lateral edge of the red nucleus. Since this was the structure especially under consideration in the present series of experiments only 2 rows of punctures were made, one at 1.5 millimetres and the other at 3 millimetres from the mid-line; in each of these rows the needle was inserted repeatedly at one-millimetre intervals, the first puncture being 4 or 5 millimetres anterior to a line drawn between the two external auditory meatus and the last being placed on this line. As the needle penetrated the substance of the brain-stem stimulations were applied at intervals of one millimetre beginning at a level approximating the boundary between the tectum and tegmentum and proceeding ventrally for, usually, 8 millimetres. The innermost of the two rows of punctures insured striking the red nucleus, while the outer one brought the electrodes into the regions from which typical responses had been obtained in the experiments previously reported. The responses elicited at each point of stimulation were carefully noted and recorded with reference to the setting of the instrument at that particular time.

At the conclusion of the experiment the animal was immediately killed by bleeding and the head injected with 10 per cent. formalin. The brain was then removed and when sufficiently hardened by immersion in formalin the portion of the brain-stem which had been explored was imbedded in celloidin. Sections were cut approximately parallel to the plane of the needle punctures and stained by Weil's method and with iron hæmatoxylin. It was then possible, since the track of the needle was visible in the section and the position of each stimulation was known with reference to the scales upon the Horsley-Clarke instrument, to identify the structures which had been stimulated as the needle was pushed ventrally through the brain-stem.

OBSERVATIONS.

As has been demonstrated, the chief elements of the response pattern under consideration are: a turning of the head toward the stimulated side, a curving of the back so that a concavity is presented toward the side stimulated, and flexion of the ipsilateral fore-limb. This response may be

somewhat modified in various ways and certain other responses superimposed upon it. In some cases the neck may be drawn toward the side on which the stimulus is applied, while the head is tilted so the face may be turned to some extent in the opposite direction. There may be an extension of the contralateral fore-limb, although this is apparently more frequent in decerebrate animals whose condition favours an increase in extensor tonus. The hind-limbs, as mentioned above, may offer varying responses, both may be flexed or swung toward the stimulated side, or the ipsilateral one extended and the contralateral one flexed. A number of other reactions may also be brought in: cries, erection of hairs, contraction of the facial and masticator muscles, movements of the nictitating membranes, and dilatation of the pupils. The latter phenomenon has been made the subject of a separate communication (Ingram, Ranson and Hannett⁶). Other atypical responses which may also be mentioned are: flexion of the contralateral fore-limb, swinging of the hind-limbs contralaterally, constriction of the pupils, spreading of the digits, cessation of respiration, acceleration of respiration, urination, movements of the eyes. There was also some variation in the intensity and extent of the response in different individuals, some of which may be accounted for by the depth of anæsthesia or shock, while in certain cases no adequate reason could be assigned for the lack of responsiveness. In others a marked hyperactivity leading to the production of exaggerated responses was equally unaccountable. Two of the 21 animals discussed here were unresponsive and are necessarily removed from consideration. Each of the remaining cats gave typical responses from stimulation of the various parts of the reticular formation of the tegmentum.

In each of these cases microscopic examination showed the red nucleus to have been stimulated in several places. It may be said at this point that while in a number of instances slight turning of the head was evidenced upon stimulation at the borders of the nucleus, in only one case was anything like a typical response obtained, and that from a point at its rostral pole where undoubtedly fibres of the ventral part of the reticular formation were also stimulated. Conclusive evidence of the failure of the red nucleus to participate in the typical response as obtained in animals with intact brains is presented in the accompanying table (Table 1). Such responses as were brought forth are indicated, and the absence of typical responses may be seen by a glance at the first six columns, where the occurrence of the components of the reaction would have been marked by crosses if the reaction had been positive. The main features of such responses as were obtainable from this region were dilatation of the pupils and a tendency towards contraction of the circumorbital muscles of one or both sides. There were also movements of the nictitating membranes and various eye movements, due no doubt to involvement of the third nerve.

Typical responses could in each case be obtained elsewhere in the tegmentum, as shown by Table 2. Effort was made to control the depth of anaesthesia so that the animal would be no more deeply under when the red nucleus was stimulated than when areas lateral to it were being explored. In most instances typical responses could be elicited at the same rostro-caudal level as the red nucleus, but farther lateral, and, usually, dorsal to it. These reactions arose from the various zones of the reticular formation as elucidated in the previous paper, the dorsal and middle lateral areas predominating, and from the region of the central tegmental fasciculus.

DISCUSSION.

The reaction pattern established in our experiments on cats with intact forebrains is essentially the same as that obtainable from decerebrate preparations. The chief difference from the work of certain investigators lies in the location of the focal areas. It is difficult to exclude the possibility of spread of current when the electrodes are placed against a more or less damp, cut surface. In the present work, however, it may well be believed that current escapes have been adequately controlled. The insulation of the needles and the condition of their bare tips were carefully examined and tested in each experiment, and the amount of current used reduced to a minimum. Contralateral pyramidal responses were only obtained when the electrodes were in or in very close proximity to the cerebral peduncle. If there had been significant escape such responses would have occurred while the needle tip was still at some distance from this structure. In this connection it is interesting to consider cat 188. In this case stimuli at various vertical levels 4 and 5 millimetres rostral to the interaural plane affected the red nucleus at several points without causing typical responses. Stimuli at the same levels but in the central tegmental fasciculus region or the reticular formation did give such reactions. At 3 millimetres anterior to the interaural plane, however, stimulation of the caudal pole of the red nucleus gave a definite turning of the head and flexion of the ipsilateral fore- and contralateral hind-limbs. At this same level typical responses became exceptionally frequent elsewhere and were obtainable even from the central gray and medial longitudinal fasciculus. This circumstance was rather suspicious, since the occurrence of such reactions from stimuli in these areas was contrary to our experience, and the situation was greatly clarified when it was found that on testing the needle at the close of the experiment two or three minute leaks were present along the shaft for a short distance above the tip. Apparently the damage to the electrode occurred at this stage of the experiment and proved to be readily detectable in the light of the microscopical examination correlated with previous experiences unaffected by faulty apparatus.

Although the red nucleus has been assigned a function in the regulation of tonus-distribution, it could probably not without reason be assumed to have a motor function. However, a supposition that the impulses causing the reactions which have been discussed arise in the red nucleus would seem to necessitate the presence of a homolateral descending rubral pathway, and the existence of such a bundle has never been definitely established. The crossed rubrospinal tract is eliminated from consideration by the experiments of Brown⁴, Környey⁷, and Hinsey, Ranson and Dixon¹, in which the rubrospinal path was severed in the decussation of Forel. There may, of course, be short connections of the red nucleus with the cells and fibres of the reticular formation, and it has been suggested that the further conducting pathway might be the reticulospinal tract. It may be, as was intimated in our previous communication, that the presence of the intact forebrain makes a crucial difference in these experiments, that stimulation of the red nucleus itself may give rise to ascending impulses which could cause inhibitory discharges affecting the nucleus, which did not come into play when the extra-rubral foci were stimulated.

It seems somewhat more logical, however, that this response pattern is the particular manifestation of the areas of the reticular formation of the tegmentum. The significance of the peculiar series of muscular responses is not as yet clear, except as one considers them to be evidence of the persistence of pathways for an ancient reaction type which, while not ordinarily in use in adult mammals of the higher orders, may yet be aroused by direct stimulation. Whatever may be its function, the present experiments give further evidence that the typical tegmental response does not originate in the red nucleus, but rather that its manifestation should be ascribed to the diffuse nuclei and pathways of the reticular formation of the midbrain and pons.

SUMMARY.

The Horsley-Clarke stereotaxic instrument with a bipolar electrode and a weak faradic current was used to stimulate the red nucleus in cats. Although in the same experiments stimulation of the tegmentum dorsal and lateral to the red nucleus caused the typical tegmental response, consisting chiefly of curving of the back and neck with concavity toward the stimulated side, associated with flexion of the ipsilateral fore-limb, this response was not obtained from the red nucleus itself. Contrary to the opinion of most previous investigators, the results of these experiments indicate that the red nucleus is not the focal point for this reaction, which should rather be ascribed to the reticular formation of the tegmentum where the cells and fibres concerned with it are scattered rather diffusely. As shown in another communication typical responses may be elicited from most parts of the tegmentum, of the mesencephalon and pons excepting the part occupied by the red nucleus. Toward the caudal end of the pons the dorsal and medial parts of the tegmentum also fail to yield the response.

SYMBOLS USED IN TABLES 1 AND 2.

- 1—Head turns to side stimulated.
- 2—Trunk curves, concavity toward side stimulated.
- 3—Flexion of ipsilateral fore-limb.
- 4—Extension of contralateral fore-limb.
- 5—Flexion of the hind-limbs.
- 6—Hind-limbs swing toward stimulated side.
- 7—Head turns away from stimulated side.
- 8—Flexion of contralateral fore-limb.
- 9—Contraction of facial or masticator muscles.
- 10—Acceleration of respiration.
- 11—Dilatation of the pupils.
- 12—Eye movements.
- +—Positive response.
- ±—Slight positive response.

Movements belonging particularly to the typical tegmental response are indicated in the first six columns of Table 1.

Position of electrodes according to coordinates of the instrument: A=number of millimetres rostral to the interaural plane; L=number of millimetres to the right of the midline; H=number of millimetres below the zero horizontal plane.

TABLE I.
STIMULATION OF THE RED NUCLEUS. SERIES B.

Cat	Location	Remarks	5										11		
			1	2	3	4	R	L	6	7	8	9	10	R	L
175	A 4, L 3, H 5 ...	Lateral border ...	...	±										+	+
	A 3, L 1·5, H 4 ...	Medial dorsal border ...	...	±	±									+	+
	A 3, L 1·5, H 5 ...	Medial third ...	...								+			+	+
176	A 4, L 1·5, H 3 ...	Dorsal part ...	...											±	±
	A 4, L 1·5, H 4·5 ...	Main part ...	...											±	±
	A 3, L 1·5, H 3 ...	Dorsal border ...	...				?			+				+	+
	A 3, L 1·5, H 4·5 ...	Lateral part ...	...	+			?							+	+
177	A 4, L 1·5, H 5 ...	Main part ...	...												+
	A 4, L 1·5, H 6 ...	Main part ...	...												+
	A 3, L 1·5, H 5·6 ...	Posterior part ...	...									+		±	±
178	No stimuli in Red Nucleus gave typical tegmental responses.														
179	A 4, L 1·5, H 4 ...	Dorsal border ...	...										±		
	A 4, L 1·5, H 5·6 ...	Main part ...	...										±	+	+
	A 3, L 1·5, H 6 ...	Most posterior cells ...	...												+

F

Cat	Location	Remarks	1	2	3	4	5		6	7	8	9	10	11		12
							R	L						R	L	
180	A 4, L 1·5, H 6 ...	Main part ...	...									+		+	+	
	A 4, L 1·5, H 7 ...	Main part ...	...											±	±	
181	A 4, L 1·5, H 4 ...	Dorsal border ...	...									±		+	+	
	A 4, L 1·5, H 5 ...	Main part ...	...									±		+	+	
	A 4, L 1·5, H 6 ...	Main part ...	...													
	A 4, L 3, H 4 ...	Lateral border ...	...											±	±	
	A 4, L 3, H 5 ...	Lateral border ...	...											±	±	
	A 3, L 1·5, H 4 ...	Dorsal border ...	...									±		+	+	
	A 3, L 1·5, H 5 ...	Post. and lat. parts ...	...									±		+	+	
182	A 4, L 1·5, H 4 ...	Main part ...	...											+	+	
	A 4, L 1·5, H 5 ...	Lateral border, ant. part ...	...													
	A 3, L 1·5, H 4 ...	Dorsal border ...	...									±		±	±	
	A 3, L 1·5, H 5-6	Main part ...	...									±		±	±	
183	A 4, L 1·5, H 5 ...	Dorsal border ...	...									±		±	±	
	A 4, L 1·5, H 6 ...	Posterior part ...	...									±		±	±	
184	A 4, L 3, H 5 ...	Med. part. Cat unresponsive ...										±		+	+	
185	A 4, L 1·5, H 4 ...	Dorsal border ...	...											+	+	
	A 4, L 1·5, H 5-6	Main part ...	...											±	±	
186	A 5, L 1·5, H 5-6	Med. border. Cat unresponsive										+				
	A 5, L 3, H 4 ...	Lateral half ...	...													
	A 5, L 3, H 5 ...	Lateral half ...	...									+				
	A 4, L 1·5, H 5-6	Medial border ...	...									+				
	A 4, L 3, H 5-6	Lateral cells ...	...													
187	A 5, L 1·5, H 5-6	Medial part ...	...									+		+	+	
	A 4, L 1·5, H 5 ...	Dorsal part ...	...									+		+	+	
	A 4, L 1·5, H 6 ...	Main part ...	...									+		+	+	
	A 3, L 1·5, H 5 ...	Posterior end ...	...									±		+	+	
	A 3, L 1·5, H 6 ...	Ventral border ...	...									±		+	±	

Cat	Location	Remarks					5		11							
			1	2	3	4	R	L	6	7	8	9	10	R	L	12
188	A 5, L 1·5, H 5 ...	Dorsal border ...	...	...										+	+	
	A 5, L 1·5, H 6 ...	Main part ...	...	...										+	+	
	A 5, L 3, H 5 ...	Dorso-lateral part ...	...	+										+	+	
	A 5, L 3, H 6 ...	Main part ...	...	...										+	+	
	A 4, L 1·5, H 5 ...	Dorsal part ...	...	...										+	+	
	A 4, L 1·5, H 6 ...	Main part ...	...	...										+	+	
	A 4, L 3, H 5·6 ...	Lateral part ...	...	...										+	+	
	A 3, L 1·5, H 6 ...	Posterior pole* ...	...	+	+		+					+	+	+	+	

* Leaks in needle.

STIMULATION OF THE RED NUCLEUS. SERIES A.

136	A 3, L 2, H 5·6 ...	Rostral cells ...	...	+				+			+			+	+	
	A 2, L 2, H 5 ...	Includes vent. retic. form.	...	+	+	+					+			+	+	
169	A 4, L 1, H 5 ...	Medial border ...	...											+	+	+
	A 4, L 1, H 6 ...	Ventromedial border	...											+	+	
170	A 5, L 1, H 5·6 ...	Medial part ...	...													+
	A 3, L 1, H 5·6 ...	Med. edge of post. part	...	?										+	+	+
171	A 4, L 1·5, H 5 ...	Main part ...	...											+	+	+
	A 4, L 1·5, H 6 ...	Ventral part ...	...											+	+	+
172	A 5, L 1·5, H 5 ...	Rostral part ...	...											+	+	+
	A 5, L 1·5, H 6 ...	Main part ...	...											+	+	+
	A 5, L 1·5, H 7 ...	Ventral part ...	...											+	+	+
	A 3, L 1·5, H 6 ...	Main part ...	...											+	+	
	A 3, L 1·5, H 6 ...	Ventral part ...	...											+	+	
173	A 4, L 1, H 5 ...	Medial border ...	...													
	A 4, L 1, H 6 ...	Main part ...	...													
174	A 3, L 1·1·5, H 5	Anterior cells ...	...	+										+	+	
	A 3, L 1·1·5, H 6	Main part ...	...								?	+		+	+	

All gave typical responses at other points. See Table 2.

TABLE 2.
TYPICAL TEGMENTAL RESPONSES OBTAINED IN EXPERIMENTS 175-188.

Cat	Location	Region
175	A 3, L 3, H 2 ...	Central tegmental fasciculus.
	A 3, L 3, H 3 ...	Reticular formation (middle).
	A 3, L 3, H 4 ...	Reticular formation (middle).
	A 3, L 3, H 5 ...	Reticular formation lateral to red nucleus.
	A 2, L 3, H 2 ...	Central tegmental fasciculus.
	A 1, L 1-5, H 4-5 ...	Reticular formation (mid-medial).
	A 1, L 3, H 2-3 ...	Central tegmental fasciculus.
	A 0, L 3, H 2 ...	Central tegmental fasciculus.
	A 0, L 3, H 3 ...	Reticular formation (middle).
	A 0, L 3, H 4 ...	Reticular formation lateral to Br. conj. fibres.
	A 0, L 3, H 5 ...	Reticular formation (ventral).
176	A 4, L 3, H 3-4 ...	Central tegmental fasciculus (lateral).
	A 3, L 3, H 2-3-4 ...	Central tegmental fasciculus (lateral).
	A 2, L 1-5, H 4-5 ...	Reticular formation (ventro-medial).
	A 2, L 1-5, H 6 ...	Reticular formation—Br. conj. region.
	A 2, L 3, H 2-3 ...	Central tegmental fasciculus.
	A 2, L 3, H 4 ...	Reticular formation (middle).
	A 1, L 1-5, H 4-5 ...	Reticular formation (mid- and ventro-medial).
	A 1, L 1-5, H 6-7 ...	Reticular formation—Br. conj. region.
	A 1, L 1-5, H 8 ...	Reticular formation (ventro-medial).
	A 1, L 3, H 1-2-3 ...	Central tegmental fasciculus (lateral).
	A 1, L 3, H 4-5 ...	Reticular formation (middle).
177	A 3, L 3, H 3 ...	Reticular formation (dorsal).
	A 2, L 3, H 1 ...	Central tegmental fasciculus.
	A 1, L 3, H 0-1 ...	Central tegmental fasciculus.
	A 1, L 3, H 2 ...	Reticular formation (dorsal).
	A 0, L 1-5, H 1-2-3-4 ...	Central tegmental fasciculus (lateral).
	A 0, L 3, H 0-1 ...	Central tegmental fasciculus (lateral).
179	A 2, L 3, H 0-1-2 ...	Central tegmental fasciculus.
	A 1, L 1-5, H 0 ...	Central tegmental fasciculus.
	A 1, L 1-5, H 2-3 ...	Central tegmental fasciculus.
	A 1, L 1-5, H 4 ...	Reticular formation—Br. conj. region.
	A 1, L 3, H 0-1-2-3 ...	Central tegmental fasciculus.
	A 0, L 1-5, H 1-2 ...	Central tegmental fasciculus.
	A 0, L 1-5, H 3-4 ...	Reticular formation—Br. conj. region.
	A 0, L 3, H 0-1-2 ...	Central tegmental fasciculus.
	A 0, L 3, H 3-4 ...	Reticular formation (middle).

Cat	Location	Region
180	A 2, L 3, H 2 ...	Lateral tegmental nucleus region.
	A 2, L 3, H 3 ...	Reticular formation (dorso-lateral).
	A 1, L 3, H 1-2 ...	Reticular formation (dorso-lateral).
	A 1, L 3, H 3 ...	Reticular formation—Br. conj. region.
	A 0, L 3, H 2-3 ...	Reticular formation (dorso-lateral).
181	A 3, L 3, H 1 ...	Central tegmental fasciculus.
	A 1, L 1-5, H 3 ...	Reticular formation—Br. conj. region.
	A 1, L 3, H 0-1-2 ...	Reticular formation (dorso-lateral).
	A 0, L 1-5, H 0-1-2-3 ...	Central tegmental fasciculus.
	A 0, L 3, H 0-1 ...	Central tegmental fasciculus.
182	A 3, L 3, H 3-4-5 ...	Reticular formation (dorsal and mid-lateral).
	A 2, L 3, H 1-2-3 ...	Central tegmental fasciculus.
	A 1, L 3, H 1-2 ...	Central tegmental fasciculus.
	A 1, L 3, H 3 ...	Reticular formation (dorso-lateral).
	A 0, L 1-5, H 1-2 ...	Central tegmental fasciculus.
	A 0, L 1-5, H 3 ...	Reticular formation (dorso-medial).
	A 0, L 3, H 1-2-3-4 ...	Reticular formation (dorsal and mid-lateral).
183	A 3, L 1-5, H 2 ...	Central tegmental fasciculus.
	A 3, L 3, H 3 ...	Reticular formation (dorso-lateral).
	A 2, L 1-5, H 1-2-3 ...	Central tegmental fasciculus.
	A 2, L 1-5, H 4 ...	Reticular formation (mid-medial).
	A 2, L 3, H 0-1-2 ...	Central tegmental fasciculus.
	A 2, L 3, H 3 ...	Reticular formation—Br. conj. region.
	A 0, L 1-5, H 4 ...	Reticular formation (mid-medial).
	A 0, L 3, H 3-4 ...	Reticular formation (mid-lateral).
185	A 3, L 3, H 1-2 ...	Central tegmental fasciculus.
	A 2, L 1-5, H 4 ...	Reticular formation (mid-medial).
	A 2, L 3, H 1 ...	Lateral tegmental nucleus region.
	A 2, L 3, H 2-3 ...	Reticular formation (dorso-lateral).
	A 1, L 1-5, H 1 ...	Reticular formation (dorso-medial).
	A 1, L 1-5, H 3-4 ...	Reticular formation (mid-medial).
	A 1, L 3, H 1 ...	Lateral tegmental nucleus region.
	A 1, L 3, H 2-3-4 ...	Reticular formation (dorsal and mid-lateral).
187	A 3, L 3, H 1-2 ...	Reticular formation (dorso-lateral).
	A 3, L 3, H 3-4-5 ...	Reticular formation (middle and ventro-lateral).
	A 2, L 1-5, H 3-4 ...	Reticular formation (mid-medial).
	A 2, L 3, H 0-1-2 ...	Reticular formation (dorso-lateral).
	A 2, L 3, H 3 ...	Reticular formation (mid-medial).

Cat.	Location.	Region.
188	A 5, L 1-5, H 1-2-3 ...	Central tegmental fasciculus.
	A 5, L 1-5, H 4 ...	Reticular formation (mid-medial).
	A 5, L 3, H 1-2 ...	Reticular formation (dorso-lateral).
	A 3, L 1-5, H 1 ...	Central gray (needle leaks).
	A 3, L 1-5, H 2 ...	Medial longitudinal fasciculus (needle leaks).
	A 3, L 1-5, H 3-4-5 ...	Reticular formation dorsal to red nucleus.
	A 3, L 3, H 0-1-2 ...	Central tegmental fasciculus.
	A 2, L 1-5, H 0-1-2-3 ...	Central tegmental fasciculus and central gray.
	A 2, L 1-5, H 5-7 ...	Reticular formation (ventral).
	A 2, L 3, H 0 ...	Central gray.
	A 2, L 3, H 1-2-3 ...	Central tegmental fasciculus.
	A 2, L 3, H 4 ...	Reticular formation (ventro-medial).
	A 1, L 1-5, H 1-2-3 ...	Central tegmental fasciculus.
	A 1, L 1-5, H 4-5 ...	Reticular formation (middle and ventro-medial).
	A 1, L 3, H 0 ...	Central gray.
	A 1, L 3, H 1-2-3 ...	Central tegmental fasciculus.
	A 1, L 3, H 4 ...	Reticular formation (mid-lateral).

REFERENCES.

- ¹ HINSEY, J. C., RANSON, S. W., and DIXON, H. H., *Arch. of Neurol. and Psychiat.*, 1930, xxiv, 966.
- ² INGRAM, W. R., RANSON, S. W., HANNETT, F. I., ZEISS, F. R., and TERWILLIGER, E. H., *Arch. of Neurol. and Psychiat.* In press.
- ³ THIELE, F. H., *Jour. of Physiol.*, 1905, xxxii, 358.
- ⁴ BROWN, T. GRAHAM, *Proc. Roy. Soc. B.*, 1913, lxxxvii, 145.
id., *Jour. of Physiol.*, 1915, xlix, 185.
- ⁵ HORSLEY, V., and CLARKE, R. H., *Brain*, 1908, xxxi, 45.
- ⁶ INGRAM, W. R., RANSON, S. W., and HANNETT, F. I., *Amer. Jour. Physiol.*, 1931, xcviii, 687.
- ⁷ KÖRNYEY, S., *Arb. a. d. Neurol. Inst. a. d. Wien. Univ.*, 1927, xxx, 120.