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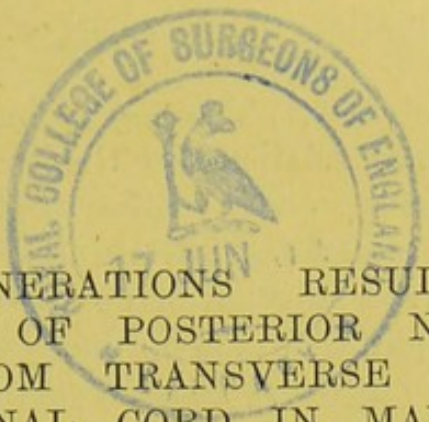

THE DEGENERATIONS RESULTING FROM LESIONS OF POSTERIOR NERVE ROOTS AND FROM TRANSVERSE LESIONS OF THE SPINAL CORD IN MAN. A STUDY OF TWENTY CASES.

BY JAMES COLLIER, M.D., B.Sc., F.R.C.P.
Assistant Physician to the National Hospital,

AND

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Pathologist to the National Hospital, and Assistant Physician to the Royal Free Hospital.

HAVING held successively the post of pathologist to the National Hospital we have had the opportunity of examining (1) two cases in which there were isolated lesions of the posterior roots in the cervical or lumbo-sacral region, and (2) twelve cases of transverse lesion of the spinal cord, at various levels. In all of these cases the method of Marchi was applicable.

In connection with the descending systems of the posterior columns we have also made use of several cases of transverse lesion of the spinal cord, which we have examined by the Weigert-Pal method.

For the Marchi method we have invariably used Busch's sodium-iodate process. Inasmuch as the literature of the subject is very extensive, we have deemed it convenient to refer only to the more recent investigations concerning such anatomical and physiological points as have been but lately brought to light, or as are still debatable, and to which our observations may add some further information. A bibliography of the more recent literature upon these subjects is appended.

The subject matter of this paper is arranged as follows :—

The posterior roots.—(1) The descending intraspinal prolongations and their relations to the coma tract, to the septo-marginal system, and to other posterior descending systems. (2) The ascending intramedullary prolongations ; Lissauer's zone ; the question of direct and crossed fibres passing above the posterior column nuclei to the cerebellum.

Degenerations resulting from transverse lesions.—(1) Descending—The mode of termination of the pyramidal tracts. The descending degeneration in the lateral limiting zone. The posterior descending system. The comma tract ; septo-marginal system ; sulco-commissural tract ; septo-ventral fibres ; the ending of the sacral triangle. (2) Ascending—The ascending system of the dorsal longitudinal bundle. The ascending system of the posterior columns.

The direct cerebellar tract — Fibres arising in the cervical region. Fibres joining this tract in the medulla. The ventral and dorsal medullary plexuses of Horsley and Thiele. The connection with Gowers' tract. Termination in the cerebellum.

The spino-vestibular system of Horsley and Thiele.

The ventro-lateral degeneration in the spinal cord.

Gowers' tract.—Direct fibres to the flocculus ; connections with the nucleus lateralis inferior ; connection with the nucleus cerebello-acusticus, Bechterew's nucleus and Deiters' nucleus, by means of fibres arising in the anterior part of the velum. Termination in the cerebellum.

The prolongations of Gowers' tract above the pons.—The dorsal and lateral spino-tectal systems. The question of fibres passing to the substantia nigra. The spino-thalamic system. Absence of fibres going to the nucleus lenticularis.

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The dorso-olivary fibres of von Solder.

Certain possibilities concerning the degeneration of different parts of the axon, and especially of the collaterals, as revealed by the Marchi method.

The Degenerations Resulting from Lesions of Posterior Roots.

Case 1.—*Lesion of third lumbar posterior root on right side—examination by Marchi (Busch) method—intramedullary fibres traced upwards to the nucleus gracilis and downwards to the coccygeal segment of the cord.*

The patient was a woman who died in the National Hospital from carcinoma of the vertebral column secondary to mammary scirrhus, the primary disease having been removed three years previously. At the autopsy the lower part of the vertebral column was found extensively infiltrated by the growth, and here and there a nodule had invaded the lumen of the vertebral canal at the level of the cauda equina.

One of these nodules had caught and compressed the third lumbar posterior root of the right side just before its entry into the intervertebral foramen. The cord and medulla oblongata were examined by the Busch and Weigert-Pal methods. The latter showed no change from the normal. Sections from the third lumbar segment stained by Busch's fluid showed the right posterior root completely degenerated, and the entry root zone full of degenerated fibres. A very few degenerated fibres could be traced in the direction of the anterior horn, and one or two towards Clarke's column, which was only sparsely represented at this level.

The remainder of the section contained no degeneration.

The ascending degeneration followed the usual course and requires very little comment: fibres running into the gray matter were seen for a segment or two, but then became scarce, and there was no evidence anywhere of fibres crossing to the contralateral side of the cord. The upward termination was entirely in the nucleus gracilis, and no degenerated fibres could be traced among the arcuate bundles, internal or external. It should be noted that the region of Lissauer's tract presented very few degenerated fibres, even at a level immediately above the entry of the third lumbar root.

The degenerated descending collaterals were seen to be numerous and in the upper part of the fourth lumbar segment were still confined to the entry root zone. A little lower they began to spread out in a streak running antero-posteriorly, and this streak gradually approached the mid-line until, at the level of the first sacral segment, the fibres could be seen lining almost continuously the posterior median septum. In their course to this position they appeared to be divided into three principal groups, an anterior, a median and a posterior, but the separation between them was by no means distinct. A continual leakage of fibres took place from the anterior group into the gray matter at the base of the posterior horn, so that the number of degenerated fibres somewhat rapidly diminished. In a section from the fourth lumbar segment about five hundred dots of blackened myelin could be counted in the posterior column, whereas in a section from the fourth sacral segment only about eighty-five could still be distinguished.

Below the first sacral segment the degenerated fibres gradually approached the posterior extremity of the median septum and eventually became bunched in the septo-marginal angle forming one half of the well-known sacral triangle. In this region they were traced in rapidly diminishing numbers as far as the coccygeal segment, and their termination at different levels in the gray matter of the sacral cord was suggested by the appearance of a few scattered dots between the periphery and the posterior commissure. No evidence was forthcoming that these descending fibres ever crossed to the opposite side of the cord.

Case 2.—*A lesion of the extra-thecal roots of the cauda equina—examination of the cord by the Marchi (Busch) method—ascending degeneration as high as the gracilis nucleus—few descending fibres — well-marked degeneration of the posterior root fibres going to the anterior horns.*

The patient was a girl, 14 years of age, who, in January, 1900, began to suffer from sharp pains in the lower extremities. At the end of May she exhibited atrophic palsy of the legs and some sensory loss in the

lower lumbar and upper sacral areas. The sensory loss spread until the end of June, when the girl died of sarcoma of the pelvis.

At the autopsy the lower lumbar vertebræ and the entire sacrum were infiltrated by the growth, which involved the extrathecal portion of the roots of the cauda equina, but did not penetrate within the theca. All the posterior roots as high as and including the second lumbar on both sides, with the exception of the third lumbar on the right, showed well-marked degeneration by Busch's method. At the level of the fifth sacral segment both entering roots were degenerated, and the blackened fibres were seen occupying the greater part of the posterior column. It was noticeable, however, that only a few fibres were degenerated in the region known as the sacral triangle, and that the cornu-commissural zone was less affected than the middle root zone. All the entering roots as high as the fourth lumbar were markedly degenerated on both sides, and all contributed their share to the degeneration of the posterior column, but the distribution of the fibres remained very much the same as was seen in the fifth sacral segment.

The sacral triangle, which gradually merged into the oval area, presented a marked contrast, by reason of its pallor, to the surrounding parts, although it always contained a certain number of black dots. The ventral field, although not so pale, was less degenerated than the middle and posterior parts of the column. About the upper sacral region another comparatively undegenerated area appeared in the form of a small triangle, lying immediately internal to the entering root on the posterior periphery of the cord.

At the level of the third lumbar segment the posterior root on the right side was seen to contain but little degeneration, and, as a consequence, the external root zone was much paler than on the left side. In the second lumbar segment this pale area had been displaced mesially by the degenerated root of that segment, and lay in the form of a crescent about a third of the distance between the posterior horn and the posterior median septum. As high as this level numerous degenerated fibres could be seen coursing

far into the anterior horns and breaking up in the neighbourhood of the ganglion cells of that part.

The oval area in the second lumbar segment was less distinct than in the segment immediately below, and disappeared altogether a little higher; it could not be traced spreading out on to the surface of the cord.

Lissauer's tract contained a few very fine fibres, which disappeared rapidly at higher levels.

Throughout the thoracic region the degenerated fibres on both sides were separated from the posterior horns by a considerable and gradually increasing undegenerated field. They occupied an area extending from the periphery to the posterior commissure, the anterior portion expanding at first in the commissural region, but later receding towards the median septum until, at the level of the sixth cervical segment, the most anterior fibres did not reach the gray matter, and the whole degenerated field assumed the shape of a triangular wedge, with its base lying on the surface. Above this the degeneration was limited to Goll's column, and ended in the region of the nucleus gracilis. A very few fibres could be traced laterally above this in the direction of the corpus restiforme, but they broke up near its internal aspect. No degeneration could be traced into the internal arcuate fibres.

The Descending Intramedullary Prolongations.

The existence of descending posterior root fibres has been shown in human embryos by histological methods and in the adult by means of the degenerations which follow extramedullary root lesions. Their presence in animals (dogs, guinea pigs, &c.) has been proved experimentally.

The questions which remain to be answered are: (*a*) Do they exist in large or small numbers? (*b*) What is their length? (*c*) What is their course? (*d*) What is their relation to descending fibres of endogenous origin? and (*e*) What is their mode of termination?

Cases of a single extramedullary root lesion, which can be examined by the Marchi method, and which are not

complicated by other intramedullary degenerations, are of some rarity, so that the one reported above affords data of considerable importance.

In the first place it proves that the third lumbar posterior root contains descending intraspinal prolongations in large numbers. In the second place, it shows that some of these fibres are short, some of medium length, and some long, the shortest terminating in the gray matter of the fourth lumbar segment, and the longest traversing seven or eight segments of the lumbo-sacral cord, to end in the lowest parts of the gray matter. Both in their course and in their length the fibres of the third lumbar root correspond closely with those of the fourth lumbar root, the degeneration of which Wallenberg has described in one of his cases. Moreover, that author has shown that still lower roots send fibres caudalwards, and that of all those roots—sacral, lumbar, and perhaps lower thoracic—which send fibres to the lower sacral region of the cord, the descending fibres of higher origin tend to take a position mesial to those of lower origin. They provide, in fact, an analogy in their course to that of the ascending root fibres; those of the latter with the lower origin assuming a position mesial to those of higher origin in their passage upwards through the columns of Burdach and Goll.

Comparing our case with those described by Nageotte, Homen, Dejerine and Thomas, Wallenberg, Zappert, &c., it seems to be very clearly shown that descending fibres of a posterior root in the cervical and in the upper five-sixths of the thoracic region follow a somewhat different course to that of similar fibres with their origin in the lumbo-sacral roots.

In both cases immediately below the entering root the fibres are bunched up in the external root zone; in both cases, too, they quickly spread out into a somewhat narrow band, with its anterior limit in the region of the cornu-commissural angle, and its posterior limit on or near the dorsal periphary of the cord. This band is rapidly displaced mesially by other entering roots. In the case of the cervical and thoracic fibres they assume a position between the

columns of Burdach and Goll; in the case of the lumbo-sacral fibres they quickly reach and lie alongside the posterior median septum. The cervical and thoracic fibres can be traced through several segments — the cervical through more than the thoracic—in diminishing numbers. The lumbar and sacral fibres enter into the sacral triangle, or dorso-medial bundle, and are thence traceable into the gray matter of the lowest part of the cord.

The difference in the path taken by the cervico-thoracic and the lumbo-sacral exogenous descending fibres is more apparent than real, and can be readily explained on anatomical grounds. The column of Goll becomes a distinct formation in the lower part of the thoracic region, and is, no doubt, responsible for checking the mesial course of fibres of higher origin. In the lumbo-sacral cord, on the other hand, there is no definite postero-internal column, and the descending fibres are free to reach the median line without having to pierce a compact bundle of ascending fibres enclosed in a septal sheath.

Although at first sight the descending fibres of the thoracic posterior roots would appear, from the smaller number of segments they traverse, to be of shorter length than those of the cervical, lumbar and sacral roots, the difference is probably not one of actual length, but due to the fact that the segments of the former region of the cord are of greater length than those of the latter.

The descending fibres of all posterior roots rapidly diminish in number as they pass caudalwards, and this diminution is undoubtedly due to the leakage of many of them into the gray matter in the cornu-commissural region, some of them passing to Clarke's column and some into the posterior gray matter of the same side.

Our second case is of much less importance in so far as it throws any light on the course of exogenous descending fibres. It resembles in origin others which have been published, notably those of Darkschewitsch, Dejerine and Spiller, Marinesco and Souques, Wallenberg and Goldstein, all of which were examined by the Marchi method. A comparison of the results obtained brings out two im-

portant facts. In the first place it affords ample evidence of the presence of descending exogenous fibres in the sacral triangle and in the region of the oval area. In the second place it emphasises a point to which we shall have occasion to refer again, namely, the unreliability of the Marchi method for the staining of degenerated collaterals. In reference to the latter point it is worthy of note that Marinesco and Souques consider that the collaterals of the posterior roots degenerate sooner than the main stems, and that consequently in late Marchi specimens the former cannot be traced.

Reviewing our results and comparing them with those of other observers we may summarise as follows :—

(1) In the cervical and thoracic regions of the cord the descending exogenous fibres occupy a somewhat curved narrow area, extending anteriorly to the cornu-commissural angle and posteriorly close to the dorsal periphery of the cord in the inner part of Burdach's column. They must, therefore, take a very considerable part in the formation of the so-called comma tract, and it remains to be proved whether or no the latter contains fibres of endogenous origin as well. (2) In the lumbo-sacral region the descending exogenous fibres rapidly reach the neighbourhood of the posterior median septum, and are present therefore in large numbers in the oval area of Flechsig and in the sacral triangle of Gombault and Philippe. (3) There is no evidence to show whether the peripheral bandalette of Hoche contains endogenous or exogenous fibres or whether it contains both,[1] but the consensus of opinion appears to be in favour of its endogenous origin. Its undoubted continuity with the oval area and sacral triangle, as shown by Bruce and Muir, suggests that those areas contain endogenous and exogenous fibres, supposing the view that the bandalette arises from cells within the cord is correct. (4) The ventral field of the posterior columns contains exogenous as well as endogenous fibres, but the former are

[1] We are unable to accept as conclusive the results obtained from the study of cases of tabes dorsalis by the Weigert-Pal method, since the degeneration in that disease does not follow exactly root distributions, and in many cases includes fibres of undoubted endogenous origin.

less numerous than the latter, and are more limited to its median part. (5) In the lumbo-sacral region a small triangular area, lying just internal to the entering posterior root on the dorsal surface of the cord, is composed mainly of descending endogenous fibres mixed with very few exogenous collaterals.

The Ascending Intramedullary Prolongations.

We do not propose to describe in detail the course of the ascending exogenous fibres, as our findings have not differed from those of previous observers. We may state, however, that we are unable to trace the very fine fibres of Lissauer's zone for more than a segment or two above a degenerated posterior root, and that even in that short course they become very few and far between. In neither of our cases could we trace any fibres passing above the posterior column nuclei to the cerebellum.

Degenerations Resulting from Transverse Lesions.

(1) Descending Degenerations.

The Termination of the Pyramidal Tracts in the Lower Spinal Cord.

The termination of certain fibres of this tract in Clarke's nucleus was very well shown in several of our cases of transverse lesion. That the degenerate fibres passing from the lateral column to Clarke's nucleus were pyramidal fibres was proved by their similarity in position and level to the degenerate fibres in a case of recent hemiplegia which we have examined.

It is so rare to find the terminations of this tract well stained with the Marchi method that we think a detailed description is not out of place in this paper.

We may add that of sixteen cases of hemiplegia which we have examined by the Marchi method, the terminations of the pyramidal tract were only demonstrable in two cases. The same was true of the majority of the cases of transverse lesions.

Few fibres could be traced out of the pyramidal tracts above the tenth dorsal segment. In the tenth, eleventh and especially in the twelfth dorsal segments, and in the first and second lumbar segments, coarse fibres passed transversely inwards to the front of Clarke's column. So directly transverse was their course that in sections 100 μ thick they could be followed from the pyramidal tract to Clarke's nucleus in the same section. Arrived at the front of Clarke's nucleus these fibres turn abruptly downwards and run for some few segments in contact with the nucleus, fine and coarse collaterals continually entering and breaking up among the cells of the nucleus.

Very few fibres passed inwards from the pyramidal tract below the second lumbar segment, but the fibres coursing down along the front of Clarke's nucleus were visible in the posterior gray matter at the first sacral segment.

No fibres could be traced to any part of the ventral horns.

We would call attention to that peculiarity in the degeneration of the distal portions of long neurones which renders them apt not to stain by the Marchi method, as the explanation of the difficulty which has been general in determining the termination of the pyramidal tract in the spinal cord.

The Degenerations in the Lateral Limiting Layer.

As a result of investigation by the myelination method and from the study of a case of amyotrophic lateral sclerosis, it has been suggested by Flechsig and by Bruce that the dorsal division of the lateral limiting layer represents ascending fibres of short intraspinal course, while the ventral division represents descending fibres of short intraspinal course.

We carefully sought in sections immediately above and below the lesions in all our cases for evidence of preponderant degeneration in the dorsal division above the lesion, and preponderant descending degeneration below the lesion, in the ventral division of the lateral limiting layer. We found only a scattered ascending and descending degeneration equally distributed over both divisions.

Descending Degeneration in the Posterior Columns.

The results obtained in all the cases examined by the Marchi method were constant, and may be briefly summarised as follows :—

Immediately below the region of the " traumatic degeneration " the degenerate fibres in the posterior columns could be divided into three classes.

(1) A large band of mixed coarse and fine fibres in the postero-external column, reaching from the gray matter at the junction of the posterior horn and posterior commissure to the surface of the posterior column, separated except at its ventral extremity from the posterior horn by a considerable mass of non-degenerate white matter. This degenerate strip extended downwards in the same position in the postero-external column for a distance which varied directly with the position of the lesion in the spinal cord ; for instance, with the lower limit of the lesions in the eighth cervical, fifth and tenth dorsal segments, the degenerate band extended to the seventh, ninth, and eleventh dorsal segments respectively. The band then separates into (1) a ventral portion, lying against the dorsal horn (sulco-commissural bundle of Dufour), the majority of the fibres of which gradually pass into the gray matter at the junction of the dorsal horn and dorsal commissure. This tract finally disappears at the fifth lumbar segment. Some of the coarse fibres of this bundle pass mesially to reach the septum, and then keeping along the septum go dorsalwards to join the degeneration of the oval area. (2) A dorsal portion, many coarse fibres of which rapidly gain the dorsal surface of the posterior column, where they subsequently spread out to form the dorsal crescent or peripheral bandalette of Hoche in the twelfth dorsal segment, and passing on to the edges of the septum at the second lumbar segment form the oval area of Flechsig, which exists throughout the third, fourth, and fifth lumbar segments. These fibres passing again dorsally in the second sacral segment form the sacral triangle of Gombault and Philippe at the third sacral segment, and from this to the end of the conus medullaris

they stream into the posterior gray matter of the same side to break up among a mass of nerve-cells in a position similar to that of the "sacral nucleus." This group of fibres is that to which Bruce and Muir have applied the term "septo-marginal tract." In addition to these fibres, we desire to draw attention to certain fine fibres of the dorsal division of this system which do not join the posterior crescent, but which remain throughout the greater part of their course in Burdach's column close to the dorsal surface.

(2) Hoche's septal fibres. Immediately below the lesion we have in all the cases found a conspicuous row of somewhat large fibres lying almost in single file along either side of the ventral one-third of the septum, but not reaching to the commissure. These fibres pass along the septum into the gray matter in the region of the commissures. They do not extend for more than two segments below the lower limit of the lesion.

(3) Scattered degeneration of fine fibres throughout the posterior columns, situated chiefly in Burdach's column and in the external root zone. They disappear for the most three or four segments below the lesion.

We have now to draw attention to certain details of our observation.

The Descending Strip of the Postero-External Column.

It has been already stated that the higher the level of the lesion in the spinal cord the farther does this strip of degeneration descend as such before dividing into its dorsal and ventral groups. It extends downwards for seven segments below a cervical lesion, three segments below a mid-dorsal lesion and only one segment below an eleventh dorsal lesion. Further, in a lesion of the twelfth dorsal we found that the coarse fibres of the dorsal and ventral divisions were already separate immediately below the region of "traumatic" degeneration. While we believe that we are the first to state this fact definitely, yet the publications and figures of Hoche, Nageotte and all the

more recent observers, if taken collectively, bear out our conclusion.

The descending strip immediately below the lesion extends from the gray matter at the junction of dorsal horn and dorsal commissure to the dorsal surface of the dorsal column. It is limited externally by the external root zone, and is composed of very coarse fibres, medium-sized fibres and fine fibres. The very coarse fibres are situated mainly on the dorsal one third of the strip, but a few are found at its ventral limit. As the tract descends it tends to assume somewhat of an hour-glass shape, with a larger dorsal expansion reaching to the dorsal periphery in which the majority of the larger fibres are collected, a much smaller ventral extremity lying against the gray horn and a connecting portion composed mainly of fine fibres. From this central portion the fine fibres are continually running ventralwards to enter the gray matter in the cornu-commissural region, till at the eleventh dorsal segment they have all disappeared, leaving the ventral and dorsal group separate.

The ventral group (sulco-commissural bundle of Dufour) retains its position against the gray horn and, inclining towards the septum as it descends, disappears constantly in the fifth lumbar segment. Fibres are continually passing from it to break up in the contiguous gray matter. Some of the coarse fibres which it contains, however, pass to the septum and, running dorsalwards, join the oval area in the upper part of the third lumbar segment. We wish to call attention to this fact especially since in previous descriptions the oval area has been said to be derived entirely from fibres reaching the septum by the dorsal periphery. We are indebted to the kindness of Dr. Bruce, of Edinburgh, for the confirmation of our results, for he informs us that he has also found similar ventral fibres passing to the oval area.

All the coarse fibres of the dorsal division of the descending degeneration in Burdach's column pass on to the dorsal periphery of the cord in the lower part of the eleventh and in the twelfth dorsal segments to form the

posterior crescent, or peripheral bandalette of Hoche. Most of the fine fibres disappear, but we would draw attention to the fact that some fine fibres remain in the dorso-external region of the posterior columns, and can be traced in lesions from the mid-dorsal region downwards as far as the conus, where they course ventrally through the thickness of the posterior column to enter the gray matter. The subsequent course of the septomarginal system, the passage of the posterior crescent to the septum, the formation of the oval area and its connection with the sacral triangle, the fibres of which end in the dorsal gray matter of the same side, corresponded in our cases with the descriptions given by other recent observers. Whatever be the level of the transverse lesion, the following degenerate tracts assume their characteristic position at the following levels:—

Posterior crescent (bandalette) } Sulco-commissure bundle }	D. 12.
Reaches septum	L. 1, L. 2.
Oval area...	L. 3, 4, 5.
Sacral triangle	S. 3.
Enters gray matter	S. 5, Co.

In connection with the termination of the sacral triangle we may again draw attention to a fact we have already mentioned more than once in this paper, that except degeneration be very recent the distal portions of degenerate long neurones may not be revealed by the Marchi method. Whereas in many of our cases the fibres of the sacral triangle entering the gray matter were well shown even to their terminal ramifications, in other cases no sign of such entering fibres could be found, notwithstanding that the fibres of this triangle and the rest of the descending posterior degenerate fibres were well stained. For example, two cases of transverse myelitis at the level of the ninth dorsal were examined. In one death had occurred five weeks after the onset, and the ending of the sacral triangle was perfectly stained. In the other death had occurred eight weeks after the onset and the ending of the triangle was not stained.

The Anatomical Limitation of the Oval Area and the Sacral Triangle by Fibrous Septa.

A most striking feature of many of our preparations has been the separation of these tracts at certain levels by fibrous septa.

As the fibres of the posterior crescentic degeneration pass ventrally at the level of the second lumbar to form the oval area, they split the posterior septum into two layers, between which all the fibres of the oval area are contained. When from the oval area the fibres incline backwards to form the sacral triangle, these two layers are carried backwards on either side of the dorsal piece of the posterior septum, so that at the level of the second sacral segment each half of the sacral triangle is separated off. These septa become less distinct at the third sacral level when the sacral triangle becomes fully formed.

The Scattered Posterior Degeneration below the Lesion.

This cannot be accounted for as "traumatic" degeneration. Some of the degeneration in the external root zone doubtless corresponds with descending collaterals of the posterior roots. Certainly much of it is derived from fibres passing away from the main descending degenerate tract in the postero-external column.

Hoche's Ventral Septal Fibres.

In all the cases we have found these fibres lying in single file along the ventral one-third of the septum, not reaching the gray matter and not extending more than two segments clear of the lesion. They are moderately large fibres and their number seems to be variable. On the whole they seem to be more numerous in cases of cervical and upper dorsal lesions than in those lower down. But in one case of lesion at the tenth dorsal we found as many as in any of our cervical cases. In the cervical and upper dorsal cases we could trace them for two segments, lower down for only one segment, while in the lowest lesion we examined (twelfth dorsal) they were breaking up in the

upper part of the segment below the lesion. Their mode of termination was clear in several of our cases. They pass ventrally along the septum towards the gray matter, breaking up and spreading out as they do so, so that just before their disappearance they are seen as a multitude of fine points in the septo-commissural angle.

(2) Ascending Degenerations.

Ascending System of the Dorsal Longitudinal Bundle.

In all the cases of transverse lesion of the spinal cord degenerate fibres were found throughout the length of the dorsal longitudinal bundle above the lesion. The majority of those fibres were fine fibres and few coarse fibres were found above the level of the sixth nucleus. In the cases of low dorsal lesions only a few fibres were found. Where mid-dorsal lesions existed the number was distinctly greater, while in the cases of lesion of the cervical enlargement many more degenerate fibres were present. It would appear, therefore, that these fibres constitute a true ascending system arising in each segment of the spinal cord. The small proportion which the degenerate fibres of the dorsal longitudinal bundle bore to the non-degenerate fibres, even in lesions of the cervical enlargement, bears out the generally-accepted view that the majority of the fibres of this system are descending fibres and, in comparing our sections from this series of cases with a series showing descending degeneration in the dorsal longitudinal bundle as a result of experimental and pathological lesions of the brain stem, published in Brain, 1901, the paucity of the degeneration in the former contrasted most strikingly with the richness of the degeneration in the latter. The degenerate ascending fibres of the dorsal longitudinal bundle appear to take their origin in the ventral horn of the same side. A few segments above the lesion they lie in part mesial and in part ventral to the ventral horn. Traced upwards the majority incline outwards to enter the anterior extremity of the ventro-lateral area of degeneration, and are situated near the surface in the mid-cervical region.

In the first cervical segment they again sink towards the mesial aspect of the ventral horn and with the other degenerate fibres, which pass mesial to the inferior olive, form a characteristic band, arc-shaped in transverse section, stretching from the ventro-lateral region towards the mesial aspect of the ventral horn. When the pyramid commences these fibres lie between the pyramid and the remains of the ventral horn, being here joined by fibres of the same system which have retained a position close to the lips of the ventral fissure throughout their course in the spinal cord. Passing mesial to the olive among the outer fibres of the fillet, the dorsal longitudinal bundle fibres separate from the degenerate dorso-olivary fibres which accompany them and ascend rapidly to the dorsal white matter, on either side of the middle line, where they are so arranged that the fibres from the lower parts of the cord lay dorsal and mesial to those from the higher segments of the spinal cord, as judged from a comparison of the areas occupied by the degenerate fibres in lesions of the lower dorsal, mid-dorsal and lower cervical cord respectively.

We wish to draw especial attention to the large number of degenerate fibres, which have been present in all our cases, lying immediately external to the pyramid directly it formed and occupying the position of the dorsal longitudinal bundle. Most of these fibres do not belong to the system of the dorsal longitudinal bundle, but pass from the ventro-lateral degeneration of the cord mesial to the olive, some entering the inferior olive, the majority passing outwards into the dorso-olivary layer to end in the restiform body (ventro-lateral restiformal system of Tschermak) and a few passing to the mesial fillet (fibres of von Solder). Above the limit of the hypoglossal nucleus the degeneration in the dorsal longitudinal bundle becomes much less marked, and many of the coarse fibres disappear. The fibres were not traced into the hypoglossal nuclei, but were easily followed to the nucleus centralis inferior, thus corresponding closely with the *descending* ponto-spinal fibres which take their origin in these nuclei. Above this level the degeneration could be

traced into the sixth nuclei, where most of the coarse fibres disappeared; a few fibres could be followed to the fourth and third nuclei and to the nucleus of Darkschewitch. None were traced across the posterior commissure.

Ascending Degenerations in the Posterior Columns.

Both in our cases of dorsal root lesions and of transverse lesions our results coincided with the classic descriptions so far as the spinal cord and posterior nuclei are concerned.

We conclude with confidence, however, that there are no direct fibres passing to the cerebellum from the posterior columns by way of the posterior nuclei, neither as external nor as internal arcuate fibres, for we have failed to find them in any of the cases. We have, in several cases, found fibres passing to the gray matter mesial to the restiform body from these nuclei, and these could be followed some distance upwards in the descending vestibular root, thus confirming the observations of Horsley and Thiele.

The Direct Cerebellar Tract.

The degeneration of Flechsig's tract in our cases corresponded in great part with the generally accepted anatomical description. It seems certain from a comparison of the bulk of the degeneration in this tract at different levels, that each segment of the spinal cord contributes fibres to the system. Though many writers have pointed out this fact, the relative contribution made by the various regions of the cord has not been made clear. We judge from our preparations—(1) that a majority of the fibres have their origin below the twelfth dorsal segment; (2) that throughout the thoracic region there is decreasing contribution from each segment; (3) that there is again a large accession of fibres from the cervical enlargement. In the case of the lowest transverse lesion we examined (upper limit in tenth dorsal), there was a copious degeneration immediately above the lesion already occupying the position of the direct cerebellar tract, while for three segments above coarse fibres lying in the region between the posterior horn and the direct cerebellar tract streamed outwards into the latter tract. These presumably

were fibres from distal and proximal segments below the lesion respectively. When the degenerations in the medulla of this case were compared with those in which the upper limit of the lesion was in the fifth cervical, it seemed obvious that more than one-half of the fibres in this tract are of lumbo-sacral origin, and less than one-half of thoracic and cervical origin.

Comparing further the degenerations resulting from lesions with the upper limit at the ninth, seventh, sixth, fourth, and third dorsal segments, the bulk of the degeneration above each lesion further cephalwards became moderately greater, while a comparison of the degeneration of the case of the highest lesion we have examined (upper limit at the fifth cervical) with that of the third dorsal lesion showed that a very large number of fibres had been added to the tract from the lower part of the cervical enlargement.

When describing the degenerations in the lateral column above transverse lesions of the lower and mid-thoracic region, we refer later to the dorsal of two angular areas of degeneration projecting inwards from the more definite dorso- and ventro-lateral degenerations of the direct cerebellar tract and Gowers' tract as being probably composed of fibres passing to the direct cerebellar tract. If this suggestion prove correct these fibres are added to the ventral and mesial aspect of Flechsig's tract, and it would seem likely that the longest fibres of this tract are situated dorsally and externally, while the shorter fibres have a position which is ventral and mesial relatively to their length.

Our observations fully confirm the opinion of Horsley and Thiele that the fibres of the direct cerebellar tract can be distinguished from those of Gowers' tract and other systems in the ventro-lateral region by their greater size. The spino-vestibular fibres, however, seem to be coarse and to occupy the dorsal limit of Flechsig's tract. We wish to point out that deductions from the size of fibres are apt to be entirely fallacious if the degeneration is not quite recent, and if the paraffin method be employed.

At the lower part of the first cervical segment the direct cerebellar tract occupies an even strip along the surface of

the cord from the posterior horn to the attachment of the denticulate ligament. Above this the inner edge of the tract is thrown into several folds as the fibres of the tract pass backwards to occupy the angle between the Rolandic substance and the lateral surface of the cord.

At the level of the commencing decussation of the pyramid a tongue-like mass of coarse fibres is seen to extend dorsalwards from the direct cerebellar tract between the Rolandic substance and the surface. This tongue-shaped process seems to us to constitute an anatomical separation between the spino-vestibular fibres of Horsley and Thiele, of which it is composed, and the direct cerebellar tract.

It is important to point out that at this level the lateral ascending degeneration is divided up into more or less completely separated groups—the spino-vestibular group, the direct cerebellar tract, Gowers' tract, and the dorsal longitudinal bundle groups.

In the medulla the spino-vestibular fibres of the direct cerebellar tract are the earliest to pass off as external arcuate fibres and, running in the layer of gray matter covering the restiform body, pass over the dorsal surface of that structure and turn ventralwards to break up in the gray matter about the descending vestibular root.

In several cases a few coarse fibres of the direct cerebellar tract were seen passing ventral and then mesial to the spinal trigeminal root. They have been regarded by Horsley and Thiele as fibres of the tract taking an unusual course. It is possible, however, that some of them end in the gray matter mesial to the spinal trigeminal root.

In the medulla the direct cerebellar tract gives off numerous collaterals to the ventral collateral plexus and to the dorsal collateral plexus, to be subsequently described. It receives coarse fibres from the degeneration of the dorso-olivary layer. These fibres come from the ventro-lateral degeneration of the cord and pass up mesial to the inferior olive, with the fibres of the dorsal longitudinal bundle subsequently crossing by the dorso-olivary layer to the restiform body.

As the restiform body enters the cerebellum we were

able to trace coarse fibres to the peduncle of the flocculus in every case.

Arriving beneath the dentate nucleus the degeneration in the restiform body became divided into two, a smaller mesial bundle and an outer larger bundle. The mesial bundle turned almost vertically dorsalwards and passed mesial to the dentate nucleus giving off fibres to this nucleus, and ran partly ventrally, partly through the root nuclei, to terminate in the inferior vermis. Some fibres crossed both in the interfastigial commissure and in the inferior commissure.

The lateral bundle passed outside the dentate nucleus, giving off many fine collaterals to the fleece of that nucleus.

Just before the outer surface of the superior peduncle becomes free this bundle receives a considerable accession from Gowers' tract, which is here in close proximity to it. The fibres of the lateral bundle terminate chiefly in the superior vermis, many crossing the middle line in the anterior commissure, some in the posterior commissure. Degenerate fibres were traceable to all parts of the cerebellar cortex, especially to the lower part of the lateral lobe.

The Collateral Medullary Plexuses of the Direct Cerebellar Tract.

These plexuses were first figured by Hoche, and were described in detail by Horsley and Thiele. They were present in all of our cases of transverse lesion, and our results entirely confirm the opinion of Horsley and Thiele that they are composed of collaterals of the external arcuate fibres of the direct cerebellar tract, and that they have no connection with the degeneration in the posterior column nuclei, as has been suggested by Barker. The following description is that of Horsley and Thiele, to which we have added certain deductions from our observations :—

Ventral collateral plexus.—"Just above the uppermost level of the decussation of the pyramid strong collaterals, springing from the fibres of the direct cerebellar tract as they turn up towards the restiform body, pass inwards, first ventrally to the spinal trigeminal root, and between that

and the antero-lateral nucleus, breaking up and apparently terminating in connection with small nerve-cells lying just ventral to the spinal trigeminal root; the uppermost limit of the plexus is the upper border of the auditory striæ."

In many of our cases we have found fibres passing inwards from the mesial aspect of the direct cerebellar tract as low as the caudal end of the pyramidal decussation, which appear to break up in that part of the central gray matter corresponding with the nucleus accessorius. Perhaps these are the fibres which have been described by Kohnstamm as passing over from the direct cerebellar tract to the pyramid.

We wish to suggest that these fibres belong to the system of the ventral collateral plexus, the lower limit of the latter being the lowest limit of the pyramidal decussation.

From our specimens it seems likely that fibres of Gowers' tract enter into this ventral plexus from the funiculus proprius lateralis medullæ.

Dorsal collateral plexus.—"Commencing at the place of the upper limit of the pyramidal decussation, and limited above by the level of the highest auditory striæ, fine collateral fibres arise from the direct cerebellar tract and pass inwards, partly through the spinal trigeminal root, to end in a fine plexus just external to the gray nucleus enveloping the fasciculus solitarius."

This plexus is very well marked in our preparations, and in several cases we find fibres actually entering the fasciculus solitarius, which we could trace for some distance upwards; these subsequently re-entered the gray matter and disappeared.

In connection with these collateral plexuses we wish to point out that, unless the degeneration is very recent, these plexuses are apt not to be revealed by the Marchi method. Degenerate collaterals lose their property of reacting much sooner than do coarse fibres, and further, unless the degeneration is quite recent, alcohol, ether and clarifying reagents tend to dissolve out the black substance from the collaterals. This fact, first pointed out by Marinesco, has been fully

confirmed by our observations, and is most important since it adds greatly to the difficulty of correctly determining the ultimate destinations of degenerate fibres in pathological material.

As an example, we have found no sign of these plexuses in one case where the degeneration of the direct cerebellar tract was well marked and stable, the tissues being prepared by the celloidin method and mounted in balsam; yet portions from the same medulla cut with gum embedding and freezing, and examined immediately in glycerine, showed the plexuses very well.

The Spino-Vestibular Tract.

This system of fibres, to which attention was first drawn by Horsley and Thiele, was distinct in all our cases of transverse lesion of the spinal cord.

The fibres are coarse fibres which occupy the most dorsal part of the direct cerebellar tract. They appear to have their origin in the lumbo-sacral region, for we were unable to find a larger number of the fibres of this system degenerate in lesions at cervical levels than occurred in lesions of the lowest thoracic segments. Their position at the dorso-external limit of the direct cerebellar tract also suggests that they are all lumbo-sacral fibres.

These fibres are partly separated from the direct cerebellar tract in the upper part of the first cervical segment, where, as seen in transverse sections, they form a tongue-like projection extending dorsally from the direct cerebellar tract between the Rolandic substance and the surface of the cord.

They pass away from the cerebellar tract as the earliest of all the external arcuate fibres to be formed, and, curving round the restiform body in the thin layer of gray matter covering that structure, they sink almost perpendicularly, to break up in the gray matter mesial to the restiform body, which is associated with the descending auditory root. In this region, also, certain fibres end which pass outwards from the gracile and cuneate nuclei, and are derived from the degenerate ascending systems of the posterior columns.

The Ascending Degeneration in the Ventro-Lateral Region of the Spinal Cord.

Immediately above the area of traumatic degeneration in lesions of the thoracic cord the direct cerebellar tract was conspicuous as a narrow strip lying against the lateral periphery and reaching from the dorsal horn to the attachment of the denticulate ligament. Gowers' tract was also plainly visible, and we can fully confirm the observation of Risien Russell that it is usually separated from the surface of the lateral column by a layer of non-degenerate fibres.

We locate this tract as ventro-mesial to the ventral part of the direct cerebellar tract.

These two fibre systems can readily be distinguished by the large size of the fibres in the former tract.

A few segments above the lesion the mesial limit of the conspicuous ventro-lateral degeneration had the form of two hook-like processes, with their concavities directed dorso-mesially. The dorsal of these two processes was the larger, and contained the coarsest fibres; it was apparently limited behind by the lateral pyramidal tract. We suggest that it is composed of fibres passing to the direct cerebellar tract. It disappears about six segments above the lesion.

The ventral hook-like process was smaller and contained finer fibres than the dorsal process. It was generally visible as high as the second dorsal segment. We suggest that it is composed of fibres passing to Gowers' tract.

The scattered degeneration in the ventral column gradually diminished as it was traced upwards and tended to assume two positions: (1) in front of Gowers' tract and close to the surface, where it reached to the upper cervical region, extending almost as far round the ventral column as the mouth of the fissure; (2) along the lips of the ventral fissure. The fibres of this degeneration were mostly fine fibres, but some coarse fibres existed. The prolongations to the medulla and brain stem were the spino-tectal and spino-thalamic systems, the fibres of Tschernak, von Solder's fibres, and the ascending fibres of the dorsal longitudinal bundle.

Gowers' Tract and the Associated Systems.

In the spinal cord the fibres of these systems could be distinguished from those of the direct cerebellar tract by the greater size of the fibres of the latter. If the size of the spino-thalamic fibres in the mesencephalon was compared with that of those fibres of Gowers' tract which pass to the cerebellum, the latter were obviously of greater calibre than the former, but such difference did not enable us to distinguish these systems one from the other in the spinal cord nor in the medulla. Horsley and Thiele locate the spino-thalamic and spino-tectal systems as mesial to the other fibres of Gowers' tract in the funiculus lateralis proprius medullæ, and while it is true that the mesial fibres degenerate in that situation are of finer calibre than the others, we were unable to come to a definite conclusion upon this point. Certainly no separation could be made in the pons. For a few segments above a lesion in the mid and lower thoracic region the mesial outline of the ventro-lateral area of degeneration took the form of two angular projections, slightly hooked, with the concavity directed dorso-mesially. We have referred to the posterior of these as probably consisting of fibres passing to the direct cerebellar tract, and we suggest that the ventral projection which is composed of finer fibres is made up largely of fibres passing to Gowers' tract. From the comparison of the number of fibres degenerate in this tract as it traverses the medulla and pons, in cases of transverse lesions at various levels of the spinal cord, it seemed certain that fibres are added to the tract from each segment of the cord.

Especially would we point out that the number of spino-tectal and spino-thalamic fibres was considerably greater in lesions of the cervical enlargement than in lesions at lower levels.

While there is no doubt that many fibres occupying the position of Gowers' tract are internuncial fibres which enter the gray matter of the ventral horns at various levels, and that a gradual decrease of the bulk of the degeneration

Description of Plates.

Plate I.

From Case 1 in text. Fig. 1 shows the degenerated third lumbar posterior root entering the spinal cord. Fig. 2 is a photograph of the posterior columns of the fourth sacral segment, showing the degenerated descending root fibres lying alongside the posterior two-thirds of the posterior median septum.

Plates II. and III.

Drawings made by means of a projection apparatus in order to show the ascending and descending degenerations from a lesion of the third lumbar posterior root (Case 1.) The dorsal and cervical sections are drawn on a smaller scale than the lumbar and sacral.

Plates IV. and V.

Drawings showing the degeneration resulting from a lesion of cauda equima involving the posterior as high as the second lumbar on both sides, with the exception of the third lumbar on the right.

Plate VI.

Photograph of a section from the second lumbar segment of the same case.

Plate VII.

Fig. 1.—Transverse section of twelfth dorsal segment, showing degenerate fibres of the pyramidal tracts passing to the ventral aspect of Clarke's nucleus.

Fig. 2.—The same more highly magnified.

Plate VIII.

Transverse section of the pons and cerebellum, showing the degeneration in Gowers' tract, and in the direct cerebellar tract.

Plate IX.

Fig. 1.—A portion of the section shown in Plate VIII. more highly magnified, and showing the degenerate fibres passing to Bechterew's and Deiters' nuclei.

Fig. 2.—Transverse section at the level of the commencing pyramidal decussation.

Plate X.

Fig. 1.—Transverse section of the third dorsal segment, showing the two projections of the ventro-lateral ascending degeneration. (Lesion at eighth dorsal.)

Fig. 2.—The comma tract at the level of the tenth dorsal segment. (Lesion at eighth dorsal.) Weigert-Pal method.

Fig. 3.—The division of the comma tract in the twelfth dorsal segment. (Lesion at tenth dorsal.) Weigert-Pal method.

Fig. 4.—The fibres of the sacral triangle passing on to the gray matter of the fifth sacral segment.

Plates XI.—XVI.

Projection drawings of the ascending and descending degeneration, revealed by the Marchi method in a case of a total transverse lesion of the seventh dorsal segment.

PLATE I.

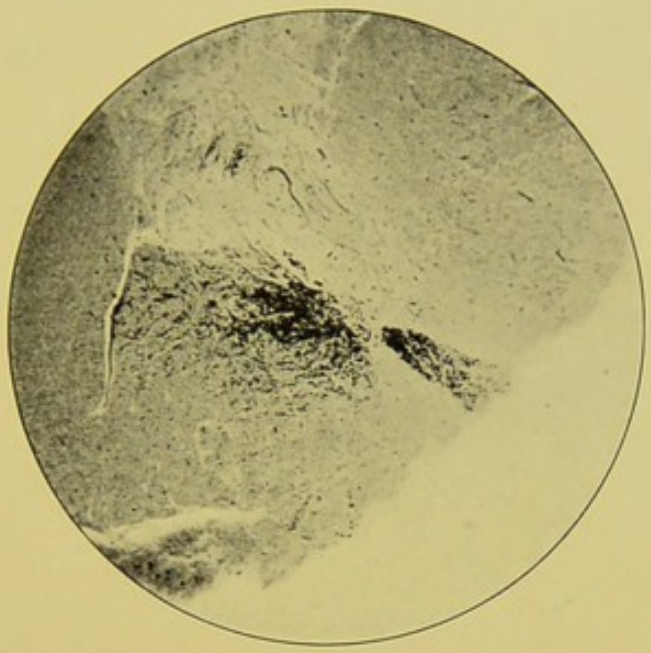

FIG. 1.

FIG. 2.


ROYAL COLLEGE OF SURGEONS OF ENGLAND
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PLATE II

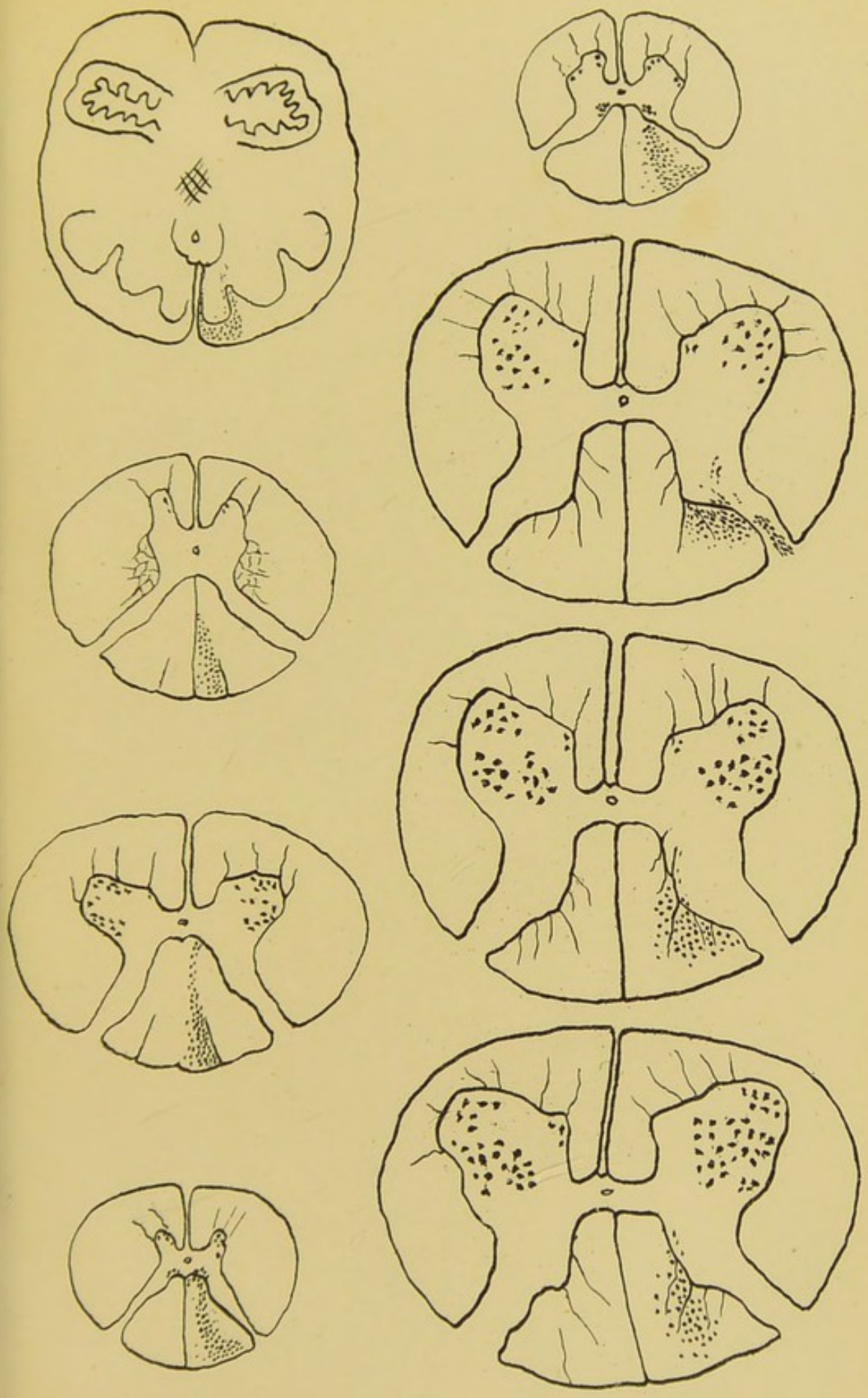


PLATE III

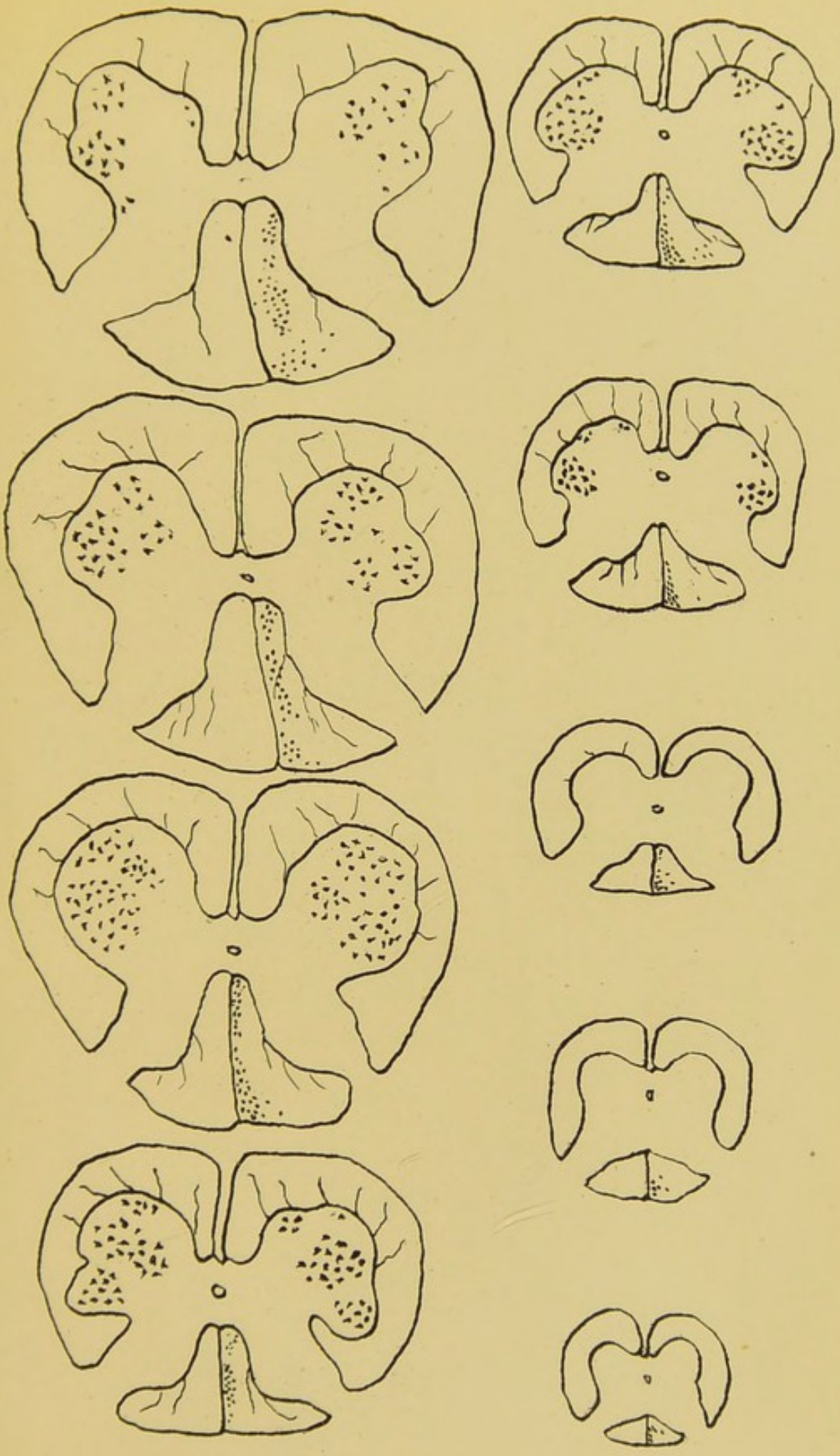
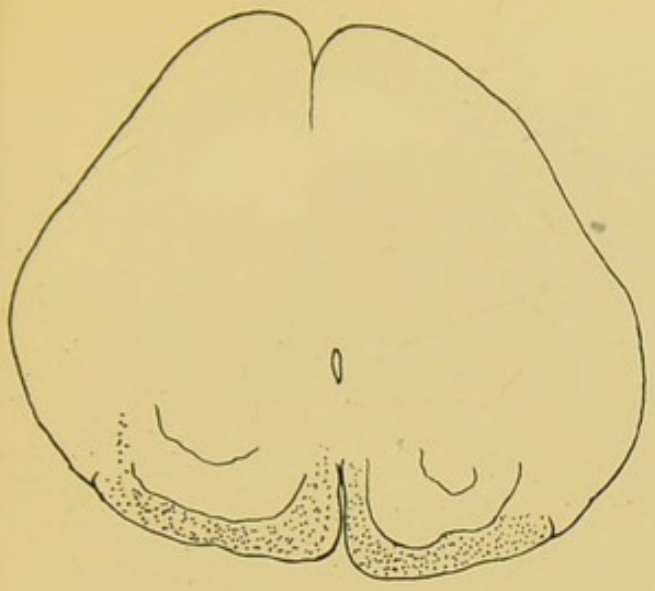
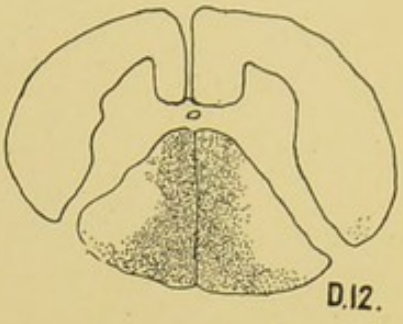
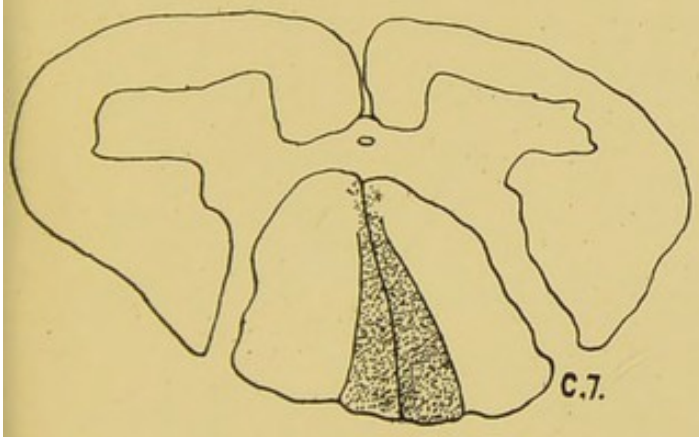
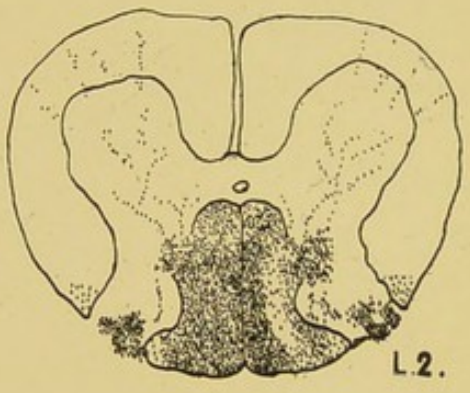


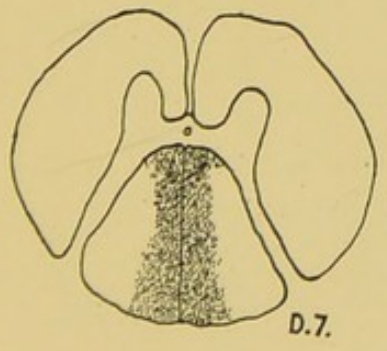
PLATE IV











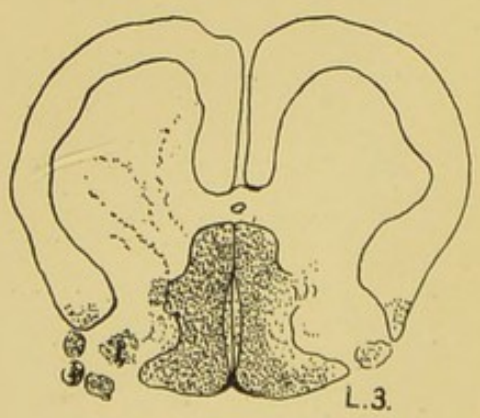
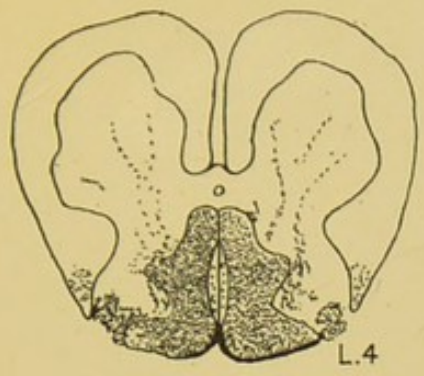
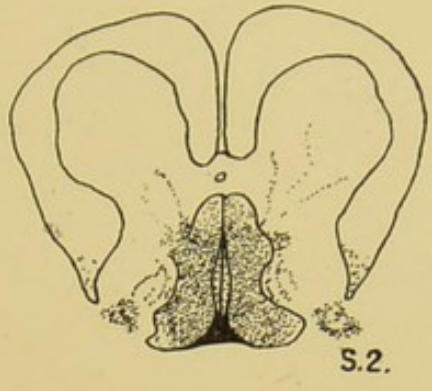
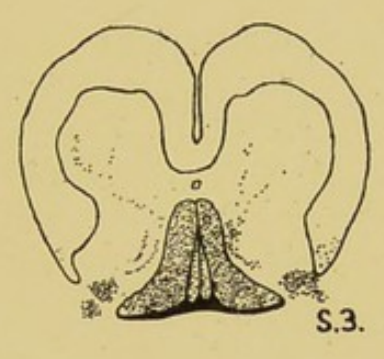
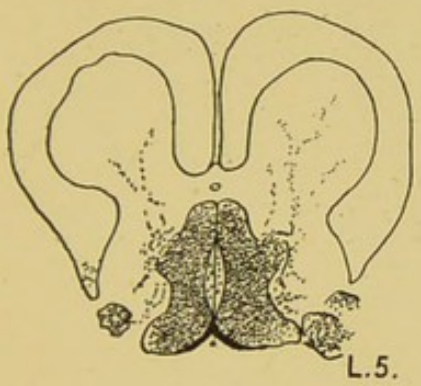


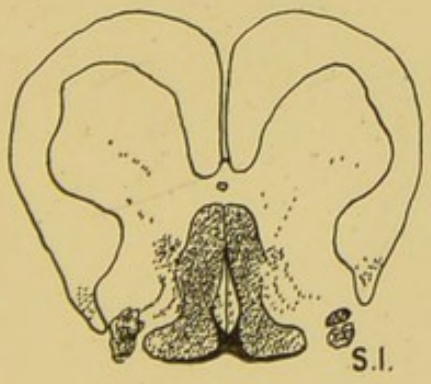
PLATE V











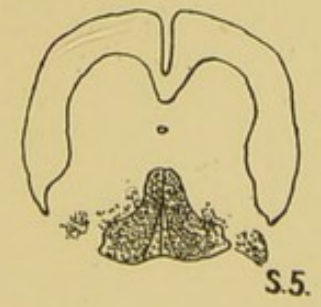
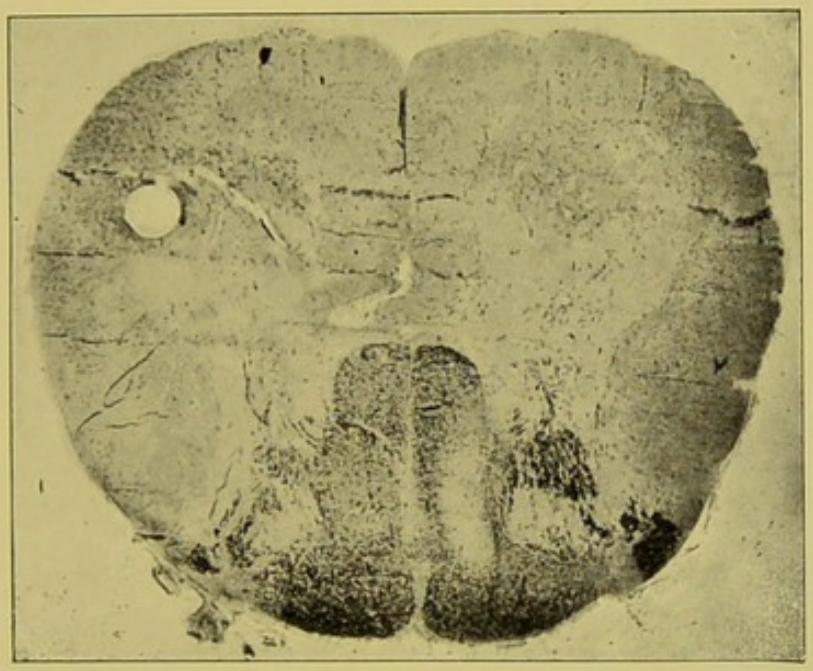


PLATE VI.



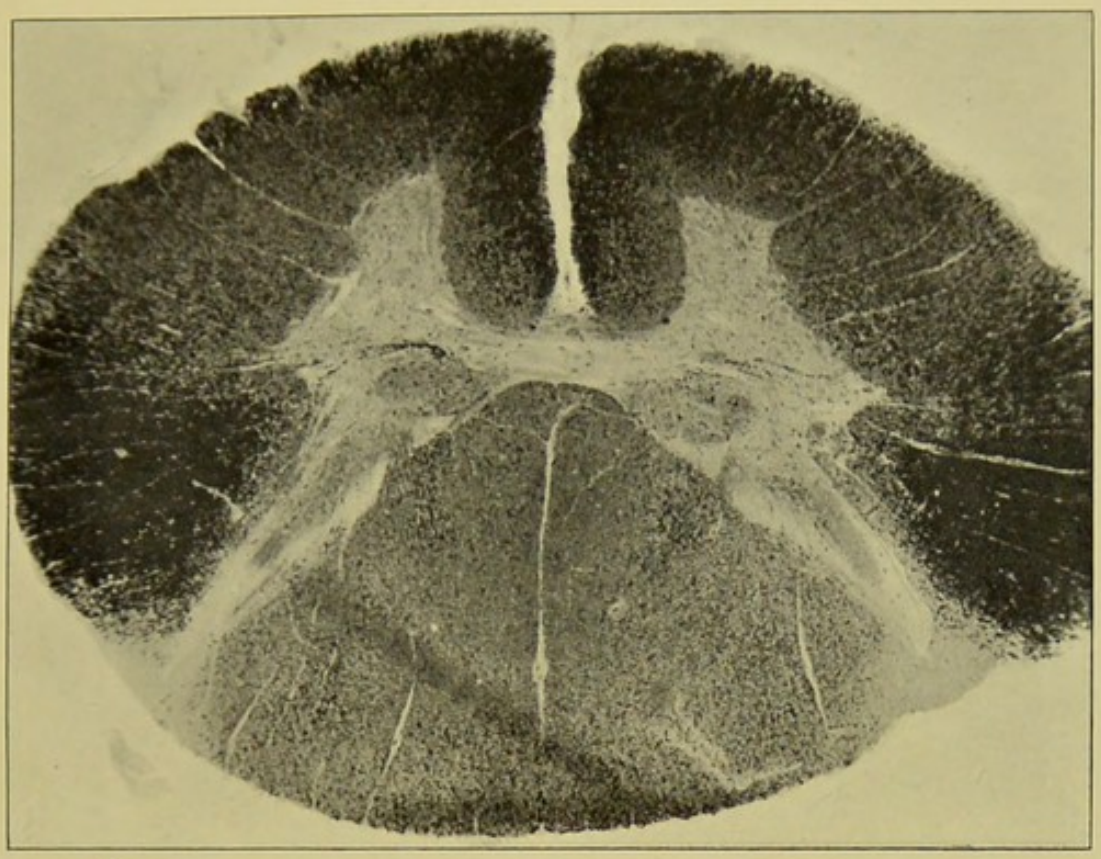


FIG. 1.

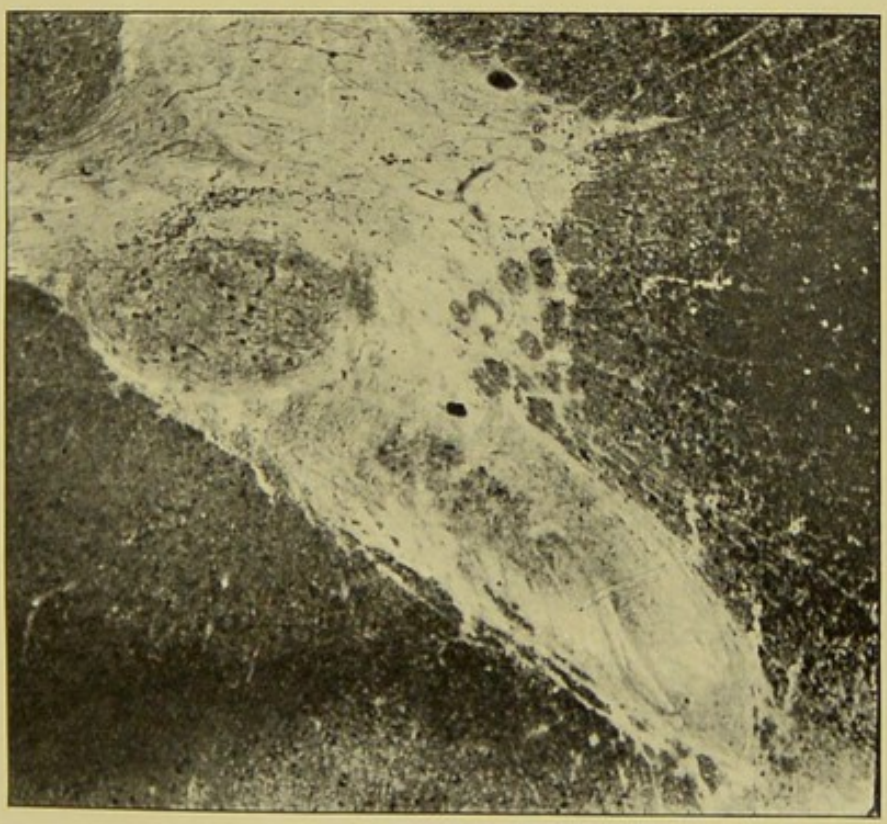


FIG. 2.

PLATE VIII.

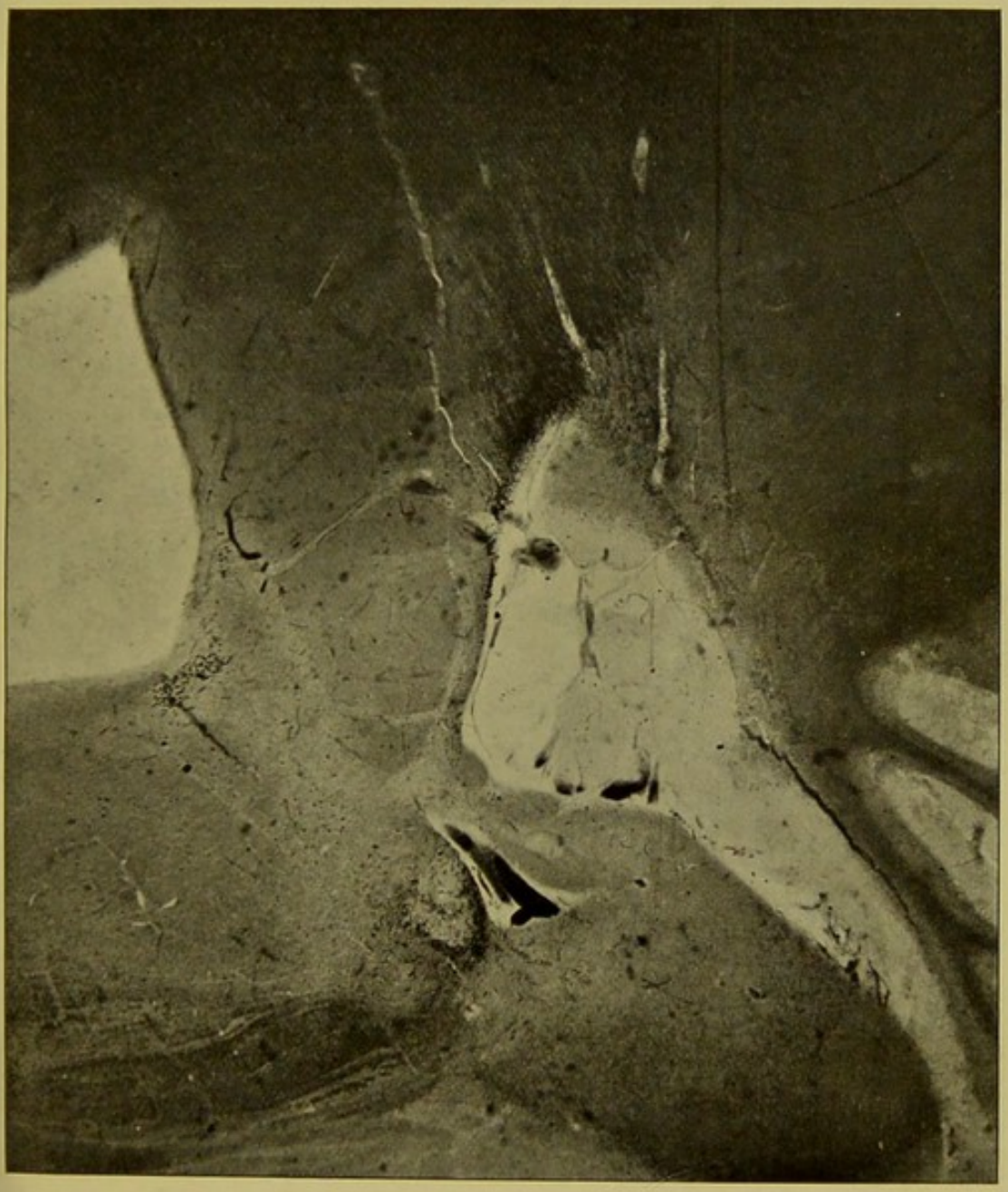


PLATE IX.

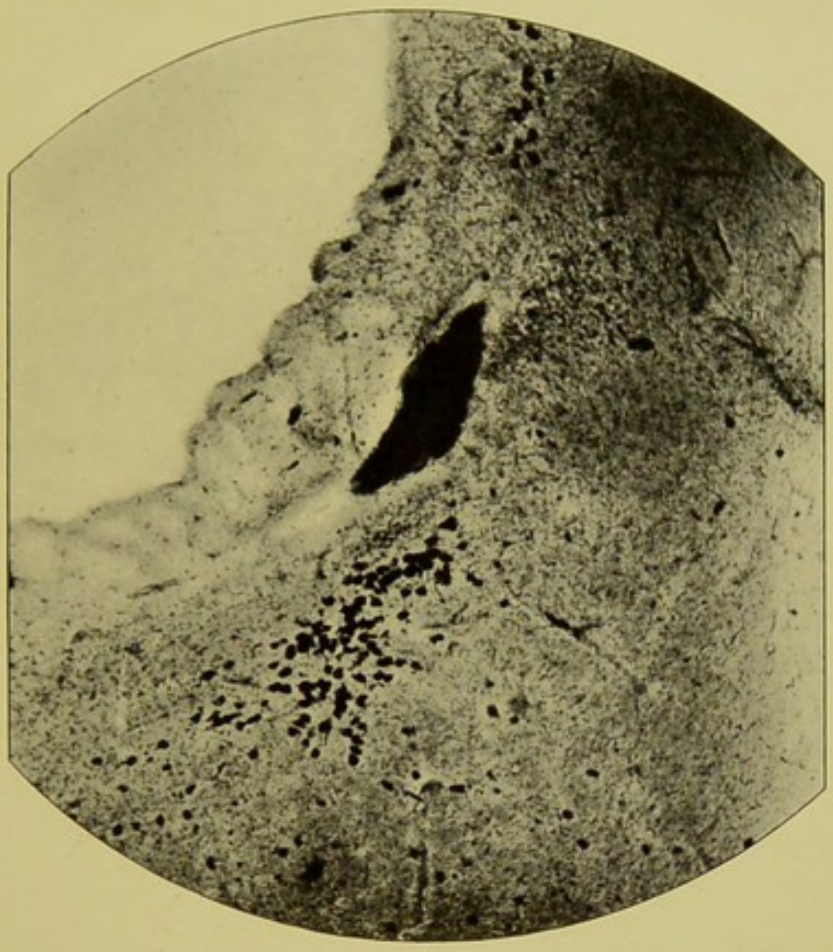


FIG. 1.

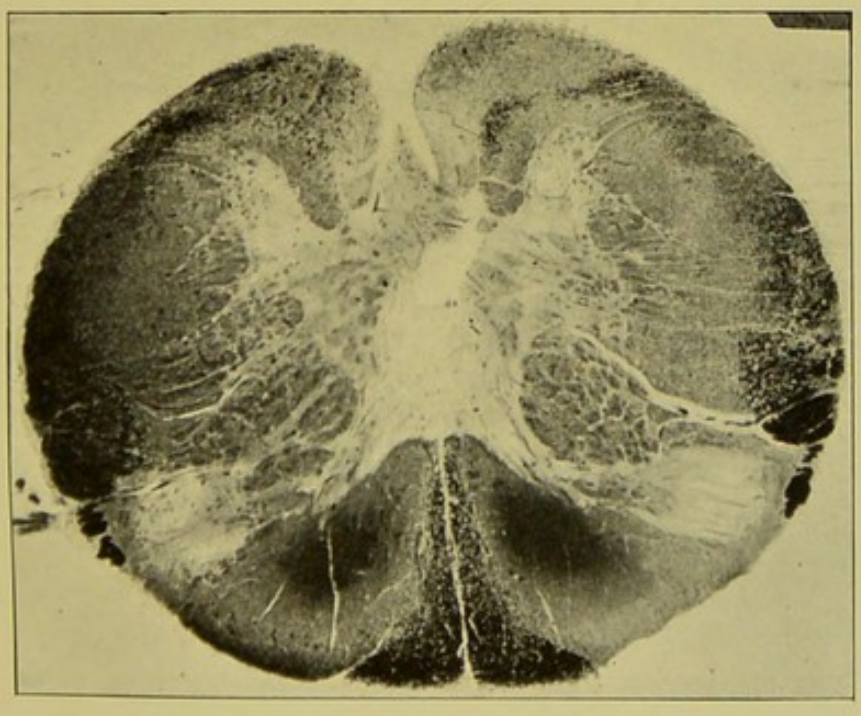


FIG. 2.

PLATE X.

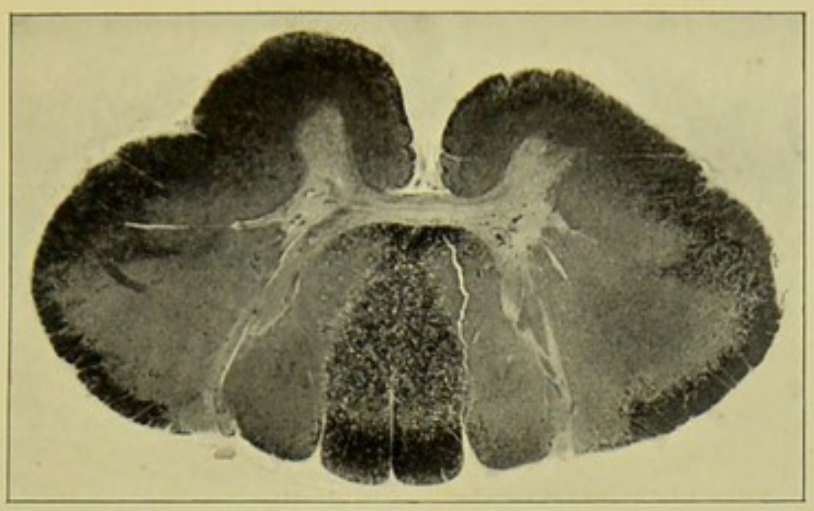


FIG. 1

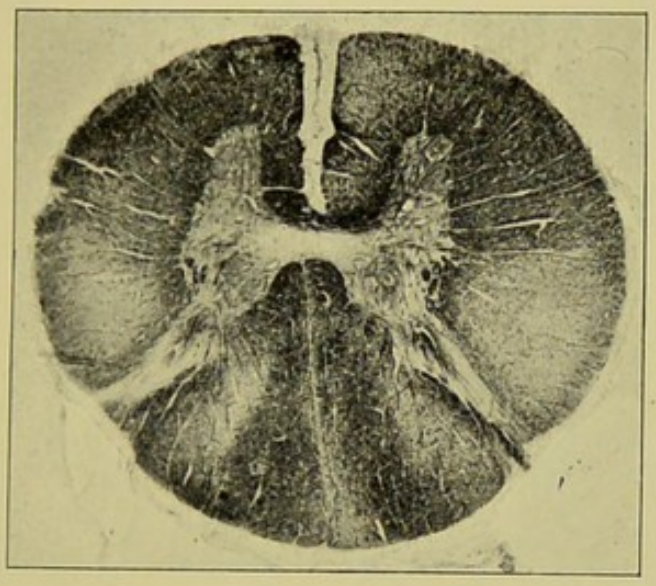


FIG. 2.

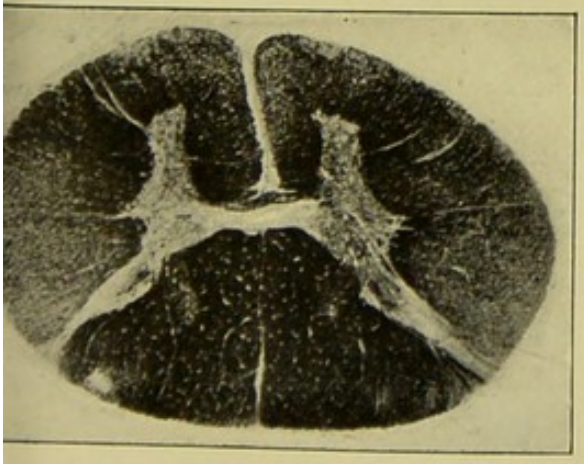


FIG. 3.

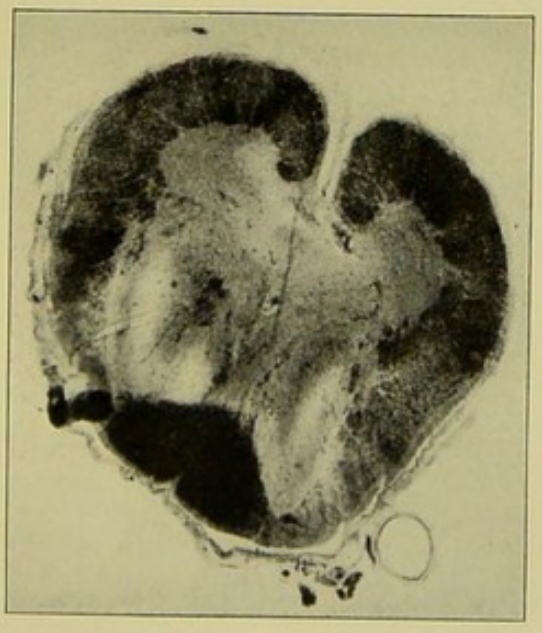


FIG. 4.

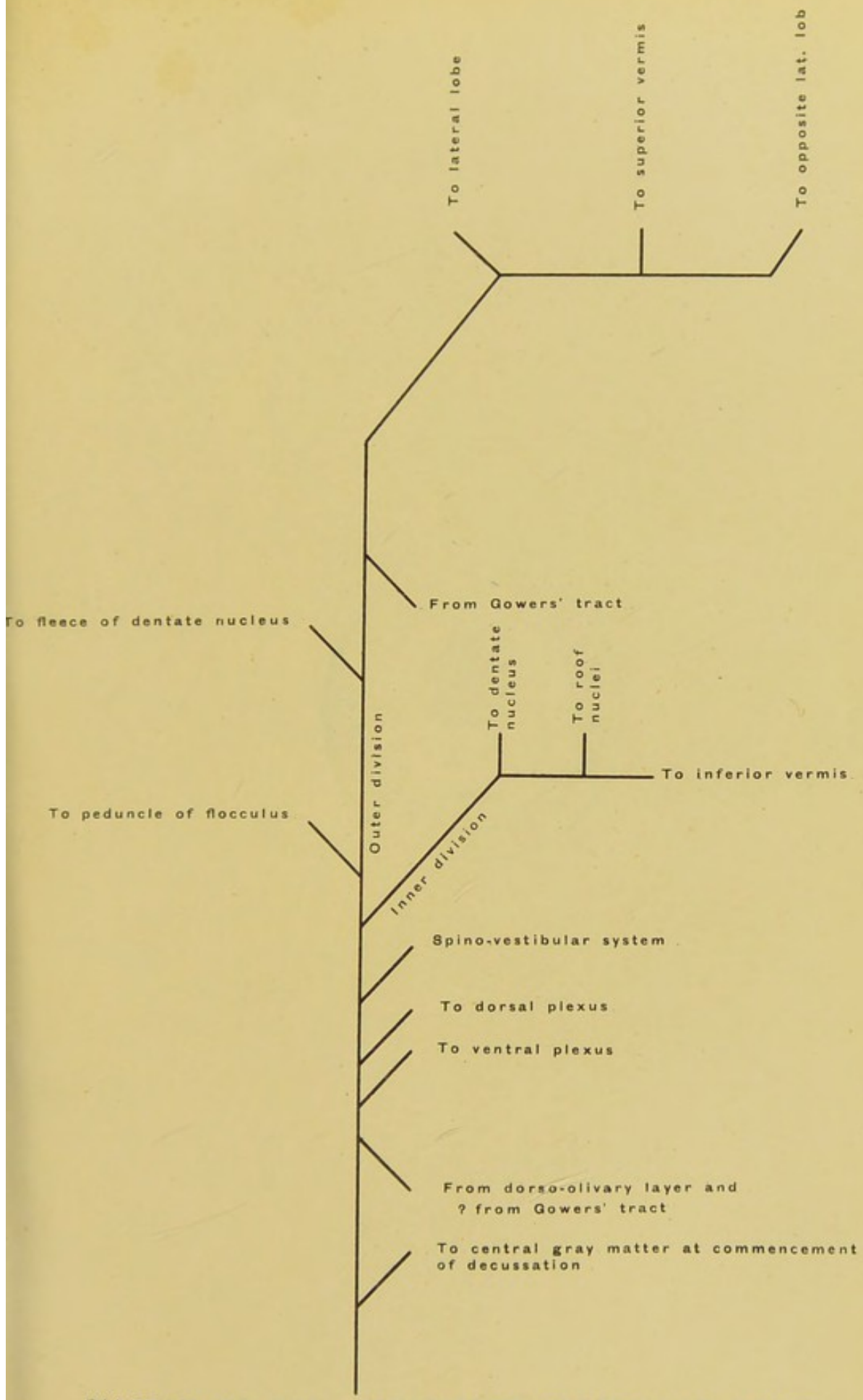


DIAGRAM OF THE LEFT DIRECT CEREBELLAR TRACT

Bale & Danielsson, Ltd., Lith.

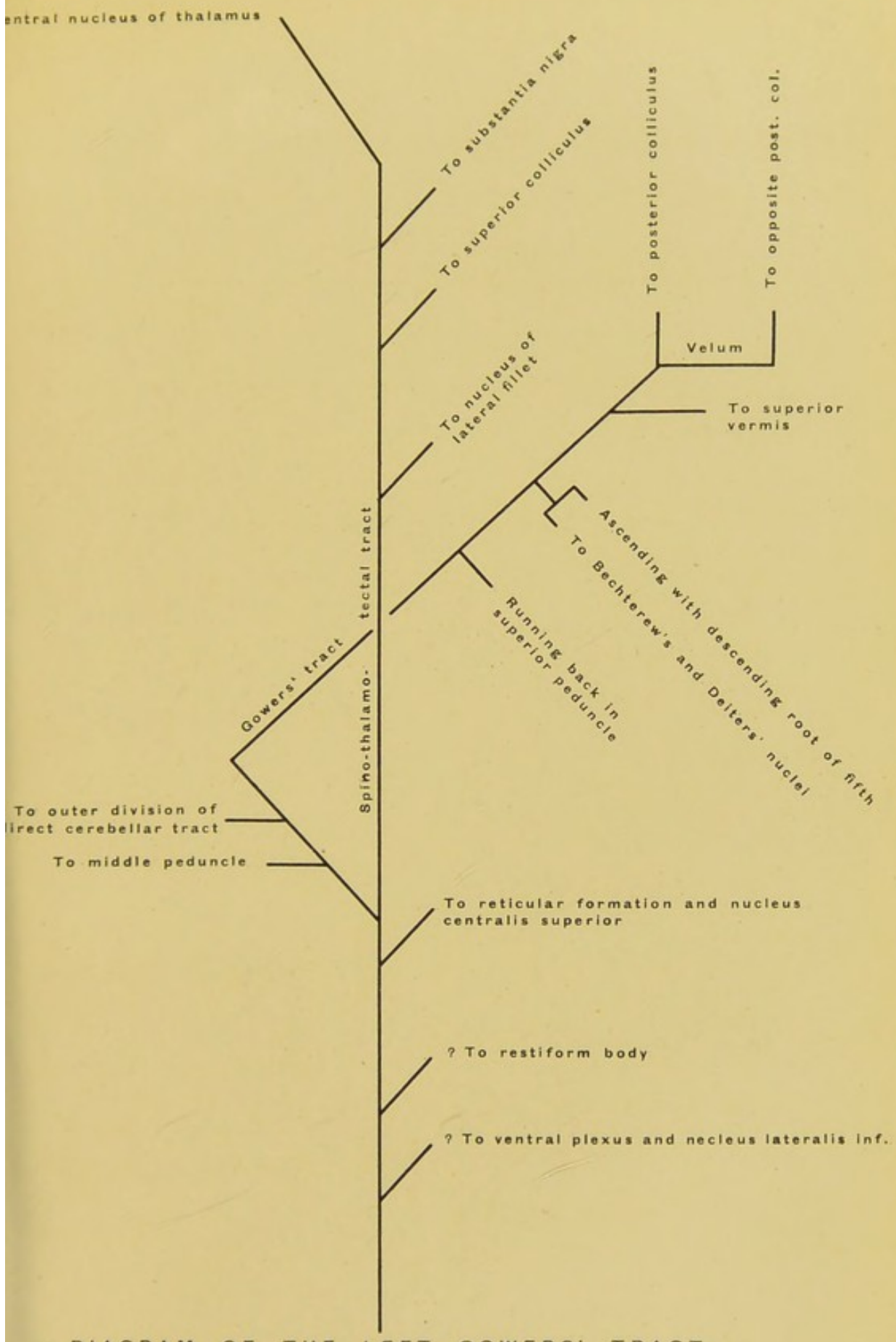
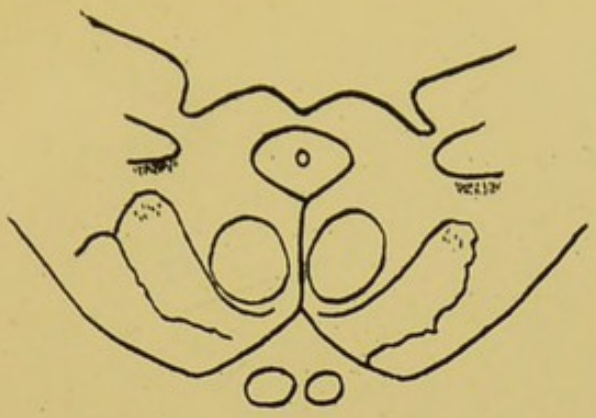
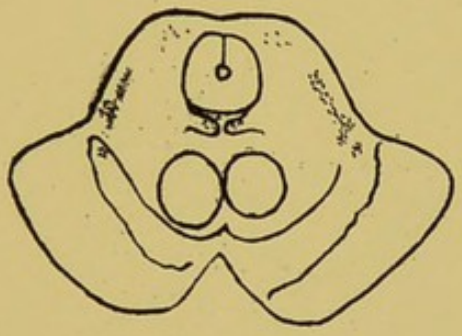


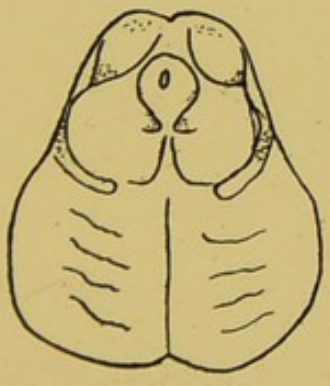
DIAGRAM OF THE LEFT GOWERS' TRACT

Bale & Danielsson, Ltd., Lith.

PLATE XI







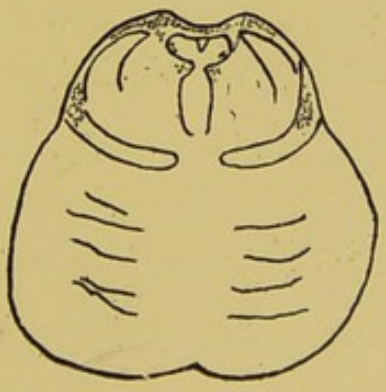
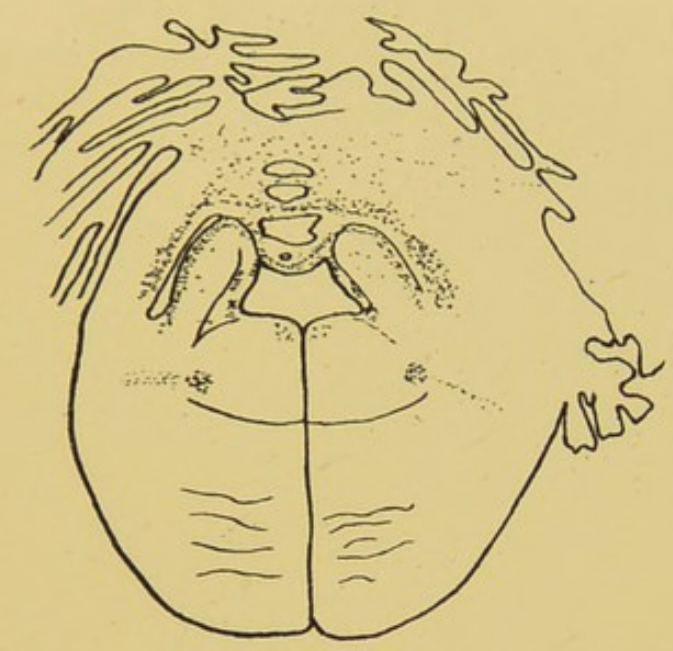


PLATE XII



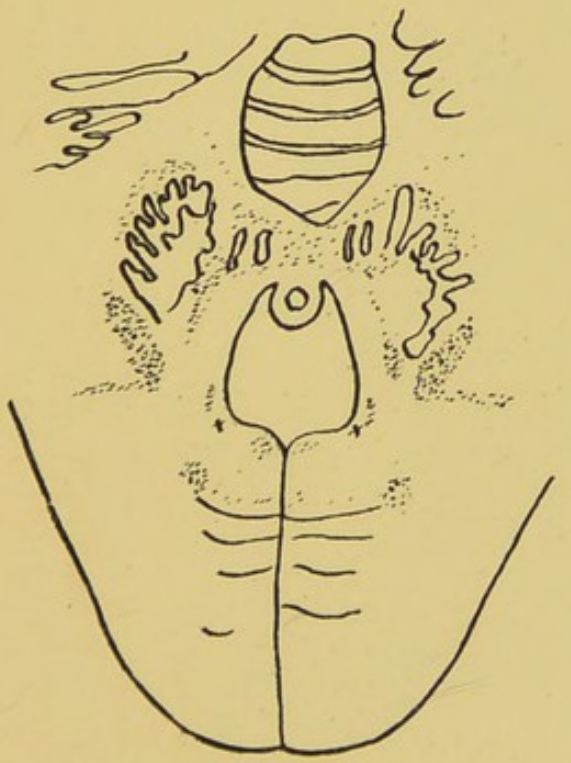
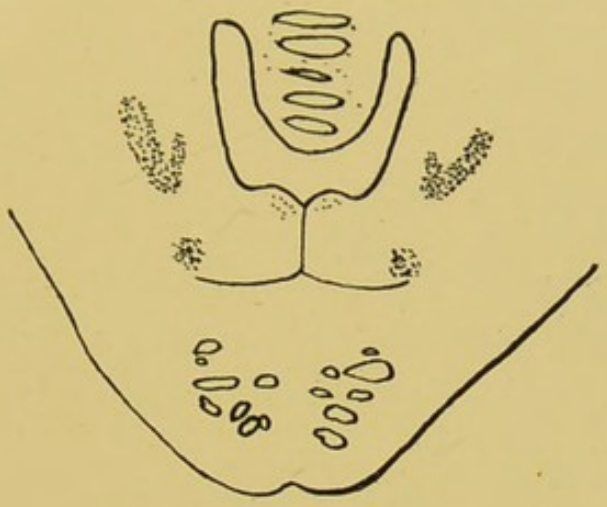


PLATE XIII



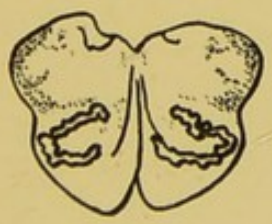


PLATE XIV

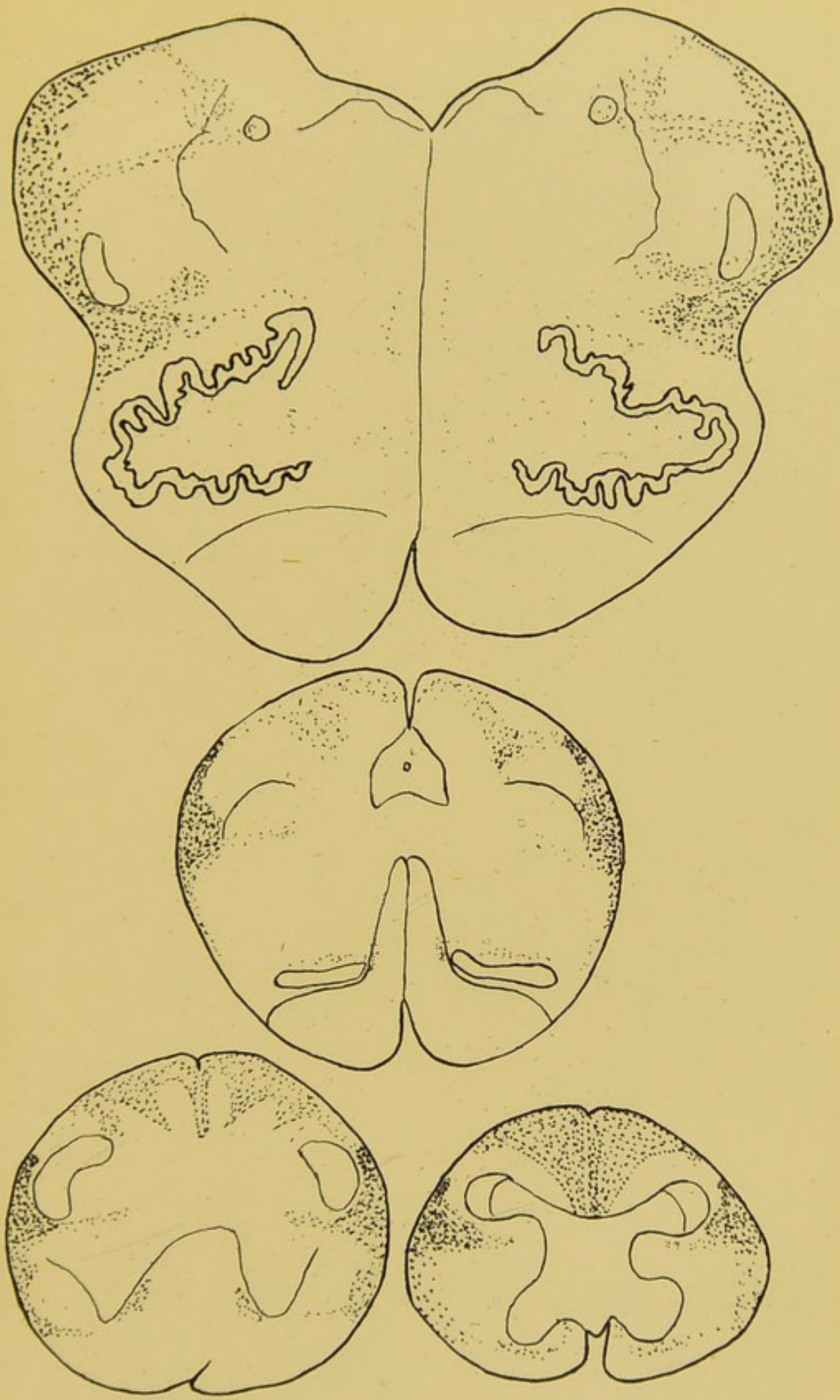


PLATE XV

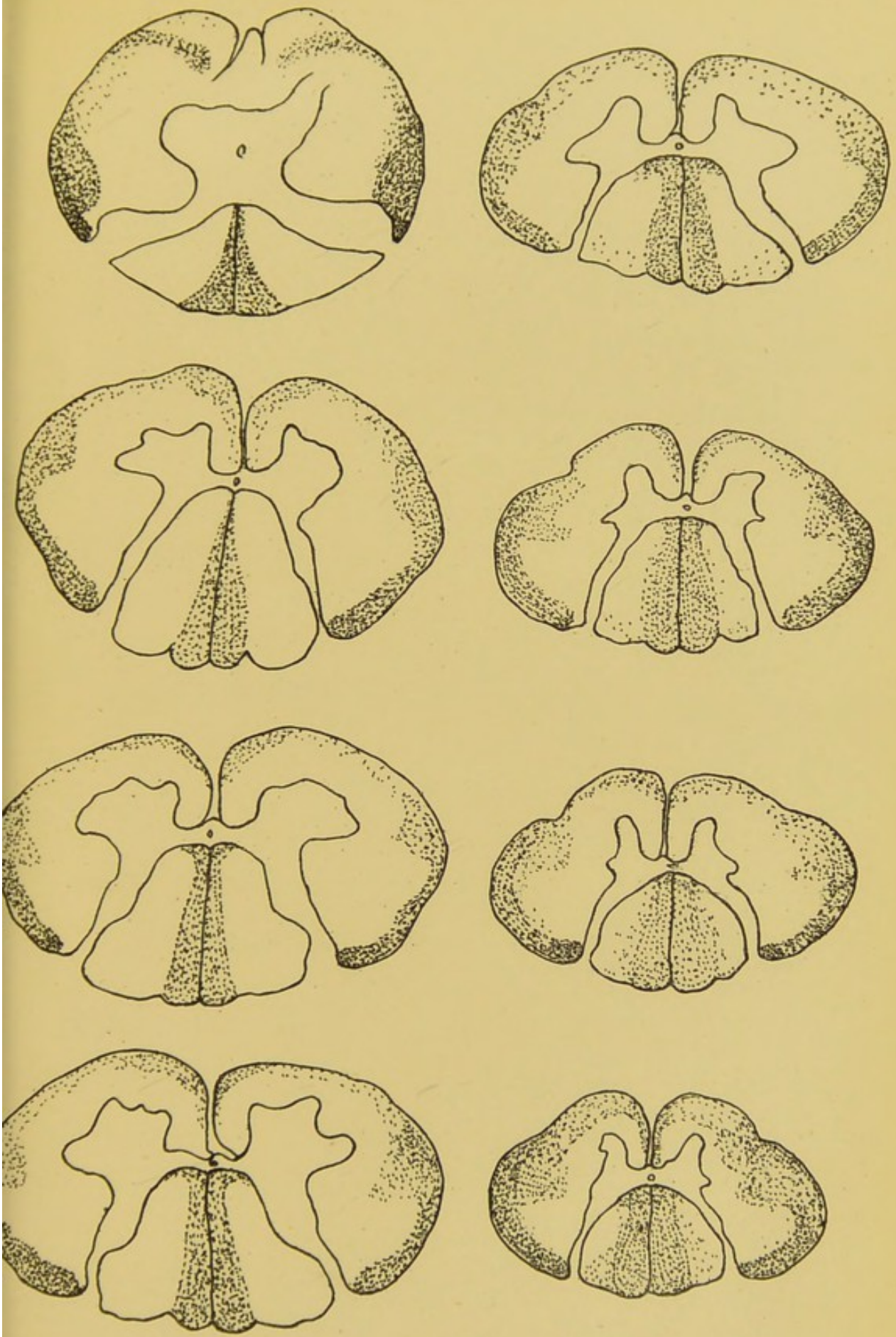
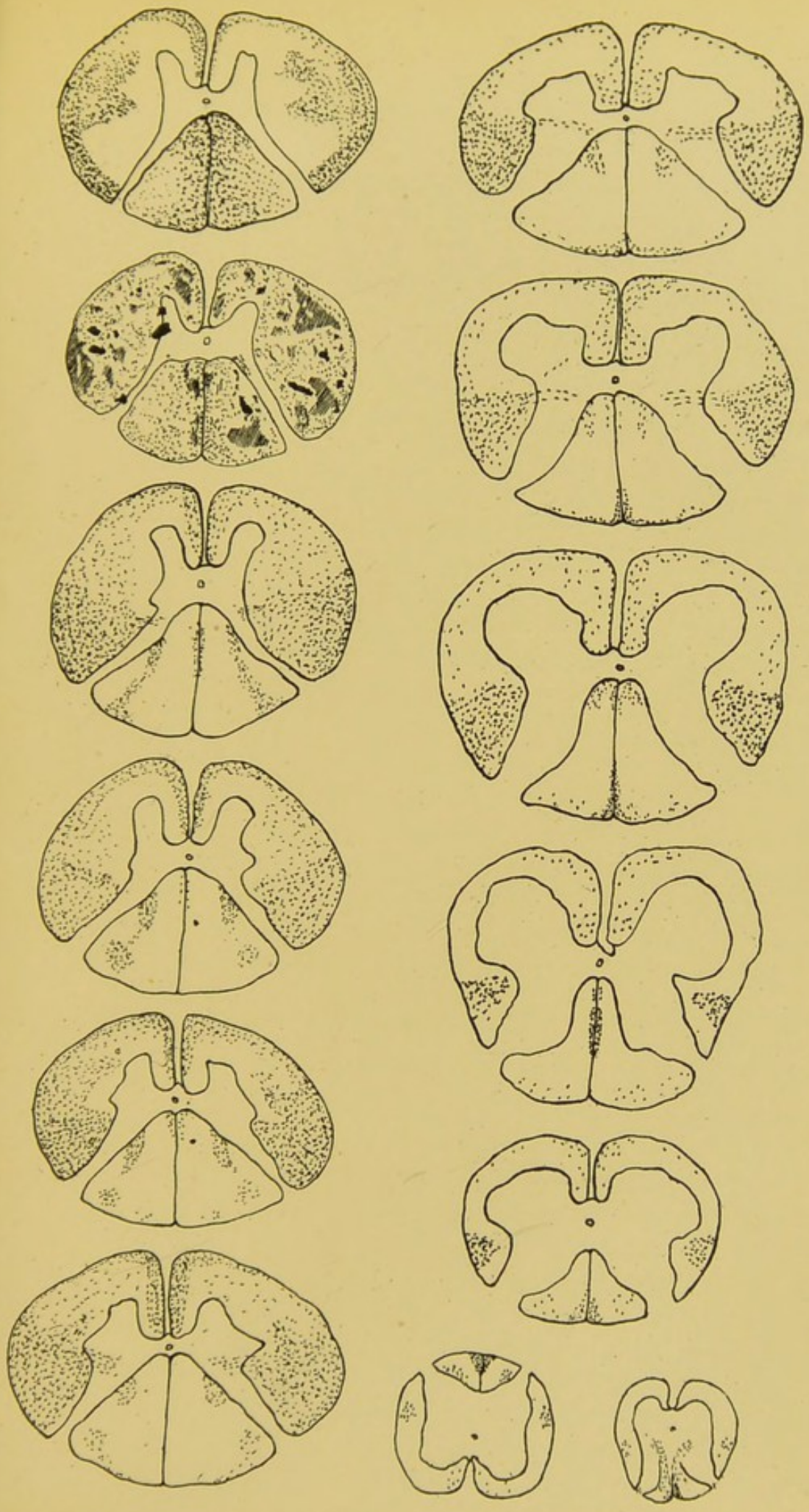


PLATE XVI



is found at successively higher levels above a transverse lesion, yet we cannot confirm the very common statement that the bulk of the degeneration in Gowers' tract cannot be traced above the cervical region, and we suggest that the earlier disappearance of the degenerated myelin from the more distal parts of degenerate neurones may account for the conflicting descriptions. We have found the position and relation of this tract in its course through the medulla and pons to be that which is usually described.

Attention may be drawn however to the very definite separation which occurs between the direct cerebellar tract, Gowers' tract, and the rest of the ventro-lateral degeneration at the level of the commencing pyramidal decussation. In the lateral funiculus of the medulla we have occasionally found the tract to occupy an unusually deep and dorsal situation lying practically between the two divisions of the antero-lateral nucleus. Fine collaterals from this tract appeared to end in these nuclei and also in connection with the ventral collateral plexus of the direct cerebellar tract.

We were unable to arrive at any definite conclusion with regard to the statement of Patrick that Gowers' tract receives an accession of fibres from the direct cerebellar tract in the lateral region of the medulla. Probably such an accession does exist, and we venture to suggest that these fibres may be those which subsequently pass from Gowers' tract at the level of the outgoing fifth nerve, to join the outer division of the direct cerebellar tract anterior to the dentato nucleus. In the lower pons we, in many cases, found the fibres of Gowers' tract arranged as a cylinder around a small mass composed of nerve-cells and non-degenerate white fibres, but no collaterals entered this mass.

From the mesial aspect of the tract a considerable number of collaterals were given off to the reticular formation, some of them passing inwards to reach the nucleus centralis medius.

No collaterals could be traced to the superior olive, nor directly from this region to Deiters' and Bechterew's nucleus.

At the level of the fifth nerve and just before the separation of the spino-tectal and spino-thalamic systems from

their association with Gowers' tract, we constantly found a strong bundle of fibres given off from the outer side of the tract, which was directed outwards, downwards, and somewhat backwards in the anterior portion of the pons, whence they run to the lateral lobe of the cerebellum *viâ* the middle peduncle.

Just before the lateral surface of the brachium conjunctivum becomes free, a strong bundle of rather coarse fibres left Gowers' tract to pass outwards and to join the outer division of the direct cerebellar tract just in front of the dentate nucleus. This bundle corresponds with that described by Auerbach, but we were unable to follow it as he described, on a path mesial to the dentate nucleus and ending in the latter body. It seemed definitely to join the outer division of the direct cerebellar tract.

Just posterior to the posterior colliculus, and as it is lying immediately ventro-mesial to the mesencephalic trigeminal root, Gowers' tract separated from the spino-tectal and spino-thalamic systems and passing obliquely upwards and backwards traversed the gray layer covering the superior peduncle and entered the velum, many of the fibres crossing to the opposite side, most of the fibres apparently ending in the superior vermis.

From the velum fibres passed conspicuously to the posterior colliculus of both sides by way of the frænulum. A certain number of fibres also turned back from the velum at the level of the decussation of the fourth nerve to run backwards in the superior peduncle.

We have now to draw attention to our observations upon an important question which has been raised by Horsley and Thiele, in respect to certain fibres descending from the velum anterius to the region of Deiters' nucleus and lying in the gray matter mesial to the brachium conjunctivum.

Those authors found these fibres degenerate in a transverse lesion of the spinal cord. They conclude that these fibres are derived from the opposite Gowers' tract, and that they are identical with the system of fibres so conspicuous in Weigert sections of the fœtal brain stem, which descend from the region of the root nuclei to Deiters' nucleus and which

has been described by Stilling, Bruce, Edinger, Kölliker, and others, and which are described as having their nuclei of origin in the nuclei tecti.

Further, Horsley has in the cat traced degenerate fibres from Gowers' tract across the root of the fourth ventricle into the gray matter lying between the brachium conjunctivum and the lateral wall of the ventricle.

In all our cases we have found degenerate fibres from Gowers' tract to Deiters' nucleus, which we describe as follows:—

In sections immediately posterior to the posterior colliculus, where the dorsal edge of the brachium conjunctivum is sinking, and where the upper part of the nucleus cerebello-acusticus is in close proximity with the dorsal fibres of the brachium, numerous degenerate fibres of Gowers' tract, certainly of the same side, and possibly also from the opposite side, were seen to turn sharply backwards and ventralwards and pass between the mesial aspect of the brachium and the nucleus cerebello-acusticus, here mingling with the fibres of the descending root of the trigeminus. In all posterior sections these fibres were conspicuous, lying first dorso-lateral to the nucleus cerebello-acusticus, then dorso-lateral to Bechterew's nucleus. These fibres could be seen constantly entering and breaking up in these nuclei, gradually diminishing in numbers, being lost below the upper part of Deiters' nucleus.

All along the lateral edge of the velum degenerate fibres could be traced from Gowers' tract into the gray matter between the brachium and the wall of the ventricle, but we were unable to trace such fibres for any distance.

It is of some importance to note that as the fibres from Gowers' tract to Deiters' nucleus turn down and back among the fibres of the descending root of the fifth, a few ascending fibres following this root were traceable in rapidly diminishing numbers as far as the superior colliculus, where they appeared to terminate in the nucleus lateralis superior.

While our conclusions confirm those of Horsley and Thiele as regards fibres derived from Gowers' tract passing to Bechterew's and Deiters' nuclei, we think that these

fibres are entirely distinct from that system described as passing from the nuclei tecti to Deiters' nuclei for the following reasons. We have examined a case of abscess limited to the root nuclei and have traced the degeneration in the descending systems of fibres passing to Deiters' nucleus (BRAIN, 1901). The plane in which these fibres run is almost a vertical plane from the root nuclei, whereas the plane of the fibres from Gowers' tract is very oblique. Again, we would point out that the point of separation of the latter fibres from Gowers' tract is comparatively distant from the root nuclei.

Lastly, the relation of the degenerate fibres to Deiters' nucleus was quite different in the case of the lesion of the root nuclei that we have mentioned.

The Spino-tectal and Spino-thalamic Tracts.

When the separation of Gowers' tract occurs these systems lie as a compact bundle of fibres ventro-mesial to the descending root of the fifth nerve. As the lateral fillet rises to cover in the brachium conjunctivum laterally, the fibres lie in that structure. Immediately behind the nucleus of the lateral fillet fine fibres arise in considerable numbers from the mesial aspect of the tracts under consideration, which pass on to the mesial side of the nucleus of the lateral fillet and end in that nucleus.

The tract now divides into a ventral and a dorsal portion; the ventral portion (spino-thalamic fibres) remains in the region of the fillet close to the lateral sulcus, while the dorsal portion (spino-tectal fibres) rises towards the oval nucleus and runs in the cup of white substance in which that egg-shaped nucleus rests. Some of these fibres end in the oval nucleus.

From the posterior colliculus the spino-tectal tract extends forwards into the superior colliculus, occupying a roughly oval area closely ventro-mesial to the commencement of the brachium posterior, and between the latter structure and the deep white fibres.

Many fibres end here in the nucleus of the superior colliculus and in the deep gray matter, and some cross in

the tectal commissure to end in a similar position upon the opposite side. The fibres occupying the fusiform area above described do not all end in the colliculus, but after all the fibres to the colliculus had been given off they appeared to shift down and out to a position roughly one-third nearer the lateral nucleus than the dorsal surface of the tectum and close to the lateral surface, where they were joined by the chief bundle of spino-thalamic fibres, which we spoke of as retaining their position in the region of the lateral fillet when the spino-tectal bundle was given off.

As a matter of fact the tendency of the fibres to sink ventralwards, as seen in transverse sections, was apparent only, and was due to the diminution of the height of the tectum. Towards the anterior parts of the superior colliculus the spino-thalamic bundle sunk rapidly to touch the substantia nigra, to which many collaterals were given off. Coming here in contact with the mesial surface of the internal geniculate body it swung abruptly outwards in close contact with the under surface of that structure into the ventral nucleus of the thalamus, beyond which we have failed to trace it. No collaterals were given off to either geniculate body. Referring to the publications of Rossolimo and of Troschin upon this subject, we would draw attention to the fact that both these authors described fibres from this tract entering the substantia nigra at the lateral angle, which could be traced across the breadth of this structure as far as the middle line. We have been able to trace the fibres only into the outer fourth of the substantia nigra.

Further, Rossolimo is quite certain, both in his statements and figures, that in his cases the fibres cross the ventral nucleus of the thalamus and end in the globus pallidus of the lentiform nucleus.

We have failed, however, to follow them farther than the ventral nucleus.

The Ventral Restiformal Spino-cerebellar System of Tschermak.

We have found a variable number of fibres passing from the ventro-lateral region of the first cervical segment to the

medulla which seem to correspond to the fibres described by Tschermak.

In the first cervical segment these fibres were situated in front of Gowers' tract and passed inwards, following the course of the ascending fibres of the dorsal longitudinal bundle to lie deeply immediately external to the pyramid; the fibres were here mixed with von Solder's fibres and the fibres of the dorsal longitudinal bundle. At the commencement of the pole of the olive some of these fibres passed directly into the dorso-olivary layer, while others passed first mesial to the olive and then turned into the dorso-olivary layer. These fibres passed outwards and appeared to join the direct cerebellar tract by looping under the spinal trigeminal root. We found the largest number of these fibres in two cases of subacute combined degeneration in which the lesion of the ventro-lateral region extended as high as the third cervical segment.

von Solder's fibres were present in variable numbers in some cases, but in several cases of quite recent degeneration we failed to demonstrate them.

They pass from the ventro-lateral region of the first cervical segment with the fibres of the dorsal longitudinal bundle and Tschermak's fibres to the mesial side of the inferior olive, from which region a few fibres entered the olive; they were then continued upwards in the outer part of the middle fillet, and appeared to join the spino-thalamic degeneration at the knee of the lateral fillet.

Their inconstancy suggests they may be fibres of the spino-thalamic system taking an unusual course.

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