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CONTRIBUTIONS TO THE STUDY OF SOME OF THE AFFERENT AND EFFERENT TRACTS IN THE SPINAL CORD.

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INTRODUCTION.

These studies deal more especially with :—

- (1.) The posterior columns.
- (2.) The direct cerebellar tract.
- (3.) The afferent antero-lateral tract.
- (4.) The pyramidal system, including the crossed, the direct anterior, and direct lateral (homolateral) pyramidal tracts.
- (5.) The efferent antero-lateral tract.
- (6.) Certain other efferent internuncial tracts.

They are based on investigations of the spinal cords of the following cases in man :—

- (1.) Degeneration of the first sacral roots in a case of alcoholic neuritis.
- (2.) A tumour involving chiefly the seventh cervical root on one side, and a limited portion of the lateral region of the cord on the same side.

(3.) An intra-medullary tumour of the lower part of the lumbo-sacral cord.

(4.) A complete transverse lesion of the spinal cord at the level of the sixth and seventh cervical segments, the result of a fracture dislocation.

(5.) A case in which a large tumour was removed from one cerebral hemisphere.

(6.) A large cyst of the centrum ovale of one cerebral hemisphere, the result of the degeneration of a malignant tumour.

My sincere thanks are due to Sir William Gowers for allowing me to make use of Case 1, to Dr. Beevor for Case 2, to Mr. Victor Horsley for Cases 3, 4, and 5, and Dr. Charlton Bastian for Case 6.

I propose to first give a brief account of the chief points in each case, as they concern our present study, and then to discuss the facts which appear to be the outcome of the investigations collectively, and in conjunction with previously ascertained facts of a like character.

DEGENERATION OF THE FIRST SACRAL ROOTS IN A CASE OF ALCOHOLIC NEURITIS.

In this case sections prepared by Marchi's method show degeneration of both first sacral roots, but that on the one side is only slight, whereas the other root is considerably, though not completely degenerated. On entering the cord the fibres at first hug the grey matter of the posterior horn, being limited to the dorsal half of that part of the posterior columns which borders on the grey matter (see fig. 1). They, however, quickly become scattered through the posterior columns, so that sections from the 5th lumbar segment show that no part of these tracts on the side of the more degenerated root is entirely free from degenerate fibres, excepting the cornu-commissural zone and septo-marginal tracts, though these are still very much more numerous in the dorsal half of the columns, and especially in the outer part next to the grey matter. No degenerate fibres are seen either in the cornu-commissural zone, that is, the ventral

part of the posterior columns bordering on the posterior commissure, septum and cornu, and to which the name cornu-commissural tract has been given by Marie, or in the septo-marginal tract, so named by Bruce and Muir in consequence of its immediate relationship to the posterior median septum.

There is distinct degeneration of many of the reflex collaterals, numerous degenerated fibres of this kind being seen coursing through the grey matter to the ventral horn of the same side, both in the 5th lumbar and first sacral segments of the cord; but none pass to the ventral horn of the opposite side, nor do any of the fibres pass beyond the grey matter of the same side as the affected posterior columns, to reach the white matter of the ventro-lateral region of the cord. A few collaterals are, however, seen passing across the base of the posterior horn towards the lateral column of the same side, without any degenerated fibres being actually seen in this column. There is also degeneration of some of the fine collaterals in the external part of the gelatinous substance of Rolando. No degenerated fibres can be seen passing by any route to the opposite posterior columns, and those seen in them clearly belong to the opposite posterior root, which is slightly degenerated.

In the 3rd lumbar segment of the cord the distribution of the degeneration differs from that above described; there is degeneration of all parts of the postero-internal column, including the cornu-commissural zone, and there is also degeneration of the ventral third of the postero-external column, and of a dorsal zone of it at the periphery of the cord, not quite amounting to a third of the dorso-ventral area of the tract. The middle third of the postero-external column is free from degeneration, especially that part of it which borders on the substantia gelatinosa Rolandi. No degenerate fibres are seen passing to the ventral horn of the same side, or to any other part of the grey, or white matter of the cord, other than the posterior columns as already described.

In the thoracic region the precise distribution of the degenerated fibres naturally varies with the level at which

they are seen ; but the degeneration tends more and more to limit itself to the postero-internal column, and more and more to the dorsal part of this, according to the well established law with regard to fibres derived from the caudal segments of the cord. Thus it comes about that less and less degeneration is seen in the postero-external column, and in the cornu-commissural zone, as we pass towards the cephalic end of the cord. No degenerate fibres are seen passing to the grey matter of the ventral horn, or any other part of the cord.

The degeneration as seen in the cervical cord is limited to the dorsal two-thirds of the postero-internal column, the area thus occupied being triangular in area with its apex abutting on the posterior median septum ventrally, and the base being situated dorsally at the periphery of the cord, at which part the degeneration occupies the whole transverse area of the postero-internal column. All other parts of this column are free from degeneration, as is the postero-external column. No degenerated fibres are seen passing to any of the other tracts of the cord, nor can any be traced to the grey matter of either ventral horn or elsewhere.

TUMOUR INVOLVING CHIEFLY THE SEVENTH CERVICAL ROOT ON ONE SIDE, AND A LIMITED PORTION OF THE LATERAL REGION OF THE CORD OF THE SAME SIDE.

This is a case in which a large sarcoma in the neck extended into the neural canal along the 7th cervical root, which it destroyed, and to some extent pressed on the 6th and 8th cervical roots, without, however, either involving or destroying them. The growth also pressed upon the right half of the cord, so as to push it over to the left side of the neural canal, and at the same time destroyed a limited area of the lateral region of it, corresponding to the areas occupied by the direct cerebellar and crossed pyramidal tracts on the right side. Otherwise the cord, as seen on transverse section, was intact.

The degenerations seen in segments of the cord above the lesion consist in a well-marked band of degeneration

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

which at the level of the 3rd cervical segment extends almost from the posterior commissure to the dorsal periphery of the cord. The ventral end of this degenerated area is separated from the posterior commissure by a narrow band of healthy fibres of the cornu-commissural zone. The dorsal end of the degenerated area at the periphery of the cord is somewhat abruptly widened out, for about a fifth of its total length, to about four or five times the breadth of its ventral four-fifths, the ventral third being in its turn slightly wider than the portion separating it from the wide peripheral dorsal area (see fig. 2). This degenerated band is accurately limited to the inner border of the postero-external column throughout the greater part of its length, coming to within a short distance of the anterior fourth of the posterior median septum from which it is only separated by a very narrow band of healthy fibres in this part. The band of degeneration maintains this position in its further course to the medulla without encroaching on the postero-internal column.

In addition to this well-marked band of degeneration extending along the inner border of the postero-external column on the right side, and separated from the postero-internal tract by the septum intermedium, there exists, on each side of the posterior median fissure, a small area of degeneration, absolutely symmetrical, and limited to the postero-internal columns. These degenerations are situated at the ventral end of the dorsal half of the postero-internal columns, and are so placed that their ventral extremities, which are broader than their dorsal, abut on the posterior median fissure. Their dorsal, narrow, or tailed ends, on the other hand, are situated at some distance from the posterior median septum, so that these degenerated areas lie somewhat obliquely across the postero-internal columns.

The only other tract degenerated above the level of the lesion is the direct cerebellar tract on the side of the damage to the spinal cord (see fig. 2).

Below the lesion, on the other hand, as seen in sections caudal to the 3rd thoracic segment, the only tract found degenerated is the crossed pyramidal tract on the side of the

tumour, and this could be traced to the most caudal end of the lumbo-sacral cord.

INTRA-MEDULLARY TUMOUR OF THE LOWER PART OF THE LUMBO-SACRAL CORD.

In this case the tumour involved the whole of the conus terminalis and extended up into the lumbo-sacral cord to a greater height on one side than on the other. At the lower part of the sacral cord it was more or less centrally situated with a margin of spinal cord tissue all round its periphery, but even here there was a distinct tendency for the one lateral half of the cord to escape to a greater extent than the other. By the time the level of the 4th lumbar segment was reached the evidence of the greater involvement of one half of the cord was most pronounced, nearly all of the grey matter on one side having escaped together with all the white matter, except both posterior columns, the direct pyramidal tract and part of the adjacent ground bundles (see fig. 3). The destruction of the other half of the cord was even more complete than at more caudal levels, in that the growth reached to the periphery of the cord, except at one or two small points.

The 3rd lumbar segment, though not itself actually involved by new growth on either side, was nevertheless swollen and softened on one side, probably in consequence of interference with its vascular supply by the growth in the adjacent segment. The swollen, softened condition corresponded to the side on which the tumour reached its highest level.

As far as can be determined the 2nd lumbar segment is free from any morbid change other than the ascending degeneration of afferent tracts, and in this lies the chief interest of the case from our point of view, in that both the postero-external and postero-internal columns are degenerated on both sides of the cord, while with the exception of a few scattered degenerated fibres the ventro-lateral ascending tract is intact on one side, but is distinctly degenerated on the opposite side, as shown in fig. 4, which

is from a photomicrograph of a section from the 11th thoracic segment of the cord. The side on which this band of degeneration exists in the region of the ventro-lateral ascending tract corresponds to that on which the tumour reaches its highest level.

The degenerations though obvious in sections stained by Pal's method, being recent in character were very much more pronounced as seen in sections prepared by Marchi's method, which revealed nerve fibres in a recent state of degeneration in all parts of the posterior columns. The latter method also allowed of degenerated fibres being traced from the posterior columns to other parts of the cord, but we do not propose to enter on the question of their distribution on the present occasion. Apart from degenerated fibres of this kind, the degeneration of the posterior columns on both sides, and the ventro-lateral ascending tract on one side, the other tracts at this and higher segments of the cord are preserved.

Before leaving this part of our subject we may state that examination of the *cauda equina* showed that while many bundles of degenerated fibres existed in it, a considerably larger number of bundles were composed of normally medullated fibres. Indeed, the degenerated bundles were not more than could be accounted for by those proceeding from the destroyed segments of the cord, without supposing that the growth in the cord had caused any direct damage by pressure of the fibres of the *cauda equina*, of which there was also no other evidence.

COMPLETE TRANSVERSE LESION OF THE SPINAL CORD, AT THE LEVEL OF THE SIXTH AND SEVENTH CERVICAL SEGMENTS, THE RESULT OF A FRACTURE DISLOCATION.

In this case the spinal cord was completely destroyed at the level of the 6th and 7th cervical segments, so that no trace of grey or white matter could be found at these levels two years after the accident, except that in the posterior part of the cicatrix some posterior root fibres (? regenerated) could be seen.

Immediately on the cephalic side of the lesion there is complete sclerosis of the posterior columns, Lissauer's tract, the direct cerebellar and afferent ventro-lateral tracts on both sides. As we pass further towards the cephalic extremity, in accordance with the well-established rule, the degeneration in the posterior columns diminishes in area in consequence of the incoming roots above the level of the lesion supplying normal fibres to the outer zone of the postero-external column which borders on the grey matter of the posterior horn as shown in fig. 5, taken from a section at the level of the 4th cervical segment. These normal fibres must of necessity be supplied by the 5th cervical and other roots nearer the brain in the series; and it is worthy of note that the incoming normal fibres are limited to the postero-external column, even at the first cervical segment of the cord.

The degeneration of the direct cerebellar tract calls for no comment, except that it is interesting to note how closely the degenerated area in this case corresponds to that in the case in which this tract was interrupted on one side by a tumour at the 7th cervical segment. I wish, however, to call special attention to the position occupied by the sclerosed ascending ventro-lateral tract of Gowers, which is situated about midway between the periphery of the cord and the ventral horn, and while it merges dorsally into the area occupied by the direct cerebellar tract, there is no evidence that it ever comes to the periphery of the cord (see fig. 5).

Immediately caudal to the lesion there is marked sclerosis of the crossed and direct pyramidal tracts, the comma tracts of Schultze in the postero-external columns, and the ventro-lateral efferent tract. The only point to which I wish to call special attention in this connection is that the ventro-lateral efferent tract occupies the extreme periphery of the cord (see fig. 6), and this contrasts markedly with the afferent ventro-lateral tract, which is separated from the periphery by a well-marked band of normal fibres; the fibres of the efferent tract in fact.

In that the case was one of such long standing the Marchi method was not available for tracing the degenera-

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 8.

tions, which were accordingly traced by Pal's method. This allowed of the crossed pyramidal tracts being traced to the caudal extremity of the cord; but the sclerosis of the direct pyramidal tract can not be made out with certainty farther than the fourth lumbar segment, where it is very slight, while the sclerosis of the ventro-lateral efferent tract is still distinct at this level, but occupies only a limited part of the periphery of the cord close to the anterior median fissure.

The comma tract in the postero-external column can be traced by this method with certainty to the 6th thoracic segment, so that it extends, as a well-defined tract, through seven segments of the cervico-thoracic cord. From its appearance at the 6th thoracic segment, I have little doubt that had the Marchi method been available it would have been possible to trace this tract much farther caudally.

CASE IN WHICH A LARGE TUMOUR WAS REMOVED FROM ONE CEREBRAL HEMISPHERE.

A large sarcoma had been removed from the right cerebral hemisphere five weeks before the patient died. The area of cerebral cortex excised in its removal was such that the lower 5 cm. of the ascending frontal, and 2 cm. of the ascending parietal were left intact; the hinder part of the superior frontal was slightly implicated, but both the other frontal convolutions escaped, the anterior boundary of the removed area being the precentral sulcus. The posterior boundary corresponded to about the posterior end of the Sylvian sulcus, on the external aspect of the hemisphere, while, on the mesial aspect, this limit was marked by the posterior end of the calloso-marginal sulcus, at which point the dura was adherent. Otherwise $1\frac{1}{2}$ cm. of the upper end of the ascending frontal, and ascending parietal convolutions, together with the superior parietal, were intact. A vertical section into the hemisphere in the direction of its long axis, and about $2\frac{1}{4}$ cm. from the middle line, showed that the region from which the tumour had been removed embraced an area 7 cm. in the antero-posterior direction and 4 cm. in the vertical, limited to the white matter as far as the

surface grey matter was concerned, but reaching to the junction of the white matter and the grey bounding the hinder end of the fissure of Sylvius. There was in addition some softening in the region of the optic thalamus.

As the patient died five weeks after the tumour was removed, the case was one in which the Marchi method proved of the greatest possible advantage in tracing the degenerations consequent on the cerebral lesion. All that we propose to do, on the present occasion, is to consider the mode of behaviour of the pyramidal system, and certain other efferent tracts which degenerated in the spinal cord.

Before the decussation of the pyramids at the caudal end of the medulla there is, of course, pronounced degeneration of the pyramid on the side of the cerebral lesion (see fig. 7), while the opposite pyramid is absolutely intact.

In addition to this degeneration of the pyramid, degenerate fibres are seen in the inter-olivary stratum, on the side of the lesion occupying a limited part of this region, which abuts on the dorsal aspect of the pyramid. Another and quite distinct tract of degeneration seen on the side of the lesion is one which occupies the ventral margin of the medulla, just outside, and opposite to the ventro-external angle of the inferior olive. This is a well-defined band of degeneration, and is quite distinct and separate from the degenerated pyramid, lying between the external arcuate fibres as they course round the medulla opposite the inferior olive (see fig. 7). It has not been found possible to establish with certainty a connection of this tract with any of the degenerated fibres met with in the pons; but on the other hand, no secondary lesion, meningitic or otherwise, has been found to account for the degeneration of these fibres.

Throughout the whole length of the decussation successive sections reveal a thick band of degenerated fibres, stained black by the Marchi method, streaming across the medulla oblongata to reach the opposite crossed pyramidal tract. So pronounced is this band that it appears as if the whole of the fibres of the degenerated pyramid at the particular level under observation were passing to the opposite crossed pyramidal tract (see fig. 8). A few scattered fibres

are, however, seen passing from the degenerate pyramid to the lateral pyramidal tract of the same side, especially towards the cephalic end of the decussation, but the number of these is small compared to what one would have expected with so extensive a degeneration of the pyramid.

It is impossible to distinguish the degenerate fibres that were seen in the inter-olivary stratum from those of the pyramid, at this level; but throughout the caudal end of the medulla there is seen a distinct tract of degenerated fibres, separate from the pyramid, and occupying the lateral region of the medulla opposite the ventral tip of the anterior horn (see fig. 9). This is the same tract of fibres which was seen opposite the ventro-external angle of the inferior olive before the decussation; but whereas in that situation it was a narrow band of some length, here it occupies a more or less oval area.

A well-defined group of degenerated fibres occupies the dorsal part of the otherwise unaffected pyramid (see fig. 10), which structure, it will be remembered, was quite free from any degeneration above the decussation. This bundle of fibres lies between the root of the ventral horn and the decussating fibres derived from the degenerated pyramid.

In the cervical cord, as seen in sections at the 5th segment, the efferent tracts found degenerated are both lateral pyramidal tracts, the direct pyramidal tract on the side of the cerebral lesion, a tract at the periphery of the ventral part of the cord, opposite the ventral horn, and another collection of fibres on the inner side of the ventral horn of the side of the cord opposite to the cerebral lesion. Of these degenerations by far the most extensive is, of course, that of the crossed pyramidal tract on the side opposite to the lesion. Degenerated fibres occupy a far wider area than that usually assigned to the fibres of the crossed pyramidal tract which are derived from the cerebrum. The peripheral region of the cord in the positions of the direct cerebellar, and ventro-lateral afferent and efferent tracts is spared, but degenerated fibres otherwise occupy the whole of the lateral area of the cord up to the grey matter of the posterior and anterior horns,

the lateral limiting layer being crowded with degenerated fibres. Moreover, the degenerate fibres are seen ventrally to the supposed limits of the pyramidal tract chiefly in that part of the white matter which abuts on the anterior horn, and they form a well-marked band which extends round in the region of the anterior ground bundles on the ventral side of the horn so as almost to meet the group of degenerated fibres situated on the inner side of the horn, though there is a distinct gap between these two areas of degeneration. A few scattered degenerated fibres are seen at the periphery of the cord in the dorsal part of the afferent and efferent ventro-lateral tracts, extending as far ventrally as to be on a level with the tip of the ventral horn.

The degeneration seen in the lateral pyramidal tract on the side of the lesion is scanty, scattered and much more limited as regards area than that of the opposite lateral tract. There is extensive degeneration of the direct pyramidal tract on the side of the lesion, limited chiefly to its dorsal two-thirds, while its ventral third is comparatively free from degenerated fibres as shown by the Marchi method.

The tract at the periphery of the cord, opposite the tip of the ventral horn on the side of the lesion, is composed of a limited number of degenerated fibres (see fig. 11), scattered and forming more of a band as they did on the cephalic side of the decussation of the pyramids, rather than a more or less oval column as was the case at the caudal end of the medulla oblongata.

The group of fibres on the inner side of the opposite anterior horn is scanty, and the fibres are scattered; they occupy the territory of the anterior ground bundles close to the grey matter, and of that part of it bordering on the ventro-internal tip of the ventral horn (see fig. 12). The portion of the ground bundles bordering on the root of the ventral horn and anterior commissure is free from degeneration, as is the direct pyramidal tract on this side.

The degenerate fibres in the crossed pyramidal tract of the side opposite to the cerebral lesion can be traced

D.V.-L.T.

D.P.

N.P.

FIG. 9.

D.P.

N.P.

C.V.T.

FIG. 10.

N.D.P.T.

V.H.

D.D.P.T.

D.V.-L.T.

FIG. 11.

V.H.

V.H.

D.D.P.T.

N.D.P.T.

C.V.T.

FIG. 12.

throughout the cord, and are still a distinct bundle in the last sacral segment; the degenerate fibres in the crossed pyramidal tract on the side of the lesion (homolateral fibres) can also be traced as far as the last sacral segment, but only a few scattered degenerate fibres are to be seen at this level, while those of the direct pyramidal tract can be traced with certainty to the last sacral segment, and form a distinct though scattered group, chiefly in the dorsal part of the anterior column. As is usual in the case of the crossed pyramidal tract, the degenerated fibres are grouped nearer and nearer to the periphery of the cord, as we pass towards its caudal extremity; but numerous degenerate fibres are seen in the lateral limiting layer through which they probably pass to reach the grey matter; while it is of interest to note that those of the direct pyramidal tract in the ventral region of the cord, on the other hand, leave the periphery and group themselves in the dorsal part of the anterior columns immediately in front of the anterior commissure, as we reach nearer and nearer to the caudal extremity of the cord.

Throughout the sacral cord numerous degenerated fibres are seen passing in the anterior commissure, and are evidently derived from the direct pyramidal tract which is degenerated. These fibres pass from the side of the degenerate direct pyramidal tract to the grey matter of the opposite side. At no other level of the cord have I been able to trace any crossing of these fibres in the way that they are seen to behave throughout the sacral region. In addition to the fibres already described as decussating, there are some which appear to take an opposite course in their passage from the grey matter of one side to that of the other, and are possibly derived from the crossed pyramidal tract.

A LARGE CYST OF THE CENTRUM OVALE OF ONE CEREBRAL HEMISPHERE, THE RESULT OF THE DEGENERATION OF A MALIGNANT TUMOUR.

In this case the right cerebral hemisphere was the seat of a large cavity measuring about 7 cm. in its antero-posterior, and 5 cm. in its transverse diameter, occupying

the centrum ovale, and extending to a depth sufficient to involve the upper surface of the basal ganglia.

This case like the last proved to be one in which the Marchi method was of the greatest possible advantage for tracing the degenerations. As in the last case, the mode of behaviour of the degenerated efferent fibres in the spinal cord is all that I propose to deal with in the present paper.

In the medulla oblongata, prior to their decussation, the left pyramid is intact, while the right (that on the side of the cerebral lesion) is markedly degenerated, though, of course, to a less pronounced degree than in the other case with a much more extensive cerebral lesion. This case also differs from the last in two other respects, in that no degenerate fibres are seen in the inter-olivary stratum and there is no evidence of degeneration in the tract of fibres at the periphery of the cord opposite to the inferior olive.

At the decussation of the pyramids the degenerated fibres of the pyramid stream off to the opposite crossed pyramidal tract. No degenerated fibres are seen passing to the lateral pyramidal tract on the side of the lesion.

There are no degenerate fibres at the periphery of the medulla opposite the tip of the ventral horn as in the other case, and there are also no degenerate fibres at the dorsal end of the normal pyramid between the grey matter of the ventral horn and the band of degenerate fibres from the pyramid of the side of the lesion, in their passage to the opposite crossed pyramidal tract.

In the cervical cord the degenerated fibres are limited to two regions of its transverse area, the opposite crossed pyramidal tract, and the direct pyramidal tract on the side of the lesion. There are no degenerate fibres in the crossed pyramidal tract of the side of the lesion, or in any tract other than the two just named. The degenerate fibres in the direct pyramidal tract are few and scattered, while those in the opposite crossed pyramidal tract are very much more numerous, and occupy an area much wider in extent than that usually assigned to the crossed pyramidal tract. These degenerated fibres are seen in the greater part of the

lateral region of the cord dorsal to the lateral horn, with the exception of a band at the periphery of the cord in the situation of the direct cerebellar and dorsal part of the afferent ventro-lateral tract; but even this area is not quite free as at about the region of the junction of the two afferent tracts, degenerate fibres are seen reaching quite to the periphery of the cord.

The lateral limiting layer is also invaded by degenerate fibres of the crossed pyramidal tract, and ventrally, such degenerate fibres are seen on the outer side of and close to the lateral horn; they extend to just on the ventral side of this horn of the grey matter.

In the thoracic cord degenerate fibres are still seen in both tracts, though fewer than in the cervical region; those of the crossed pyramidal tract are, however, just as scattered as in that part of the cord, occupying an area far greater than that formerly supposed to belong to this tract.

The lumbar cord is characterised by a few degenerate fibres in the dorsal part of the direct tract, in front of the anterior commissure, while an extensive area of degeneration still represents the opposite crossed pyramidal tract. The latter tract is as usual wedge-shaped in this region of the cord, the base of the wedge reaching quite to the periphery, while its apex encroaches on the lateral limiting layer.

A degenerate fibre here and there is all that remains of the degenerated part of the direct pyramidal tract when the first sacral segment is reached, while a fair number of degenerated fibres are seen throughout the whole area of the opposite crossed pyramidal tract at this level; the diminution in the number of such fibres even in this tract is, however, marked.

No degenerated fibres are seen crossing in the anterior commissure from the degenerate direct pyramidal tract to the opposite ventral horn, at any level examined.

SUMMARY OF RESULTS.

In brief, then, the facts which appear to be the outcome of these investigations are :—

(1) Fibres derived from the first sacral posterior root while on entering the cord, first occupy that part of the postero-external column which abuts on the grey matter of the posterior horn, subsequently become scattered so as to occupy all parts of the posterior columns, including the cornu-commissural zone and septo-marginal tract, a region supposed to be exclusively occupied by fibres of endogenous origin.

(2) Reflex collaterals derived from this root pass through the grey matter to the anterior horn of the same side, but not beyond it to the white matter of the ventral part of the cord, nor can any fibres be seen decussating to the opposite posterior columns, ventral horns, or other part of the opposite half of the cord. Such fibres are only seen passing to the anterior horn in the segment of the cord to which the root corresponds and that immediately on its cephalic side, viz., the 1st sacral and 5th lumbar segments; no such connection is detectable in other lumbar segments or in the thoracic or cervical regions of the cord.

(3) According to the already well-established law fibres having this origin are limited to the dorsal part of the posterior-internal column in the cervical cord, and are all destined to terminate in the nucleus of the funiculus gracilis.

(4) The band of degeneration in the spinal cord, consequent on destruction of the 7th cervical root, is limited to the postero-internal column, and does not encroach on the limits of the postero-internal column in its course to the cuneate nucleus in the medulla.

(5) The degeneration of this root four segments above its point of entry into the spinal cord occupies the whole dorso-ventral length of the postero-external column, as seen on transverse section, but few of the fibres of the cornu-commissural zone escaping.

(6) The afferent ventro-lateral tract commences to take origin in the spinal cord as far caudally as the third lumbar segment.

(7) In the lumbar, and lowest part of the thoracic region of the cord, this tract is situated at the periphery just ventral to the position of the crossed pyramidal tract.

(8) In the upper cervical cord, on the other hand, the tract occupies an area considerably removed from the periphery of the cord, and separated from it by a well-marked band of healthy fibres. In addition to this, the tract extends much further ventrally than in the thoracolumbar cord.

(9) The efferent ventro-lateral tract, on the other hand is situated at the extreme periphery of the ventral part of the cord in its lower cervical and upper thoracic regions. In fact, the fibres which separate the afferent ventro-lateral tract from the periphery of the cord in the cervical region are evidently those of the efferent ventro-lateral tract. This tract preserves its peripheral position throughout the whole length of the part of the cord through which it can be traced. The part of the tract which can be traced farthest towards the caudal end of the cord, by the Weigert-Pal method of staining, being that which abuts on the anterior median fissure.

(10) The degeneration of the comma tract of Schultze, in the 8th cervical segment of the cord after a transverse lesion at the 6th and 7th cervical segments, occupies the greater part of the postero-external column.

(11) After a transverse lesion of the 6th and 7th cervical region of the cord the comma tract can be traced as a distinct band of degeneration, through seven segments of the cord, to the level of the 6th thoracic segment.

(12) Fibres of the crossed pyramidal tract, derived from the opposite cerebral hemisphere, extend throughout the whole length of the spinal cord.

(13) The fibres which degenerate in the crossed pyramidal tract on the side of the lesion (homolateral fibres) pass to this tract from the degenerate pyramid, at the decussation at the caudal end of the medulla, instead of passing to the opposite crossed pyramidal tract in the way that the bulk of the degenerated fibres do.

(14) These homolateral fibres pass to the caudal extremity of the cord, and can be seen with certainty as far as the last sacral segment, where, however, only a few such fibres are to be seen.

(15) The direct pyramidal tract extends throughout the whole length of the cord, in that degenerate fibres can be distinctly seen in the anterior columns as far caudally as the last sacral segment.

(16) Fibres derived from the direct pyramidal tract appear to decussate throughout the whole length of the sacral cord, crossing in the anterior commissure to the grey matter of the opposite side.

(17) Every lesion of the brain, which results in degeneration of the pyramidal fibres, does not of necessity cause degeneration of those of them which pass to the lateral pyramidal tract on the side of the lesion (homolateral fibres), as shown by the case of tumour of the centrum ovale, with degeneration of the direct and opposite crossed pyramidal tracts, without any degenerate homolateral fibres being found.

(18) The real mode of origin of the efferent degenerate fibres seen in the cervical cord, occupying regions other than those belonging to the direct pyramidal tract on the side of the lesion, and to the two crossed pyramidal tracts, is doubtful. The degenerate fibres in the inter-olivary stratum on the side of the degenerate pyramid are the continuations of degenerated fibres which exist in the fillet throughout the pons, and which may possibly be the result of the lesion of the optic thalamus.

(19) All that can at present be said with regard to the efferent tracts, other than those occupying the usual areas of the pyramidal fibres, is, that they are probably composed of internuncial fibres, and that there seems little doubt that the tract seen at the periphery of the medulla, external to the inferior olive, and traced to the cervical cord, where it occupies a limited region at the periphery opposite the tip of the ventral horn, is distinct from the degenerate pyramid, and that its fibres do not appear to be derived from this source.

(20) The degenerate fibres seen in the dorsal part of the otherwise normal pyramid, at the caudal end of the medulla, close to the root of the ventral horn, and between it and the decussating degenerate fibres from the pyramid on the

side of the lesion, may be derived from the degenerate pyramid, or they may be derived from the degenerate fibres seen in the inter-olivary stratum, in that no degenerate fibres from the latter source are seen passing to the posterior column nuclei by way of the internal arcuate fibres; but from which of these sources it is not at present possible to say with certainty. The possibility of their being derived from the degenerated fibres in the inter-olivary stratum is, however, further suggested by the fact that in the case of cyst of the centrum ovale, neither the degenerate fibres in the inter-olivary stratum nor those in the dorsal part of the opposite pyramid are seen. Too much cannot be made of this argument, however, in that in this case not even all the fibres, which we expect to find degenerated in a lesion of the cephalic end of the pyramidal system, are found in this condition, for, as far as can be ascertained, the homolateral fibres in the lateral pyramidal tract on the side of the lesion are intact. Under such circumstances it is possible that other fibres, such as those now under consideration, though derived from the pyramidal system, may escape degeneration in a limited lesion of the cerebrum, in the same way that the homolateral fibres have. But from whichever source these fibres are derived, it is clear that they belong to a decussating system, in that the pyramid in which they are found is absolutely intact on the cephalic side of the pyramidal decussation, unless we assume that they result from compression of the healthy pyramid by the swollen fibres of the degenerated pyramid, in the way that Hallopeau and Rothmann attempt to account for the degeneration of the homolateral fibres.

COMPARISON OF RESULTS WITH PREVIOUSLY ASCERTAINED FACTS.

It will be profitable for us to compare the results that have been just summarised with those facts which have been previously ascertained by similar investigations in man, and by experiment, or otherwise, in animals. In doing so it will conduce to clearness if we preserve the same

order of considering the various tracts as has been observed in previous parts of the paper, dealing with the afferent tracts first, and the efferent tracts subsequently.

The Posterior Columns.

Instances in which there has been an opportunity of examining the spinal cord in man after lesions of nerve roots are so rare, and especially instances in which a single root has been damaged, that the two cases here recorded are of considerable value. Moreover, in that the case of degeneration of the first sacral roots allowed of the Marchi method being used to trace the degenerations, it is of special value, as allowing us to trace connections of the collaterals of this root, which would have been impossible by the Weigert-Pal method.

The previously recorded cases of destruction of a limited number of roots in man, in which the degenerations in the spinal cord have been studied, are as follows: A case by Gombault,⁸ in which the 5th cervical root was affected; one by Sottas,¹² in which the 6th and 7th cervical roots were involved; another by Souquez,¹³ in which the 7th cervical root was completely atrophied; a case by Déjérine and Thomas,⁷ in which the 8th cervical root was markedly degenerated, while the 1st thoracic was only slightly so affected; a case by Pfeiffer,¹¹ in which the 1st and 2nd posterior thoracic roots were affected; and lastly, a case by Nageotte,¹⁰ in which the lesion was limited to the 2nd and 3rd thoracic roots.

It will thus be seen that all the cases of the kind previously recorded deal with the cephalic end of the spinal cord, from the 5th cervical to the 3rd thoracic roots. The case of destruction of the 7th cervical root here recorded belongs to this group of cases, two of which are available for comparing directly with the results arrived at in it, viz., that of Souquez,¹³ in which the 7th cervical root was alone atrophied, and that of Sottas,¹² in which the 6th and 7th cervical roots were involved. In both these cases the degeneration in the spinal cord occupied a position in the postero-external column identical with that met with in the

present case, and, as in it, the band of degeneration remained limited to the postero-external column, coming up to the septum intermedium without encroaching on the limits of the postero-internal column, and terminating in the cuneate nucleus. This case, therefore, tends to strengthen the previously established fact that the postero-internal column of the cervical cord is composed almost entirely of fibres derived from the thoracic and lumbo-sacral roots, and that few fibres derived from the cervical roots take any part in the formation of this column.

If we next turn to consider the case of degeneration of the 1st sacral roots we find that it is practically unique, and that of the cases of previously recorded limited root destruction in man none are strictly comparable to that now under discussion, for I know of no case of single root destruction in which the affected root has been one of the sacral series. There have, however, been some carefully recorded observations by Souquez and Marienescio, Darkschewitch, and Déjérine and Spiller, of the results of destruction of the *cauda equina* in man. The case observed by Déjérine and Spiller,⁶ who were fortunate enough to examine the cord since the Marchi method has been in vogue for tracing degenerated nerve fibres, serves well for the study of the connections of the exogenous fibres of the spinal cord, derived from the lumbo-sacral roots, especially as the cord escaped injury, the nerve roots alone being involved. It may be profitably compared with the results of the single root degeneration met with in the case here recorded.

To discuss the problems connected with the degenerations in these cases properly, it is necessary for us to keep before us the fact that the posterior columns in the lumbo-sacral region of the cord are composed of endogenous as well as exogenous fibres; that is, that in addition to the fibres which pass to these columns from the posterior roots, there are others in it which take their origin in the grey matter of the cord itself. These endogenous fibres occupy two regions of the posterior columns, as seen on transverse section; the one set of fibres that has been alluded to in previous parts of this paper as the cornu-commissural zone, being

situated in the ventral part of these columns bordering on the posterior commissure, septum and horn, and the other, whose position varies at different levels, being situated in the part of the dorsal portion of these columns which abuts on the posterior median septum, and which has been previously alluded to as the "septo-marginal tract," adopting the terminology of Bruce and Muir.¹⁶ The former of these tracts of fibres is that to which Marie has applied the term cornu-commissural tract, and is identical with what German writers describe as the "ventrales Hinterstrangsfeld," while the latter is the same as what Obersteiner²¹ calls the "dorso-median sacral bundle," and Eninger the "medianes Hinterstrangsfeld," and in one part of its course at the most caudal end of the lumbar region of the cord corresponds closely to the "oval field" of Flechsig. With regard to the variations in the position of the septo-marginal tract, the reader is referred to papers on the subject of endogenous fibres by Dufour,¹⁷ and by Bruce.¹⁶

Both of these tracts of fibres have been regarded as occupying parts of the posterior columns entirely composed of endogenous fibres, but Déjérine and Spiller⁶ found that in their case of compression of the *cauda equina* degenerate fibres of exogenous origin were present in both these areas of the posterior columns, so that they contend that while these tracts are largely composed of endogenous fibres, others of exogenous origin are also met with within their confines. The case of degeneration of the first sacral roots, here recorded, supports their contention, in so far as the cornu-commissural zone is concerned, for the presence of numerous degenerated fibres in this zone, at the 3rd lumbar segment of the cord is unquestionable. It is interesting in this connection to note that this zone, containing so many degenerated fibres in the 3rd lumbar segment, is free from any such degeneration in the 1st sacral and 5th lumbar segments. This case also confirms the observation of Déjérine and Spiller as far as the septo-marginal tract is concerned, in that degenerated fibres have been found in this area of the lumbo-sacral cord in some sections. With degenerated fibres scattered all through other parts of the posterior

columns this tract remains free from any such abnormality in some sections, while in others the presence of degenerated fibres in it is distinct.

On further comparing this case with that of Déjérine and Spiller, we find a close agreement as regards the mode of distribution and connections of the reflex collaterals which have been found degenerated.

These observers have, like myself, traced such degenerated fibres to the region of the ganglion cells of the ventral horn on the side on which the degenerated root enters the cord, and our observations are further in accord in that I have failed to find any evidence that such fibres pass beyond the grey matter of the ventral horn to reach the ventro-lateral tracts of the cord, as is supposed to be the case by Edinger, Berdez, Schäfer, and others. Déjérine and Spiller did not find any degeneration sufficiently precise to enable them to support this hypothesis. On the other hand, like myself, they have traced a few collaterals across the base of the posterior horn towards the lateral column of the same side; but I have not seen any such degenerated fibres actually in the lateral columns, nor do these observers say that they have done so. They also describe the degeneration of the fine collaterals in the external part of the gelatinous substance of Rolando, as has already been described in my case. In that their case was one in which all the lumbar roots with the exception of the first pair were degenerated, they were able to trace degenerated collaterals to the column of Clark also, a condition of things that has not been found possible in my case of partial degeneration of the 1st sacral root, in which, as we have already seen, it has not been possible to trace any degenerated reflex collaterals in segments of the cord other than the 1st sacral and 5th lumbar.

My case supplies further evidence of importance as regards the question as to whether any fibres derived from the posterior roots of one side cross to the opposite posterior column. So limited was the degeneration of the root on one side that, as we have seen, no degenerations were met with in the corresponding posterior columns three segments above the point of entry of the root into

the cord. This allowed me to make out definitely that no fibres passed from the more degenerated posterior root to the opposite posterior columns.

If we next compare the conditions met with in these cases with what has been found experimentally, we find that there is a close agreement with Mott's³ results of section of lumbo-sacral posterior roots in the monkey, for the findings of this observer do not confirm the results of Löwenthal,² Berdez,¹ Oddi and Rossi,⁴ and others who have found extensive degeneration in the white matter elsewhere than the posterior columns of the same side—Mott³ concludes, from eight observations, that fibres do not pass into the opposite posterior column from divided roots on one side of the cord, and prefers to regard any degeneration met with in the crossed afferent tract of Gowers and Edinger as depending on vascular changes in the grey matter of the posterior horn, rather than by supposing that fibres from the posterior roots pass directly across to ascend the cord and reach the corpora quadrigemina. It will thus be seen that Mott's conclusions are in entire harmony with the facts ascertained in my case of degeneration of the 1st sacral root, where the experimental error of interference with the vascular supply of the cord is naturally excluded.

Before passing to the discussion of the results obtained in connection with tracts other than the posterior columns, the Comma tract of Schultze, contained in these columns, calls for brief consideration. This tract though first noted by Schultze²⁴ in 1883, was previously figured, though not described, by Bastian²⁵ in 1867, and Westphal²⁶ in 1880. Tooth²⁷ was able to trace it through seven or eight segments of the cord, after a transverse lesion at the level between the 8th cervical and 1st thoracic roots, and through seven segments in a case in which the transverse lesion of the cord was precisely in the same position as in my case, viz. : between the 6th and 7th cervical segments. It is of interest to find a tract, whose extent is admittedly so variable, having precisely the same length of course, after a lesion at the same level of the cord, as was met with in Tooth's case and

in mine. This tract is said to be composed of fibres from the posterior roots of the same side which turn back and take a caudal course after entering the cord, and also of other fibres, which pass in the same direction, but take origin in the cells of the cord itself. The researches of Cajal, Lenhossek and Kölliker have proved conclusively that fibres of the posterior roots after entering the cord divide, some taking a cephalic and others a caudal course, but it is curious that after section of posterior roots in animals no evidence of degeneration of the branch which passes caudally has been found. If we relied on the experimental evidence alone, therefore, we should be obliged to conclude that all the fibres of which this tract is composed take their origin in cells in the spinal cord. But in their case of atrophy of the 8th cervical and 1st thoracic roots, Déjérine and Thomas⁷ found evidence of degeneration of the branch which runs caudally, as did Nageotte¹⁰ in his case of a lesion of the 2nd and 3rd thoracic roots.

The Direct Cerebellar Tract.

Nothing that we have obtained directly in connection with this tract calls for comment, but in that in the case of the tumour of the caudal extremity of the lumbo-sacral cord the afferent ventro-lateral tract was degenerated on one side, while the direct cerebellar tract escaped on both sides, we have negative evidence of value in confirming the previously ascertained fact that, inasmuch as the direct cerebellar tract probably takes its origin in the cells of Clarke's column, and inasmuch as this column of cells only commences to be at all well marked at the 12th thoracic or 1st lumbar segment, though a few cells may be found as far caudally as the 2nd or 3rd lumbar segments, in a lesion of the cord at the 3rd and 4th lumbar segments, as in our case, it may well escape degeneration.

The Afferent Ventro-lateral Tract.

With regard to this tract, the position of things is different in that we have evidence of a direct kind with

regard to it. In the first place, we have seen that if we allow that its degeneration is consequent on the destruction of the cord caused by the tumour directly, then we have evidence that this tract commences as far caudalwards as the 4th lumbar segment, but if we regard the softening and œdema of the one half of the 3rd lumbar segment of the cord sufficient to induce such a degeneration, as it undoubtedly appears to be, then we must regard the tract as commencing at the level of the 3rd lumbar segment. Whichever view we take does not alter the value of the case materially, in that I know of no previously recorded instance in which the origin of this tract from so caudal a level of the cord has been established in man. In Gowers'²⁸ case in which this tract was degenerated, the crush to the cord was at about the 11th thoracic segment, while Schultze³⁰ mentions a case in which the whole lumbar cord was crushed by a fracture of the 1st lumbar vertebra. Mott³⁹ has, however, shown that mesial section of the spinal cord in the monkey, involving the 3rd, 4th and 5th lumbar segments, results in symmetrical degeneration of the afferent ventro-lateral tracts, so that, at any rate in this animal, the tract takes its origin as far caudally as the 3rd lumbar segment, or it may be even at the 4th or 5th.

The other point of interest with regard to this tract, as brought out by the present investigation, is supplied by the case of transverse lesion of the spinal cord, at the level of the 6th and 7th cervical segments. The position of this tract, as seen in the 5th, and all other segments of the cervical cord on the cephalic side of the lesion, is distinct, and leaves no room for question that it is situated more or less mid-way between the periphery of the cord and grey matter of the ventral horn, the band of fibres between this sclerosed area and the periphery of the cord being absolutely intact. Now, in all figures which appear in books dealing with the subject, and which represent this tract, it is placed at the periphery of the cord. Even in the last edition of Foster's "Physiology,"⁷ recently published, and containing new diagrams of the positions of the tracts in the spinal cord, this tract is represented as at the peri-

phery of the cord, and external to the efferent ventro-lateral tract, the very reverse of what obtains in the case recorded in this paper. We must, therefore, either regard this case as anomalous, or the majority of the diagrams in our textbooks representing the position of this tract as wrong. That the afferent and efferent tracts must overlap greatly is obvious on comparing fig. 5 with fig. 6; but the evidence supplied by the case from which fig. 5 is taken suggests strongly that the major representation of the afferent tract is internal to the main part of the efferent tract. In all the experimental degenerations of the efferent ventro-lateral tract, which I have had an opportunity of studying, the degenerated fibres have invariably occupied the extreme periphery of the antero-lateral region of the cord. So marked has this always been that I was early led to wonder how, even allowing for intermingling, the afferent tract fibres could find room so close to the periphery as they are usually represented; but this is the first case that has enabled me to observe the point in the human cord since my attention was called to it in the cords of animals. I would suggest, therefore, that the relative position of the afferent and efferent ventro-lateral tracts to each other, while there is no doubt considerable overlapping, is such that the efferent tract is situated externally to the afferent, *i.e.*, nearer the periphery of the cord.

The Pyramidal System.

The peculiarities in the behaviour of the pyramidal system fibres noted in my two cases have been also observed by Hoche,³³ in a case published in the *Neurologisches Centralblatt* for November 1, 1897, while my present paper was in process of preparation, and some time after I had discovered these peculiarities in my cases.

In the first place, the degenerated fibres belonging to the crossed pyramidal tract on the side opposite to the cerebral lesion occupies an area of the lateral region of the cord far wider than that formerly ascribed to this tract. It is especially the degenerated fibres bordering on the ventral horn and extending as far as its ventro-external angle,

and those occupying the periphery of the cord more or less in the position of the dorsal end of the afferent and efferent ventro-lateral tracts, which call for comment.

Hoche³³ also noted the scarcity of the homolateral fibres in the crossed pyramidal tract on the side of the cerebral lesion, as in one of my cases. In his case, as in mine, and in one recorded by Déjérine and Thomas,³¹ the degenerated fibres are seen leaving the pyramid at certain points, a condition of things first observed in 1894, when I found fibres passing from one pyramid to both crossed pyramidal tracts, in a cat³⁶ with defective development of the central nervous system, in which one pyramid was entirely absent, and by Mellus³⁴ and Sherrington,³⁷ who each found fibres passing to both crossed pyramidal tracts from one pyramid after extirpation of portions of the cerebral cortex in monkeys. That there should have been a complete absence of such homolateral fibres in my second case is possibly to be accounted for by the fact that in a less extensive lesion than in the first case, they have escaped, inasmuch as the degeneration of the crossed and direct pyramidal tracts in this second case is only slight compared with that seen in the first. That the difference does not depend on whether or not the basal ganglia are implicated is shown by the fact that both Mellus³⁴ and Sherrington³⁷ found that these fibres degenerated after lesions which were limited to the cortex cerebri in the monkey. The proportion of homolateral fibres noted in my cat, and by Mellus and Sherrington in their monkeys, was such as to lead one to expect a much greater number of such fibres in a case with such an extensive cerebral lesion as the first of the two cases now under discussion. Rothmann³⁸ has comparatively recently revived Hallopeau's view as to the mode of origin of these degenerate homolateral fibres, supposing that they result from compression of fibres from the normal pyramid by the swollen fibres of the degenerated pyramid at the decussation. Difficult as it is to disprove such a view, there are many considerations which make it improbable that this is the true explanation.

No special comment is called for as regards the behaviour

of the direct pyramidal tract on the side of the lesion, in the cephalic end of the spinal cord, either in Hoche's³³ case or in mine; but a special, and hitherto unobserved, or at any rate unrecorded set of fibres in the opposite anterior column demands our close attention. We have in these fibres to deal, undoubtedly, with a crossed tract, unless we accept, as accounting for their occurrence, an explanation like Hallopeau's in regard to the homolateral fibres, for both in Hoche's case and in mine the pyramid on the side opposite the lesion was absolutely intact on the cephalic side of the decussation of the pyramids at the caudal end of the medulla. The only previous observation at all comparable to this is one by Pitres³⁵ who has shown that both direct pyramidal tracts may be degenerated secondarily to a unilateral lesion. A comparison of my two cases left me, though in doubt, inclined to regard these fibres as possibly derived from the degenerate fibres seen in the inter-olivary stratum in the case in which this crossed tract in the anterior column was found. This was suggested by the fact that in my other case in which no such degeneration in the inter-olivary stratum, immediately dorsal to the degenerated pyramid was found, no such degenerated fibres were seen in the opposite anterior column. On comparing my results with those of Hoche, however, this does not appear to be the true explanation of the source of these fibres, for though he describes this tract at the caudal end of the medulla, and in the cervical cord, he makes no mention of having seen any degenerated fibres in the inter-olivary stratum in his case. All that Hoche states, is that the one pyramid was degenerated, while the other was absolutely intact on the cephalic side of the pyramidal decussation. Assuming that there was no degeneration of the inter-olivary stratum in Hoche's case, we must conclude that this crossed tract of fibres at the dorsal end of the otherwise intact pyramid, at the decussation, and subsequently seen in the territory of the anterior ground bundles on the inner side of the ventral horn, is in reality derived from the degenerated pyramid. This being the case, one cerebral hemisphere is brought into communication with the spinal centres on both sides of the cord by

a direct and crossed tract of fibres in the anterior columns, as well as a direct and crossed set of fibres in the lateral columns of the cord, all of which fibres are derived from one pyramid.

There still remains for our consideration one tract of fibres which, so far as I know, has not been hitherto described at all, I allude to the tract which is so definite in the medulla, occupying the ventral periphery of this part of the hind brain, external to the inferior olive, on the same side as, but quite distinct and separated from, the degenerated pyramid. We have seen that it preserves this peripheral position through the caudal end of the medulla, and throughout the cervical region of the spinal cord, though altering its shape at different levels. In that I have not been able to satisfy myself as to the precise point of origin of these fibres, I prefer, at present, to record the existence of such a tract without entering into any speculations as to its significance, or possible functions.

We have already seen that both the new tracts here described can be traced throughout the cervical cord, but are not seen at any point caudal to the 8th cervical segment. It is, however, different as regards the degenerated fibres seen in the direct pyramidal tract on the side of the lesion, and in both crossed pyramidal tracts, which, of course, pass much farther caudally, all of them as we have seen, reaching the last sacral segment of the cord, though only very few of the homolateral fibres are to be seen at this level.

Most authors have regarded the direct pyramidal tract as terminating about the mid-thoracic region of the cord, and, curiously enough, Foster and Sherrington²⁸ in Part III. of the seventh edition of "Foster's Physiology," recently published, still give this as the level at which this tract terminates. Tooth,²⁹ however, as long ago as 1889 traced this tract to the 2nd lumbar segment, while Déjérine and Thomas,³¹ by the aid of the Marchi method, have been able, in a case of hemiplegia from a lesion of the internal capsule, to trace the crossed pyramidal tract to the 5th sacral segment, and the direct pyramidal, and homolateral

degenerated fibres they have traced with certainty to the 4th sacral segment. It will thus be seen that their observations agree closely with what I have found in one of the cases of degeneration of the pyramidal system, the only difference being that I have been able to trace the degenerated fibres of the direct pyramidal tract, and those of the lateral pyramidal tract on the side of the lesion, to one segment of the cord further caudally than in their case. Moreover, they only mention the crossed pyramidal tract fibres as reaching the 5th sacral segment, while in my case they passed beyond this segment to the tip of the cord. This case has, therefore, allowed of my tracing the three sets of pyramidal fibres farther caudally than has previously been done, after any lesion, much less a cerebral one, in that of previously recorded cases, that by Déjérine and Thomas occupied the position which mine does now.

I am not aware of any previously recorded instance in which fibres derived from the direct pyramidal tract have been shown to decussate in the anterior commissure to reach the opposite ventral horn. It has been argued that these fibres must decussate somewhere in the cord, because in cases in which there had been pronounced degeneration of this tract, there has been no paralysis on the same side during life. The case here recorded, however, furnishes the first actual demonstration of the decussation of fibres of the direct pyramidal tract, this decussation taking place, as we have seen, throughout the whole extent of the sacral region of the cord. This is of interest when compared with the surmises of Foster and Sherrington⁸⁸ on this point, in that while admitting that the fibres of the direct pyramidal tract must cross in the cord, they regard the ventral white commissure as the path in which they cross, but conclude that only a small part of the commissure can serve this purpose, and that in the lower regions of the cord, where they assume that the direct tract no longer exists, all the fibres of the ventral commissure must have some other functions. It is not a little curious, therefore, that I should have been able to trace the decussation of the direct pyramidal tract fibres in the ventral commissure of a

part of the cord where these authors would least expect to find them.

Efferent Ventro-lateral Tract.

I have so recently dealt with the ventro-lateral efferent tracts which exist in the spinal cord, from the experimental stand-point, in this Journal, that I need do no more than remind my readers that the area of sclerosis at the periphery of the ventro-lateral region of the cord, the result of a transverse lesion at the 6th and 7th cervical segments, represents the position of fibres derived from very different sources. One set of these fibres appears to be derived from the superior corpora quadrigemina (Held⁴² and Boyce,⁴⁰) while the precise origin of another set of such fibres is in dispute. According to some they are derived directly from the cerebellum (Marchi,⁴³ Biedl,³⁹ and Thomas,⁴⁶) while according to others (Ferrier and Turner,⁴¹ Risien Russell,⁴⁵ and Mott,⁴⁴) they take their origin in Deiters' nucleus.

There can be little doubt that had the Marchi method been available for tracing the degenerations in the case of fracture dislocation here recorded, it would have been possible to trace this tract much further caudally than has been possible by the Weigert-Pal method of staining, for in experimental lesions of the medulla oblongata in animals the tract can be traced with ease throughout the lumbar cord, by means of the Marchi method.

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(A) POSTERIOR COLUMNS.

I. Exogenous Fibres.

- (a) Experimental Section of roots in animals.
- (b) Destruction of roots in man.

II. Endogenous Fibres.

- (a) Cornu-commissural and Septo-marginal tracts.
- (b) Comma tract.

* A more extensive bibliography will be found in an excellent critical digest by Dr. Alfred W. Campbell, which appeared in the Winter number of this Journal, vol. xx., after my present paper was in print.

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³² FERBIER AND TURNER, *Ibid.*, 1894, vol. clxxxv., B. p. 719.
³³ HELD, *Archiv. f. Anat. u. Physiol.*, 1892.
³⁴ MARCHI, *Riv. Sper. di Frenatria*, 1886, 1887, 1891.
³⁵ MOTT, *BRAIN*, 1895, p. 1.
³⁶ RISIEN, RUSSELL, *Phil. Trans. Roy. Soc.*, 1895, vol. clxxxvi., B., p. 633.
³⁷ THOMAS "Le Cervelet, étude anatomique, clinique et physiologique," Paris, 1897.

DESCRIPTION OF FIGURES.¹

¹The figures are from photomicrographs taken for me by Mr. L. B. Fleming, of Hanwell.

Figures 1, 4, and 7 to 12 are from sections prepared by Marchi's method, and figures 2, 3, 5 and 6 from sections prepared by the Weigert-Pal method.

FIG. 1.—Degenerated fibres of the 1st sacral root entering the cord. The posterior horn, lateral and posterior columns on the same side, and part of the opposite posterior columns are shown. D.M.S. = dorsal median septum. D.R. = degenerated root. D.H. = dorsal or posterior horn. V.H. = part of ventral or anterior horn.

FIG. 2.—Third cervical segment of the spinal cord from a case in which the 7th cervical root was destroyed. D.7th C. = degeneration the result of destruction of the 7th cervical root. D.C.T. = degenerated direct cerebellar tract.

FIG. 3.—Fourth lumbar segment of the spinal cord. T. = tumour occupying the whole of one half of the cord, and the posterior columns, &c., on the opposite side. V.M.F. = ventral median fissure. V.H. = ventral horn. D.H. = dorsal horn.

FIG. 4.—Eleventh thoracic segment of the spinal cord, from the case of tumour of the cord shown in fig. 3. D.P.C. = degenerated posterior columns. A.V.-L.T. = degenerated afferent ventro-lateral tract.

FIG. 5.—Section from the 4th cervical segment of the spinal cord in a case of transverse lesion at the level of the 6th and 7th cervical segments. A.V.-L.T. = degenerated afferent ventro-lateral tract.

FIG. 6.—Section taken from the 3rd thoracic segment of the same cord as fig. 5. E.V.-L.T. = degenerated efferent ventro-lateral tract. C.T. = degenerated comma tracts.

FIG. 7.—Ventral part of a section of the medulla through the inferior olive in a case in which a large cerebral tumour was removed. O. = Olive. V.L.T. = degenerated ventro-lateral tract. D.P. = degenerated pyramid. N.P. = normal pyramid.

FIG. 8.—Section at level of decussation of pyramids from same case as fig. 7. D.P. = degenerated pyramid crossing to opposite lateral pyramidal tract region. N.P. = Normal pyramid.

FIG. 9.—Section from same level as fig. 8, to show degenerated ventro-lateral tract (V.L.T.). D.P. = degenerated pyramid. N.P. = normal pyramid.

FIG. 10.—Section from same levels as figs. 8 and 9, to show supposed crossed ventral tract (C.V.T.) at dorsal part of otherwise normal pyramid. D.P. = degenerated pyramid. N.P. = normal pyramid.

FIG. 11.—Section from 5th cervical segment in same case as figs. 7 to 10, showing ventral part of cord. N.D.P.T. = normal direct pyramidal tract. D.D.P.T. = degenerated direct pyramidal tract. V.-L.T. = degenerated ventro-lateral tract. V.H. = ventral horn of grey matter.

FIG. 12.—Section from same level as fig. 11, but showing more of the opposite half of the ventral region of the cord. D.D.P.T. = degenerated direct pyramidal tract. N.D.P.T. = normal direct pyramidal tract. C.V.T. = degenerated crossed ventral tract in the region of the anterior ground bundles. V.H. = ventral horns of grey matter.