THE GOULSTONIAN LECTURES ON SECONDARY DEGENERATIONS OF THE SPINAL CORD.

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LECTURE II.

My first lecture has been devoted to the study of the histological appearances of degenerations. My present task is one of much wider scope.

If we examine a transverse section of a normal cord, we see grey matter and white matter only, the division into regions being of the most superficial character. We can have no idea from the appearances which part transmits motor and which sensory impressions; which carries fibres passing from above downwards and *vice versa*. But pathology does the work of the anatomist with the greatest precision, and we find that fibres which pass from the brain run invariably in certain areas of the transverse section, and those which pass to the brain travel up in equally definite paths. Moreover, fibres passing from one point of the cord to another, upwards and downwards, have also their own place.

It has become the custom to speak of degenerations of tracts containing efferent fibres as descending, of those containing afferent fibres, as ascending degenerations. But it must be clearly understood that the terms descending and ascending apply to the course of the fibres in the tracts themselves, and not to the degeneration. Therefore the full expression of the term descending lesion should be, a "lesion of a descending tract." There is every reason to believe that the degeneration of a fibre cut off from its trophic centre takes place, if not equally and simultaneously all along its course, at any rate very rapidly.

Early Observations.—The earliest observer to study this method was Cruveilhier,¹ in 1835. But it was Türck,² in 1851, who really gave us the first complete account of the descending tracts and later, in 1853, he studied and figured with great exactness the principal ascending tracts. There does not appear to have been anything of particular importance in this direction written after Türck's time, till 1866, when Bouchard wrote some admirable papers in the *Archives Générales de Médecine*.³ After Bouchard, we have numbers of writers treating of this subject, with more or less minuteness, too numerous to mention in this place, but to whom I shall refer as occasion shall arise. The anatomical facts established by pathological methods are strikingly borne out by the study of the embryology of the cord, a branch of investigation followed most completely first by Flechsig, later by Bechterew, von Monakow, and others.

Preliminary Anatomical Considerations.—In addition to the gross anatomical division of the white matter, we have one or two histological points to draw attention to. There are two forms of larger white medullated nerve-fibres. First, the large fibres which are familiar to all. Secondly, there are medium-sized fibres, smaller than the last. Schwabe has tried to show some relation between the size of a fibre and its length; but Gaskell, with more probability, suggests that the size varies with the functions of the nerve; for instance, the hypoglossal nerve supplying the tongue is composed of fibres of very much smaller calibre than we find in an ordinary anterior root. Whether this theory can be applied to the cord-fibres I am unable to say. It is certain that the fibres supplying the smaller and larger muscles only communicate with the cord through ganglion-cells in the grey matter. It is possible that the medium and large-sized fibres are in connection with medium and large-sized ganglion-cells, and these in their turn with corresponding fibres in the cord. Lastly, there are the small, medullated fibres. These are very minute, a tenth part of the size of the

large fibres. They are morphologically exactly similar to the large fibres. They tend to run in certain tracts of the cord, and I shall deal with them in detail hereafter. They are connected with correspondingly small ganglion-cells. We shall also have to notice the white fibres which run into the grey matter. Among these are very few large fibres, but there are many of the small fibres just mentioned. The larger number of the white fibres in the grey matter are extremely minute; seen in cross section by Weigert staining they appear as little black dots, displaying no structure to the highest powers. In longitudinal section they are, by the same method, fine black lines, with an occasional varicosity. These are axis cylinders diminished in size, and coated with a trace of myelene sufficient to take the stain. It is highly probable that the hardening and staining operations may have some contracting effect on them.

Fibres which Degenerate Downwards.—When any considerable portion of the motor area of the cortex is destroyed, the fibres in connection with that part are degenerated. The degenerated fibres can be traced through the middle third of the internal capsule, through the crura of the crus cerebri, through the pons, the anterior pyramid of the same side, across in the decussation to the crossed pyramidal tract, down the cord in that tract to certain cells in the grey matter, and no further. Though the motor impulses, originating in the cortex of the brain, must take this course, and pass out to their destination through the anterior roots, degenerating fibres are never found in these roots; they must, therefore, stop at the ganglion cells in the grey matter. This fact was fully recognised by Bouchard. As I have not had the opportunity of examining lesions passing down through the capsule and crus, nor had the time to undertake experiments in that direction, I confine my remarks to lesions in the cord and medulla only.

Descending Fibres in Pons and Medulla.—In the pons the motor fibres lie in bundles, separated from one another by the transverse fibres of the pons. Case III, mentioned in my first lecture, a lesion of the middle and posterior part of the right internal capsule, would naturally afford the most extensive and complete degeneration of the motor tract below the lesion. All the longitudinal fibres of the right side of the upper and middle pons are deeply degenerated, but no degenerated fibres can be found in the fillet. The next section at the commencement of the pyramids shows that the total sectional area of degeneration has undergone a very great diminution in size. It must be supposed in explanation of this that the motor tract here is constantly giving off fibres to the various nuclei of grey matter, as in fact it must do to a less degree in its course down the cord. At the decussation the degenerated fibres can be seen crossing to the opposite lateral tract interlacing with healthy fibres. When this crossing has been completed we have the crossed pyramidal tract.

Crossed Pyramidal Tract.—This area forms roughly an isosceles triangle with one of its sides close to and parallel with the posterior horn, its apex at the point of junction of the posterior horn with the rest of the grey matter, and its base lying parallel with the periphery of the lateral column, but not touching the periphery in the upper parts of the cord. The description of the shape I have just given applies to the human cord. In dogs and monkeys it appears to be more circular in its outline. It will naturally also vary in its shape according to the extent of the lesion; most of my cases are of total transverse section, which of course will give the greatest possible degeneration of this tract. It would appear that certain parts of the tract convey fibres from corresponding regions of the brain. This has not been made out with exactitude, but Langley and Sherrington⁴ found in Professor Goltz's dog, in which parts of the motor area had been removed at different times, distinct patches of degeneration at different stages in the crossed pyramidal tract. For further information I must refer to their paper.

I shall here relate very briefly the clinical details of a case which I shall have occasion to refer to several times, especially in connection with the ascending degenerations.

CASE V.⁵—A.P., aged 18, fell forty feet, fracturing left thigh and sustaining a fracture-dislocation of the seventh cervical vertebra. On admission the breathing was diaphragmatic, and remained so. Manipulation of the fractured thigh gave no sign of pain. Sensation was retained in the hands and arms, but there was some paresis. There was retention of urine and involuntary defecation and priap-

¹ Cruveilhier, *Anat. Pathologique*, vol. xxxii, p. 15.

² Türck, *Sitzungsber. der Akad. der Wissensch. in Wien.*, 1851 and 1853.

³ Bouchard, *Arch. Gén. de Méd.*, 1866, t. vii, viii.

⁴ Langley and Sherrington, *Journal of Physiology*, vol. v, p. 419.

⁵ The clinical features of this case have been detailed in the *Lancet*, 1887, vol. ii, p. 261, by Mr. Baker, who allows me to make use of the spinal cord.

ism. There was complete anæsthesia and paralysis below a line drawn round the body two inches and a half above the nipples. There was also complete absence of reflexes. He complained of pain in the upper part of the back, which became more localised in the neck as time went on.

I mention this case here because it affords the best illustration I have of descending lesions following complete transverse crushing high up in the cord. It will be noticed how extensive the degeneration is for the distance of a root below—that is, at least one inch. (Fig. 7, D. i.) There can only be said to be natural fibres close round the grey matter; all the rest is degenerated. Of course this is principally the traumatic degeneration. At the level of the second dorsal (Fig. 7, D. ii) the crossed pyramidal

Fig. 7.—Fracture-dislocation of seventh cervical vertebra, with crushing of cord between the eighth cervical and first dorsal roots (Case V), a. t. (antero-lateral tract), d. c. t. (direct cerebellar), p. m. (posterior median), c. p. t. (crossed pyramidal), c. d. ("comma-shaped" tract); $\times 2$ diam.

tract may be said to have its greatest possible development. At the next root it is considerably smaller, and then diminishes gradually and regularly from above downwards. Vulpian, Singer, Loewenthal, and others say that the crossed pyramidal tract ends at the level of the second lumbar. From my own observations I come to the conclusion that degenerated fibres can be found as low down as the fourth lumbar, and even lower (Fig. 8, S). Neither is this contrary to what might be expected, for the fourth lumbar root enters obviously into the formation of the lumbar plexus: and, though the nerves given off below this point are many of them visceral, yet, as I shall endeavour to show later, these must have their connection with the higher centres, and the path for this connection is probably the lateral column. In the upper parts of the cord the crossed pyramidal tract, as we have already noticed, does not reach the edge of the section, because the direct cerebellar tract intervenes. In the middle of the dorsal region the crossed pyramidal tract comes to the surface. I find that this takes place at levels varying from the sixth to the eighth dorsal roots (Fig. 7, D VII, and Fig. 8, D VII). The significance of this will be apparent on consideration of the direct cerebellar tract. The crossed pyramidal tract, having gained the surface, retains its shape and its position close to the posterior horn at first, but further down the triangle becomes smaller and smaller, and gradually leaves the posterior horn, till at last it is a small patch on the periphery of the lateral column (Fig. 8, L III and S). Bouchard speaks of the crossed pyramidal tract as composed of short and long commissural fibres; the short are on the inner side of the tract, and the long on the outside. He also makes the statement that the long fibres are degenerated after injury to the medulla, and not after injury to the brain.

What becomes of the fibres forming this bundle? The most careful examination fails to discover any degenerated fibres in the anterior roots. It is highly probable, therefore, that they in some way form connections with the ganglion cells of the grey matter. On physiological grounds it is certain that they do not cross, at least, as a whole.

As Schiefferdecker has remarked, it is impossible to understand how such small bundles of fibres as the two descending tracts can convey the multitude of voluntary impulses, unless we regard them as bearing only fibres which control subordinate centres in the cord.

I am not aware, however, that any observer has been able definitely to trace the degenerated fibres to their ganglion cells, and it is curious to note that the bundle takes up and maintains a position in the section as far away from the anterior roots as it is possible to assume.

Fig. 8.—Semisection between seventh and eighth cervical on the left side (monkey 7); a. t. (antero-lateral tract), d. c. t. (direct cerebellar), c. p. t. (crossed pyramidal), r. d. (? recrossed fibres), c. d. ("comma-shaped" tract), m. z. (descending fibres in the "mixed zone"); $\times 3$ diam.

Development of Crossed Pyramidal Tract.—The position and shape of the tract in the cord at birth resembles very much the degenerated tract, but, considering the size of the cord, the former is rather larger than the latter. In both the tract diminishes from above downwards, but that of course means that the process of development, as a whole, takes place from below upwards. The tract comes to the surface at about the fifth or sixth dorsal root level. It can be traced to the upper sacral region with certainty; but shows a tendency to leave the position close to the posterior horn, and to take up one a little further along the periphery of the section.

The direct pyramidal tract consists of fibres, which, after leaving the pyramids, do not cross, but run down in the anterior median column on the same side. It may be said to commence in the cord at the same time as the crossed pyramidal tract. It occupies a position close to the anterior median fissure, any lessening of size being on the side next to the anterior root zone. In cases in which the degeneration is extensive, its anterior part may be extended towards the anterior roots along the outer edge of the section. In its fullest development it is a strip of degeneration, extending the whole length of the anterior fissure. (Fig. 7 D III and V). It is, so far as I know, always associated in degeneration with the crossed pyramidal tract. I have never seen or heard of a case in which this tract only was degenerated secondarily.

Pitres⁶ has shown that the tract is sometimes, though not always, affected in cortical lesions of the brain, and also that both tracts may be degenerated secondarily to a unilateral lesion.

Bouchard says the fibres composing it do not reach below the middle dorsal; but this is plainly not the case, for in Case III it is distinct as low as the eleventh dorsal, and in another case, to which I shall refer later, it can be seen by the naked eye as low even as the second lumbar.

The destination of these fibres is a disputed point. They must be for conduction of motor impulses, because in semisections, as Homén points out, the paralysis is much more complete if the anterior column is cut, as well as the lateral, than if the lateral is cut alone.

Dr. Gowers⁷ considers that the direct pyramidal tract conducts

⁶ Pitres "Recherches anatomo-cliniques sur les Scléroses bilatérales de la Moelle Epinière, etc." *Arch. de Phys.* 1884, p. 142.

⁷ Gowers. *Diseases of Nervous System*, vol. i, p. 114.

motor impressions for the upper extremities. This may be the case, but it can scarcely be the whole answer, because the degeneration, as I have said above, can be traced as low as the second lumbar. It is possible that it may contain many commissural fibres. It is almost certain that the fibres composing this bundle cross somewhere in the cord, for, in cases in which it is deeply degenerated, we get no paralysis of the same side. If they cross, it is only reasonable to suppose that they should go by way of the anterior commissure. This commissure is practically a decussation of medullated fibres from one side to the other. The fibres seem to spring from the anterior column of one side to pass into the corresponding column or anterior horn of the opposite side; and yet the most careful examination fails to discover a single degenerated fibre in the commissure. The destination of this tract is, therefore, at present conjectural.

Development of Direct Pyramidal Tract.—Developmentally, the direct pyramidal tract resembles the crossed, that is, the fibres are medullated late; and, therefore, these two tracts remain as unstained patches by osmic acid or Weigert hæmatoxylin when all the rest of the white matter is stained black. It is also developed from below upwards, but, generally speaking, it is further advanced in development at birth than is the crossed pyramidal tract.

Re-crossed Fibres.—In cortical lesions of the motor area another descending tract in the lateral tract of the same side as the lesion has been often noticed. Pitres,⁹ in the important paper just referred to, brings forward ten out of forty cases of hemiplegia from unilateral brain-lesions, many with contractures and increased tendon jerks. In all he found a degeneration of the pyramidal tract on the same, as well as on the opposite side. In several of these the degenerations on the two sides were of equal intensity; in others it was less intense on the same side. In six cases the direct pyramidal tract was also affected, and in three both direct pyramidal tracts. The pyramid of the opposite side was quite unaffected. He remarks also that there is clinical ground for the suspicion of this double degeneration; that in many hemiplegias we find loss of power—slight, it is true—of the same side. He moreover draws attention to the very common occurrence of increased reflexes, and the less common occurrences of contractures on the same side. It must be said, however, that in many of his reported cases these symptoms are not noted, though the degeneration was obvious after death. He considers that these fibres come from the pyramid of the same side; that is, that the fibres of that pyramid may pass into the crossed pyramidal tract, the direct pyramidal tract, and the pyramidal tracts of the same side. Charcot,⁹ who recognised this degeneration, suggests that the fibres re-cross from the crossed pyramidal tract of the opposite side by way of the anterior commissure. The absence of any anatomical evidence for this statement must be the answer to it for the present. Drs. Hadden and Sherrington¹⁰ add another case in the human subject in which they discover a few degenerated fibres in the opposite pyramid.

According to Dr. Sherrington,¹¹ this "re-crossed tract," as he calls it, does not make its appearance till about the third cervical root. It is much smaller, and the degenerated fibres in it are fewer than in the tract of the opposite side. It cannot be traced so far down the cord. Dr. Sherrington found it after extensive experimental lesions on the dog.

Professor Schäfer¹² figures the same tract in the monkey. In some monkey's cords that I have examined for Messrs. Horsley and Spencer, in which the lesion of the cortex was sufficient to cause a very obvious degeneration of the crossed pyramidal tract, there was at this time a very scanty degeneration of fibres in the corresponding tract on the same side as the lesion.

Another important piece of evidence of the existence of these re-crossed fibres is that of Homén,¹³ who, after semi-section in the cervical region in dogs, found distinct degenerating fibres in the opposite lateral tract, beginning about one centimètre below the level of the lesion. He traced the degeneration as far down as that on the opposite side. This experiment would show that this so-called re-crossing of the fibres is going on all through the cord. He found at the same time degeneration of the anterior pyra-

midal tract, which appears to me to answer the question of Messrs. Langley and Sherrington, as to whether that tract exists in the dog, in the affirmative. The most difficult points in connection with this degeneration are that it causes such slight symptoms, and that it is not really very common after unilateral lesion, and therefore perhaps ought to be regarded as a deviation from the normal.

To look at the figures and sections in Pitres's paper, one would certainly expect a double hemiplegia. Again, one must suppose a similar re-crossing of healthy fibres from the crossed pyramidal tract of the same side into that of the opposite side, and therefore, if they be motor fibres, so much less a degree of paralysis on that side; but the clinical evidence lends no colour to this view. In my Case III of extensive lesion of the middle and posterior parts of the capsule I can find no degeneration on the same side in the lateral tract.

The descending lesions after a half-section of the cord are very well shown in monkey 7 (Fig. 8), already mentioned in Lecture I. The semisection was not complete; that is, the anterior column and posterior median column escaped. The lesion was between the seventh and eighth cervical. The crossed pyramidal tract was very completely degenerated, and could be traced as low as the sacral region, and came to the surface as low as the seventh dorsal.

For a short way below the lesion, at about the level of the second dorsal, descending fibres are found in the periphery of the opposite lateral column, in a position respected by the ascending fibres of the direct cerebellar tract in the section above the lesion. (See Fig. 8, r.d.) These are the only fibres corresponding to re-crossed degeneration that I could find in this experiment.

Descending Fibres in the "Mixed Zone."—In the antero-lateral region, and extending round the anterior periphery—that is, in the anterior root zone—are seen many degenerated fibres, but in these situations are many normal ones also. This diffuse descending degeneration of the antero-lateral region, or "mixed zone" (Flechsigs), extends to about the eighth dorsal, but in the anterior root zone a thin strip can be seen as low as the sacral region. This degeneration is also seen in Fig. 7 for a considerable distance below the crush, and in Fig. 8 m.z. It is figured by Drs. Hadden and Sherrington in the paper referred to above.

Postero-lateral Descending Degeneration or "Comma-shaped" Tract.—In complete transverse sections can be seen by the naked eye, and after staining, a distinct tract of degeneration in the postero-lateral column below the lesion. It is situated so as to divide the column, as seen in transverse section, into two almost equal halves (Fig. 7, c.d. and Fig. 8). It has the shape of a comma—that is, a rounded thickened head and thin curved tail, reaching nearly to the periphery of the section. It was noticed first by Schultze,¹⁴ but it was figured, not described, by Dr. Bastian¹⁵ and Westphal¹⁶ previously to Schultze's observations, and later by Kahler and Pick.¹⁷

I have seen several instances of this degeneration, and I believe that it is rarely absent in cases of transverse lesion. Schultze figures it in a case of complete compression by tumour of the middle of the cervical swelling, 2 centimètres below the lesion. In Case v, Fig. 7, in which the cord was crushed completely between the eighth cervical and first dorsal roots, the degeneration is very distinct as low as the fifth dorsal root, and can be traced without much trouble with the microscope as far down as the seventh and eighth dorsal. In another case, in which the cord was crushed between the sixth and seventh cervical roots, the degeneration to the naked eye after hardening was very distinct in the cervical and upper dorsal region, and could be seen as far as the sixth dorsal. In a case of fracture dislocation of the fifth dorsal vertebra that I reported elsewhere, I have since, by careful examination, found it, but it is very faint, and extends little more than one inch below the lesion. It may be said that the "comma-shaped" tract is generally more distinct after lesion of the higher parts of the cord, above the fifth dorsal root probably. Homén finds that this tract degenerates downwards on the same side after semisections, an observation borne out by my monkey 7 (Fig. 8, c.d.). It is rather unexpected to find descending fibres in the middle of a column which is essentially a conductor of centripetal fibres. As to the function of its fibres we are at present

⁹ Pitres, *op. cit.*

⁹ Charcot, *Leçons sur les Localisations dans les Maladies du Cerveau, etc.*, Paris, 1876, p. 252.

¹⁰ Hadden and Sherrington: Bilateral Degeneration [in Spinal Cord, *Brain*, vol. viii, p. 502.

¹¹ Sherrington, "Degeneration in Spinal Cord," *Journ. of Physiol.*, 1885, p. 177.

¹² Schäfer, *Journal of Physiology*, vol. iv, 1883, p. 316.

¹³ Homén, *op. cit.*

¹⁴ Schultze, "Beitrag zur Lehre von der secund. Degen.," etc., *Arch. f. Psych.*, 1883, p. 375.

¹⁵ Bastian, "Case of Concussion Lesion with Second. Degen.," etc., *Med.-Chir. Trans.*, 1867, p. 499.

¹⁶ Westphal, *Arch. f. Psych.*, Bd. x, 1880, p. 788.

¹⁷ Kahler and Pick, *ibid.*, p. 179.

quite ignorant. Schultze considers that it must either consist of fibres which degenerate both upwards and downwards when cut in their course, a condition which is quite irreconcilable with recognised facts, or else that it contains fibres from the posterior roots, which are bent back, as it were, after entering the cord, to pass into the grey matter at a point below. This supposed bending back of the posterior root-fibres has been suggested by Stilling and Brown-Séquard. It is, however, extremely improbable that such bending back of posterior root-fibres can possibly extend so far as this degeneration does; then, again, if the fibres of the "comma-shaped" tract were derived from the posterior roots, they should degenerate after section of those roots; but I can find no evidence of such in my experiments. It seems more likely that the fibres forming it are commissural.

Fibres which Degenerate Upwards.—Degeneration of ascending tracts may be secondary to complete or partial transverse sections of the cord, crushing, pressure, invasion of new growths, focal inflammation, involving the whole or part of the transverse section, and, lastly, the section or disease of the posterior roots. Close above the lesion, supposing it to be a crush, for instance, we find the traumatic degeneration affecting most of the section, but even here tending to affect the ascending tracts most. As a rule, the whole of the posterior region is deeply degenerated; the same may be said of the whole periphery of the section, even including to a greater or less extent the anterior column and the anterior radicular zone (Fig. 7, C VII). The fibres, however, lying next the grey matter in the lateral region, called the "lateral limiting layer," usually escape, unless, of course, there be much inflammation, in which case the whole section may be affected, grey matter as well as white. The traumatic degeneration is said by Homén and Schiefferdecker to extend for about 1 to 2 centimètres above the lesion. Above this we may speak of the degeneration as being true secondary degeneration.

Posterior Region.—This consists of the postero-lateral column and the posterior median column, as stated above.

Postero-lateral Degeneration.—The postero-lateral column is never degenerated far from the point of lesion. At the second root from the lesion in Case v this column begins to show a few normal fibres, and these fibres are obviously principally acquired from the posterior root. The normal fibres can be seen if the section be made through the point of entrance of the root, flowing in considerable numbers into the posterior part of the column, where they form a little group. At the next root above there is quite a considerable area of non-degenerated fibres, extending forwards parallel to the posterior horn of the grey matter. With each root, as we ascend from the lesion, then the postero-lateral area seems to receive a fresh contingent of normal fibres; and at the fifth root from the lesion we find the postero-lateral area beginning to assume its normal dimensions. This influx of new fibres from the posterior roots is, however, scarcely enough to account for the whole of the postero-lateral column, as we shall see when we come to study degeneration from sections of the root. It is, therefore, probable that a large number of these are commissural.

The above statements are based principally on the examination of Case v, but they apply equally well to lesions lower down in the cord. We may look upon the postero-lateral column as one of the principal conductors of the posterior root fibres. This, of course, explains many of the phenomena of *tabes dorsalis*, which is essentially a disease of this column.

Posterior Median Column.—With the appearance of the postero-lateral column, the position and shape of the posterior median column becomes defined. The two together make up an area having a V-shape, the angle of the V being truncated and applied to the posterior commissure. The sides of the V bend outwards and backwards towards the posterior root at first. Root by root, however, this tract becomes smaller, compressed as it were by the increasing number of fibres from the postero-lateral region, till at last it becomes a thin strip of degeneration each side of the posterior septum, but still reaching forwards to the posterior commissure. If the lesion be below the fourth or fifth dorsal, the tract in the cervical region not only becomes thinner, but at about the third cervical root retreats backwards, forming a wedge with the thin end forwards. The further down the cord the lesion is, the sooner this shape of the degeneration is assumed, till at last the lesion is only a small triangular patch at the posterior extremity of the posterior septum. The ascending degeneration of the posterior median column is one of the most constant lesions we have to do with. Any considerable damage of the cord high up or low down is certain to be followed by more or less degeneration of this

tract. From remarks above made concerning the postero-lateral fibres, it is practically certain that large numbers of the fibres of that tract pass directly into the posterior median column. Hence it is that in *tabes*, in which the postero-lateral column is sclerosed in the lower parts of the cord, in the higher parts we find the posterior median column affected only.

A large number of the fibres composing the posterior median column run from one end of the cord to the other, that is, into the medulla. This is shown by the records of many cases of pressure and disease of the cauda equina; moreover, I shall quote experiments on monkeys in further proof of this point.

It is probable that very few, if any, of the fibres cross in unilateral lesions to the opposite column, that is, they run up on the same side. This is certain from semisections by Homén and others, and by my own cases.

Destination of Posterior Median Fibres in Cord.—But though a large number of the fibres run straight up to the medulla, yet the tract progressively diminishes in size from below upwards, and therefore its fibres must be diminishing in numbers *pari passu*. But this diminution appears, according to Schiefferdecker,¹⁹ to be not regular, but subject at certain points to sudden alterations in size. These points were (1) between the fourth and fifth dorsal, (2) between the first and second dorsal, (3) between the seventh and eighth cervical, and lastly, between the second and third cervical. His method of determining this was ingenious, but seems open to many errors of observation; it consisted of drawing very accurately by the camera lucida the outline of the degeneration on paper and then cutting out the drawn figure and weighing it with the most delicate balance. Of course this takes no account of normal fibres in the area of degeneration, of which the tract receives many as it passes upwards. Between the points of sudden diminution in size, the tract alters very slightly in area from root to root. Schiefferdecker concludes therefore that these fibres end in certain centres or collections of ganglion cells in the cord.

In Medulla.—But though large numbers of the fibres disappear in the grey matter of the cord, yet there is no doubt that a certain number, more or less, traverse the whole length of the cord to the medulla. As we trace the postero-lateral column and the posterior median column upwards to about the level of the first cervical root, we find that the angle formed by the two posterior horns becomes wider, owing to the divergence of the horns. At the same time the tips of the posterior horns become swollen as it were by a local increase of the so-called *substantia gelatinosa* Rolandi, this local swelling being named the tubercle of Rolandi, still at this level the general appearances of the spinal cord section remain; but above this the appearance changes. The whole section is larger, owing to the appearance of new material. Anteriorly we have the lowest part of the decussation of the pyramids, pushing the remains of the anterior horns of the grey matter aside, so that the lateral region is relatively smaller than it is in the lower part of the cervical regions. The *substantia gelatinosa* retains its position, but assumes a crescentic shape; between this crescentic *substantia gelatinosa* and the periphery lie a number of medullated fibres, part of which, at any rate, make up the ascending root of the fifth cranial nerve. At this level, moreover, a change takes place in the constitution of the posterior region. In both the posterior median column and the postero-lateral column, we find what appears as a prolongation backwards of the grey matter around the central canal; this is no longer the thin commissure that it was lower in the cord, but a large mass, containing many nuclei and many ganglion cells, which higher up are grouped to become the nuclei of certain cranial nerves, such as the hypoglossal, glosso-pharyngeal, etc. This central grey mass then sends back prolongations of its substance into the posterior median and the postero-lateral columns. So that at this level the posterior median and postero-lateral columns consist each of a peninsular of grey matter with white matter nearly surrounding it. They here have received other names, the posterior median is called the *funiculus gracilis*, the grey matter in it the *nucleus gracilis*, or *nucleus clavatus*; the postero-lateral is called the *funiculus cuneatus* with its *nucleus cuneatus*.

It is with the *nucleus gracilis* that we are now more particularly concerned. The ganglion cells in it are peculiar; they are not so large as those in the anterior horns of the grey matter anywhere in the cord, and they are also of the oval, bipolar, or unipolar kind, such as are found in the posterior vesicular column of Clarke. Among these ramify horizontally medullated fibres. As

¹⁹ *Op. cit.*

we pass still higher in the medulla the two funiculi graciles become separated by a fissure, the first beginning of the calamus scriptorius. At the same time the central canal, with its grey matter and nerve nuclei, passes backwards to open into the fourth ventricle, and finally the grey matter forms the floor of that ventricle.

To return to the degeneration of the posterior median column. Where the degeneration is extensive, as in Case v, Fig. 9, Sections 6 and 7, p.m.,¹⁹ the peninsula of grey matter or nucleus gracilis has a mass of degenerated fibres lying along its inner side, and also along its posterior aspect. If, however, the degeneration is that of posterior root fibres, as in monkey 3 (*vide infra*), it will be found lying against the internal aspect only.

Fig. 9.—Medulla of Case v (see Fig. 7): a. t. (antero-lateral tract), d. c. t. (direct cerebellar), d. a. (direct cerebellar and antero-lateral tracts combined); p. m. (posterior median), c. r. (corpus restiforme); $\times 2$ diam.

Higher up, the encroachment of the nucleus gracilis, as it were, forces backwards the degenerated fibres till at last there remains little more than a small patch posterior to the nucleus, and finally this disappears also. (Fig. 9, Section 5 p.m.) There can be no doubt that these degenerated fibres are absorbed one by one into this nucleus gracilis. It is probable that the fibres are in direct communication with the bipolar ganglion cells of the nucleus. Seeing the great similarity between the cells of this nucleus and those of the posterior vesicular column, it is not unreasonable to suppose that the fibres which are disappearing from time to time

in the upward progress of the tract end in a similar manner in the posterior vesicular column of the cord.

Now I shall speak more particularly concerning the posterior vesicular column and its relations, in my next lecture; but it will not be out of place to remark here that the posterior median column carries vast numbers of small nerve-fibres, which have been proved by Gaskell, Onodi, and others to be visceral in function, and to be probably in direct communication with the posterior vesicular columns; also that lesion of the posterior median column alone gives rise to no known symptoms at all comparable, at least, to such as follow corresponding lesion of the postero-lateral column. Also that the fibres of this column do not cross, at least in the white matter, whatever they may do when they reach the grey, but tend to run a very long course on the same side.

Development of Posterior Median Column.—I may mention here that the posterior median column, as is the case with the other columns of the white matter, develops from below upwards, and therefore the tract of unmyelinated fibres appears to diminish from above downwards, the opposite of the degenerated tract.

We have seen, then, that the posterior median column degenerates secondarily after lesions involving the columns themselves, and after lesions involving the postero-lateral column; we have next to consider the course of degenerations following on lesions of the posterior roots.

Results of Division of Posterior Roots.—At the suggestion of Dr. Gowers, and with the kind help of Mr. Horsley, I have been enabled to try the experiments of such sections on monkeys. I have made careful examination of the cords of three monkeys, which I know as monkey 2, 3, and 4. I have already referred to them in my first lecture, and have mentioned in what respects the resulting degeneration differs from ordinary secondary degeneration.

In monkey 2, Mr. Horsley divided all the posterior roots of the right side of the cauda equina at a level about 1 centimetre above the tip of the sacral end of the cord. The operation was quite successful, and the animal rapidly recovered without a bad symptom. There was complete loss of common and pain sensation, and probably of muscular sense, in the lower limb of that side; there was also loss of knee-jerk on the same side. The animal lived thirty-six days, then died from diarrhoea, which was causing a high mortality at that time among the monkeys at the Brown

Fig. 10.—Section of posterior roots of cauda equina on the right side (monkey 2); p. l. (postero-lateral column), p. r. (degenerated posterior roots, proximal end), p. v. (visceral fibres of posterior column), p. m. (posterior median degeneration); $\times 4$ diam.

Institution. Unfortunately the necropsy was made twelve hours after death, and therefore there is some *post-mortem* change, but not very much. Fig 10, L v., is made from a section of the cord with

¹⁹ The sections in this figure will be more minutely described in the next lecture; it is placed here for convenience of reference.

the nerves of the cauda round it, at about the level of the fifth lumbar. The degenerated nerves are shaded, as is the degeneration in the other figures. At this level no affection of the posterior region can be made out except just close to the tip of the posterior horn, where the posterior root fibres begin to enter; here the entering fibres are deeply degenerated, and can be traced into the grey matter as short broken bundles of varicose, deeply-staining fibres. A root above the area of the postero-lateral column next the horn is highly degenerated, but, as can be seen in Fig. 10, L IV, only a small area is affected. At the third lumbar the greater part of the posterior region, in fact, nearly all the postero-lateral column, is affected. At the first lumbar the degenerated area has attained its largest extent, the whole of the posterior region except a very small triangle at the posterior part of the posterior septum, and a small patch close to the tip of the posterior horn. This small area close to the posterior septum is found to consist, under the microscope, almost exclusively of fine nerve-fibres (p.v.), and is continued right up the cord. That next the posterior horn indicates the entrance of new nerve-fibres from the unaffected posterior roots. A glance at the remaining figures is sufficient to show the course of the degeneration. Though it affects the posterior median column, it affects it most extensively at the eleventh dorsal, and even there respects the small area above mentioned (p.v.).

Higher up, it dies away till it remains as a small patch against the posterior septum, rather below its middle. On closer microscopical examination, it is found that degenerated fibres can be traced passing into the posterior horn at levels from the fifth to the third lumbar inclusive. The posterior vesicular column, as a collection of ganglion cells, does not commence till about the second lumbar. Therefore, if these degenerated fibres enter that column, they must do so by passing up in the grey matter for some distance. The evidence seems to point to the correctness of this supposition. If the section at the fourth lumbar be examined, large bundles of degenerated fibres can be seen entering the horn, but then they seem to stop suddenly, only a few can be traced forward. It is, therefore, probable that they do pass upwards. I have been unable to trace with certainty any fibres crossing to the opposite side of the grey matter. But a considerable number of these fibres can be seen passing up towards the anterior horns, probably to form communication with the ganglion cells for reflex purposes.

The experiment on monkey 4 was of a similar description. Mr. Horsley divided the posterior roots of the last dorsal and upper three lumbar nerves on the left side. The result was anaesthesia of the side of the trunk corresponding to the distribution of the nerves. The animal was killed on the fifty-second day. It will be seen from Fig. 11 that the resulting degenerations exactly correspond to those of the last case.

Fig. 11.—Section of posterior roots of twelfth dorsal and first three lumbar on the left side (monkey 4).

At the level of the third lumbar the fibres entering the horn are practically all degenerated; the result is that, comparing the horn on that side with the opposite healthy horn, we find that whereas in the latter there is a wealth of fibres, in the former there is a great dearth of them. Apparently the animal had lived long enough for complete disappearance of the degenerated fibres. Again, comparing the grey matter of the central and lateral regions, we find a similar difference between the two sides, though less marked. Even in the anterior horns there appear to be fewer medullated fibres on the side of the lesion. At the second lumbar the

posterior vesicular column has commenced, and there is in it on the side of the lesion scarcely a normal fibre visible, contrasting in that respect very strongly with the opposite side. This is also very striking at the first lumbar. There is, however, no sign of alteration of the ganglion-cells of the posterior vesicular columns themselves. Between the tenth and eleventh dorsal, the degenerated fibres have ceased to flow into the posterior horn, but even here the posterior vesicular column shows few normal fibres.

It should be noticed that the postero-lateral and posterior median columns are the only two columns affected in these two experiments; that the direct cerebellar tract and the antero-lateral escaped entirely. There is a number of vacuoles on the other side of the posterior septum in sections at the level of the twelfth dorsal and first and second lumbar, at which points the degeneration on the same side as the lesion is at its maximum; at the level of the eleventh dorsal the degeneration is no longer to be seen. So far as I know, the first to study degeneration after section of posterior roots was Singer,²⁰ in 1881, though a short notice exists of experiments in the same direction by Bufalini and Rossi.²¹ Singer's experiments were on dogs, and in the main the resulting degenerations coincided with those in monkeys 2 and 4.

Rossolymoz²² in 1886 made similar experiments on guinea-pigs. He found degeneration of the postero-lateral column, and also some degeneration of the lateral column near the tip of the posterior horn, but says that none was found in the posterior median column at any level. No doubt results will vary in detail in different animals. I cannot help thinking that the results in the monkey must resemble closely those in man, the anatomical features of the spinal cord being remarkably alike in both.

Singer's experiments and monkeys 2 and 4 seem to show that though some of the fibres of the posterior roots undoubtedly pass straight into the posterior horn, and so in the direction of the posterior vesicular column, and probably also end in the posterior vesicular column, yet a very large number pass up in the postero-lateral and posterior median columns, even to the medulla.

Lesions of Posterior Roots in Man.—Such pathological data as we possess in man point in the same direction as the experiments above quoted. Several observers have suggested that in many cases of tabes dorsalis the initial lesion may be in the peripheral nerves. It is difficult to understand, however, how the degeneration can pass up the nerves past the ganglion on the posterior roots. After section of peripheral nerves the central end certainly does degenerate to a certain extent, but the degeneration has not been traced beyond the ganglion. After amputation the side of the cord corresponding to the amputated limb becomes smaller, but no true degeneration has been observed; but if the initial lesion be in the posterior roots, that is between the ganglion and the cord, then we may have the same degeneration resulting as follows experimental section.

Many cases have been recorded of lesion of the roots, more particularly of the cauda equina. In all secondary degeneration has followed of the postero-lateral column first, and higher up of the posterior median. In this connection also should be mentioned an exceedingly interesting case of locomotor ataxy of the upper extremities only, reported by Déjerine.²³ The lesion was situated in the cervical and upper dorsal cord only. There was the most intense degeneration of the posterior roots of the region affected. There was also posterior sclerosis, complete in the upper cervical region with the exception of the small triangle at the posterior part of the posterior median column. Lower down the postero-lateral column was much affected; the posterior-median column less so; in fact the case presented the same lesions as result from section of the posterior roots.

Lange²⁴ records a case which appeared to give all the signs of locomotor ataxy. *Post mortem* was found a tumour involving and pressing on the posterior roots of the cauda equina, most on the right side, with ascending lesions to as high as the middle dorsal region.

Summary of Connections of Posterior Roots.—In conclusion, then, we may say that the fibres of the posterior roots in the lower parts of the cord, most of them, pass into the postero-

²⁰ Singer: Ueber secund. Degen. im Rückenmark des Hundes, *Sitzungsber. der Wien. Akad.*, 1881, p. 403.

²¹ Bufalini et Rossi: Atroph. de la Moelle Épinrière par la Section des Racines Nerveuses, *Arch. de Phys.*, 1876.

²² Rossolymoz: Zur Frage ueber den Weiteren Verlauf der Hinterwurzelfasern, *Neurol. Centralbl.*, 1886, p. 391.

²³ Déjerine: Contrib. à l'Étude de l'Ataxie Locomotrice des Membres Supérieurs, *Arch. de Phys.*, 1883, p. 331.

²⁴ Lange: Ueber die Leitungs verhältnisse in den hinteren Rückenmarks-Strängen, etc., *Schmidt's Jahrb.*, Bd. 155, 1872, p. 281.

lateral column, though some undoubtedly pass straight into the tip of the posterior horn. In the postero-lateral column the fibres remain only for a short distance of their course; they then pass in one or two directions. They may either pass into the grey matter of the posterior horn at various levels, or else they may pass into the posterior median column. In the grey matter they form connections undoubtedly with the posterior vesicular column, and also with ganglion-cells in the anterior horns. In the posterior median column they run a long course right up to the medulla, where they end in the nucleus gracilis. Physiological experiments point undoubtedly to the probability of a crossing of these fibres in the grey matter to the opposite side. Do they cross in the posterior white columns? In the first of the above experiments, there is an appearance of swollen fibres in the opposite posterior region, but this may be accounted for by an accidental degeneration of one or more of the posterior roots of that side. In the second experiment, the appearances are more difficult to explain, except on the supposition that some of the posterior median fibres cross through the septum. Singer's experiments show nothing of the kind, and in a third experiment (monkey 3), to be described in my next lecture, in which there was section of the lower cervical posterior roots, there was no such affection of the opposite posterior median column. The appearances may be due to the reagents used. At any rate, I draw no definite conclusions from them. Except this experiment, the evidence points to an absence of intercommunication between the posterior median columns. It has yet to be determined by experiment what kind of impressions the fibres of the posterior median column convey. The effect of lesion of the postero-lateral column is better known, but such lesion includes affection of both the sets of fibres above mentioned. It is highly probable, as I shall insist in my next lecture, that most of the fibres of the posterior median column are visceral in function.

In my next lecture I shall study the course of the ascending fibres in the lateral column and their destination in the medulla, and also the course of the visceral fibres in the cord.

THE TREATMENT OF CONFIRMED CATHETER LIFE BY A PERMANENT PERINEAL OPENING.¹

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I AM quite aware that I am treading very closely upon the heels of those who have recently and very ably brought before the notice of this Society matter kindred in character to the subject of my communication, but I intend, so far as the interest of my subject will permit, to avoid going over any of the ground traversed on previous occasions.

My immediate object this evening is to submit for your consideration a plan which I have for some years found to be effectual, and I believe to be novel, in the treatment of men suffering from enlarged prostate who have not only arrived at catheter life, but have advanced to the stage when all prospects of their ever again being able to pass urine in the natural manner have to be abandoned as hopeless.

In these cases, Sir Henry Thompson, the veteran pioneer of all that relates to bladder surgery, advocates one of two plans: either the permanent retention of a tube through an opening established in the bladder above the pubes; or the plan of suspending the action of the bladder from seven to ten days by the temporary maintenance of a drainage-tube through the perineum. By the latter plan, he says, speaking of one case, "the relief was immediate and most remarkable," but he is compelled to admit that in every instance the patients have had sooner or later to resume their original practice of passing the catheter.

From Mr. Reginald Harrison's admirable Lettsomian lectures, I gather that he is in favour of drainage from the perineum. Previously we had those who were successful in many cases in relieving their patients by the constant use of retained catheters. As an alternative plan of treatment, we have also prostatotomy and prostatectomy, and more recently the suprapubic prostatectomy of Mr. McGill. Each of these plans appears to have fulfilled to a certain extent the purpose for which it was designed, but not one of them embraces the entire condition, or provides all that is

desired in confirmed prostatic obstruction. For instance, the high outlet of a suprapubic opening leaves that particular part of the bladder which most requires drainage more remote than ever from the benefit of treatment. The perpetual presence of a perineal drain-tube is even less tolerable than a retained catheter, and a retained catheter can only be borne by a limited number of those who might otherwise be benefited by its use, and it is questionable whether the presence of these tubes does not as a rule aggravate the mischief and shorten life.

Mr. Harrison is singular, I believe, in the view he entertains that the prostate undergoes a diminution in size owing to the influence of the prolonged retention of a tube, and I am not aware that he claims to have had more than one case where the benefit from this plan has been more than partial and temporary.

Perineal prostatectomy appears to me an operation without any of the advantages of precision. You can neither regulate the amount, nor define the limits, of what you remove, and there is always the possibility that an undue mass may be taken away and permanent incontinence result.

McGill's suprapubic prostatectomy has, at least, the merit of affording the operator an opportunity of seeing the overgrowths, which project into the bladder, *in situ*, but it affords no facilities for the removal of those growths which are confined to other portions of the prostate. The results of the cases reported by Mr. McGill were most excellent, but the number was small, and the conditions under which they were operated upon were exceptional. The mortality of suprapubic cystotomy in men over 50, it must be remembered, amounts to over 33 per cent., and this mortality is not likely, in the long run, to be lessened by the additional risk which must necessarily attend prostatectomy.

About six years ago I was more than ever impressed with the desirability of avoiding the pain and inconvenience which attend the constant passage of catheters; and I also became more familiar about this time with the facility with which a bladder could be entered for the purpose of digital exploration, and the idea occurred to me that at least three most important desiderata might be attained by a perineal urethrotomy. The bladder could be drained, it could be given necessary rest, and a considerable length of urethra would be relieved from the irritation of repeated catheterism. In consequence of the relapses which almost invariably followed the closure of the perineal wound and the re-establishment of the *status quo*, I further decided to maintain permanently the direct passage through the perineum. In the conception of this operation advantage was taken of the fact, which had been generally overlooked, that an opening in the membranous urethra does not involve, as many suppose, incontinence of urine.

I am aware that there are numerous instances on record where, after perineal cystotomy, the wounds have failed to heal, and a permanent fistula has remained; but in these cases the fistulæ have been accidental, and never, to my knowledge, have they been claimed as the result of a deliberate intention on the part of the operator. And, further, a perineal fistula in itself would afford no advantage; but if the fistula is made, and utilised in the manner I have to propose, then it becomes the key to the difficulty which attends the treatment of prostatic enlargement. I will now proceed, in the first place, to describe to you the operation itself, which differs in no essential detail from an ordinary median urethrotomy. A staff is passed into a previously moderately distended bladder. A lithotomy-knife, with the edge upwards, is plunged directly into the groove of the staff from a point an inch above the anus to a point a little in front of the prostatic apex. I prefer to enlarge the skin incision as I withdraw the knife, leaving the external wound, when finished, about an inch in length, and directed from the raphe towards the centre of the space between the anus and the left tuber ischii. As the staff is withdrawn the finger is passed into the bladder when possible, and the opportunity is taken of making a digital exploration. When nothing is discovered admitting of immediate operation, the tube I have been at some pains in getting made to my satisfaction is introduced and maintained by a T-bandage, which I have found quite as effectual and much more comfortable to the patient than tapes. My preference for enlarging the external wound by one sweep of the knife during its withdrawal, in the place of cutting down on the staff by repeated incisions, is to secure a clean section and thus avoid an irregular wound, which gives greater facilities for the lodgment of discharges. The limited space between the point where the knife first enters the urethra and the rectum does not afford sufficient room for a

¹ Read before the Medical Society of London, March 4th, 1889.