The post-posterolateral group begins in the eighth cervical segment and extends through the first dorsal segment. The posterolateral segment gradually disappears from the lower part of the eighth cervical segment, and is absent in the first thoracic segment, although the post-posterolateral group is so well developed in the first thoracic segment that the posterolateral angle still remains prominent in spite of the disappearance of the posterolateral group proper.

In the region of Nn. lumbales and Nn. sacrales the lateral group of cells first appears at the second lumbar segment, though a small central anterior group of cells is present at the anterolateral angle of the first three lumbar segments.

The anterolateral cell group is enlarged in the fourth and fifth lumbar segments, causing there a special projection of the anterolateral angle; its maximum size, however, is attained at the level of N. sacralis I., below which the group rapidly decreases in size, disappearing entirely before the third sacral segment is reached.

The posterolateral cell group begins rather abruptly in the second lumbar segment, increases rapidly in size below this level, becoming largest in the fourth and fifth lumbar segments. The group undergoes some reduction in size in the first sacral segment, and this diminution goes on gradually through the second and third segments, the cell group disappearing entirely at the lower part of the third sacral segment.

As the researches of Onuf, van Gehuchten, and Bruce have shown, there is some difficulty in deciding upon the lower limits of the anterolateral and posterolateral cell groups in the sacral region, owing to the fact that the posterolateral and post-posterolateral cell groups become displaced forward so that they come to occupy the position previously held by the anterolateral and posterolateral cell groups respectively.

The post-posterolateral cell group has its upper limit in the lumbosacral region in the first sacral segment. It is remarkably developed in the lower half of the second sacral segment, but rapidly diminishes in size again through the third sacral segment, to cease entirely at its lower limit.

The central cell group, peculiar to the lumbosacral region of the spinal cord, extends from the level of N. lumbalis II. to the level of N. sacralis II. It is a tolerably compact column of cells, situated medial from and between the anterolateral and posterolateral groups of cells. It is best developed at the level of N. lumbalis V. and N. sacralis I.

Before leaving the arrangement of cells in the columna grisea anterior, we should say a word or two about a special group of motor cells situated in the upper cervical segments, viz., the *nucleus nervi accessorii*. In sections through the first cervical segment, the posterolateral group of about sixteen cells per section represents the nucleus N. accessorii; in sections through the second cervical segment this nucleus is situated near the middle of the anterior horn, and consists of about eight cells per section; in the third cervical segment the nucleus occupies a position near the middle of the lateral margin of the anterior horn, and there are about five cells per section; in the fourth cervical segment the cells of the nucleus lie slightly behind the anterolateral angle. Some authors class these cells as belonging to the columna intermedio-lateralis rather than to the columna grisea anterior. The relations are well shown in Bruce's "Atlas," Plates I. to IV. The lateral groups of motor cells so richly represented in the enlargements, corresponding to the innervation of the muscles of the extremities, are spoken of collectively in the intumescentia cervicalis as the *nucleus extremitatis superioris;* and in the intumescentia lumbalis as the *nucleus extremitatis inferioris*.

The number of ganglion cells present in the anterior horn of human beings has been estimated for several segments by Kaiser. His figures are as follows:

In the fourth cervical segment, 28,440; in the fifth, 64,230; in the sixth, 44,560; in the seventh, 36,850; in the eighth, 47,970; in the first thoracic segment, 27,600.

Kaiser's article contains also the figures for several segments in the spinal cord of the five-months' embryo and of the new-born. Birge's article contains enumerations of the anterior horn cells of the frog.

The form of the anterior horn cell is typically polygonal when seen in cross-section, the multangular shape being dependent upon the origin of the dendrites and axones from the cell body.

Anterior horn cells vary in diameter in human beings between 11 and 110 μ (Stilling), though the majority measure from 67 to 135 μ, according to newer measurements. The cells of the posteromedial group average smaller, the diameter varying between 30 and 80 μ (von Kölliker). Ziehen has collected from the literature measurements made in a whole series of animals and he has combined them in a table given on pp. 130–131 of his article (*loc. cit.*).

The growth in size of the anterior horn cells in human beings is well illustrated by Kaiser's measurements in the lateral group of cells of the anterior horn: Fœtus at beginning of fifth month, 16–27.5 μ; at sixth month, 17–33 μ; at seventh month, 23–44.5 μ; at eighth month, 23–48 μ; newly born, 17.5–53 μ; fifteen-year-old boy, 26–53 μ; adult 23–59 μ.

Not all the cells of the anterior horns give rise to axones of fibres of the anterior root. Some of them send their axones to the white funiculi of the spinal cord itself, chiefly to the funiculi of the opposite side of the cord through the commissura anterior alba and hence designated "commissural cells" or "heteromeric neurones,"
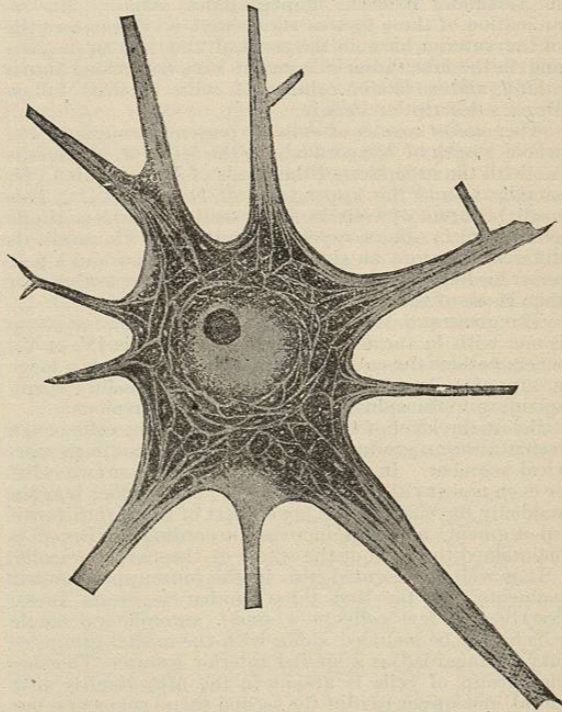

FIG. 4392.—Motor Nerve Cell from Ventral Horn of Gray Matter of Spinal Cord of Rabbit. (After Nissl.) Of the three lower processes, the middle one represents the axone. All the other processes are dendrites. The margins of the cells and of the mass of stainable substance appear too sharp in the reproduction. At the angle of the division of the large dendrite at the left superior angle of the cell is shown one of the "wedges of division" (Verzweigungskegeln). The spindle-shaped Nissl bodies are well shown, especially in the dendrites. This cell is classed by Nissl as a stichochrome nerve cell in the apyknomorphous condition.

but partly to the white funiculi of the same half of the spinal cord, and hence called "tautomeric funicular cells." According to von Lenhossék, the medial group of cells in the anterior horn is made up of commissural cells; he therefore calls it the commissural group, while the cells whose axones go into anterior root fibres are chiefly limited to the lateral group of nerve cells.

As to the large motor cells of the anterior horn, they form the most prominent elements in cross-sections of the spinal cord. They are typical multipolar stichochrome cells in the sense of Nissl (Fig. 4392). The dendrites pass out in all directions from the cell body, medialward, dorsalward, and some lateralward. They may reach the surface of the cord, having passed through the whole thickness of the white matter; in some animals there is a definite subpial plexus of dendrites. The axone, single for each cell, arises at the axone hillock, and shortly after leaving the cell becomes medullated and passes more or less horizontally through the white matter to enter one of the fila radicularia of the anterior root at the sulcus lateralis anterior. One to four delicate branches, the so-called side fibrils of Golgi, come off from the non-medullated portion of the axone and run back toward the cell body in the gray matter. The differences in calibre of the anterior root fibres have been mentioned above. According to von Bechterew the coarser fibres are medullated earlier than are the finer. It is the opinion of Gaskell and Mott that the coarse fibres are distributed to the voluntary muscles, the fine fibres to the involuntary muscles, by way of the systema nervorum sympathicum. An immense amount of work has been done upon the finer internal structure of the anterior horn cells, a very full résumé of which may be found in my book on the "Nervous System," pp. 101–157. Too much space would be required to introduce the details of structure here.

The glia cells in the anterior horn consist chiefly of typical astrocytes, some with long fibres, some with short. Of the processes of ependymal cells so abundantly present in the gray matter of the embryo cords, relatively little is to be made out in the adult.

In among the nerve cells and glia cells of the anterior horn are to be seen a very large number of medullated nerve fibres and collaterals. These include the medullated proximal portions of anterior root fibres, the medullated axones of tautomeric neurones, the cell bodies of which are situated in the gray matter of the anterior horn, the medullated axones of fibres going to or coming from the commissura anterior alba, the medullated axones and collaterals entering the anterior horn from the anterior and lateral funiculi, and lastly, but among the most important, the reflex collaterals from the posterior root fibres, which pass forward through the gray matter to terminate, as Golgi preparations from the embryo demonstrate, in end-arborizations around the anterior horn cells.

The researches dealing with the relations of the special groups of anterior horn cells to function are numerous. Among others may be mentioned those of Ferrier and Yeo, Risien Russell, Waldeyer, Sano, and Kaiser. M. Allen Starr's table of localization of function in the different segments of the spinal cord is invaluable in clinical diagnosis. (Vide Plate LII. in the present volume.)

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Columna Grisea Posterior (Posterior or Dorsal Horn).—The structure of the posterior gray column is much less well understood than that of the anterior gray column. Its gross subdivision into cervix, apex, substantia gelatinosa, and nucleus dorsalis has been described above under the macroscopic appearances. The prominent posterior part, just ventral from the substantia gelatinosa, sometimes called the caput and badly designated, by Waldeyer, *Kern des Dorsalhorns*, is a striking feature in Weigert preparations, since it is closely crowded with medullated fibres and contains relatively small nerve cells.

The nerve cells in the posterior horn are, on the whole, much smaller than those of the anterior horn. The total number of nerve cells present is probably smaller and their distribution and arrangement are irregular. The most constant cell group is the nucleus dorsalis or column of Clarke, which lies at the medial margin of the base of the posterior horn. The nucleus dorsalis is best developed in the lower segments of the thoracic region, and in the segments corresponding to the two uppermost Nn. lumbales. In the intumescentiæ the cells are scanty or absent altogether. In the gray matter of the sacral segments the cells are again more numerous (sacral nucleus of Stilling). There is also a good representation of Clarke's nucleus in the uppermost portion of the cervical cord (cervical nucleus of Stilling). The exact position of the nucleus dorsalis varies in different animals, having a tendency to be situated more dorsalward in human beings than in lower forms. The number of cells in the nucleus dorsalis has not yet been determined. The greatest number in any one cross-section is usually to be met in sections from the segment corresponding to the twelfth thoracic nerve, at which level the nucleus dorsalis measures as much as 0.75 mm. in diameter.

In ordinary carmine or hæmatoxylin preparations the cell bodies of Clarke's nucleus look rounded or elliptical, sometimes polygonal. In Golgi preparations they are shown to be actually multipolar, having very numerous dendrites and a single axone. The dendrites, however, are much less coarse at their roots than are the dendrites of the anterior horn cells, and this accounts for the difference in appearance in carmine preparations. The individual cell bodies vary greatly in diameter, according to Ziehen, between 15 and 70 μ. Von Kölliker's figures are 45–90 μ, while Mott gives as the average diameter 50 μ in the eighth thoracic segment, 109 μ in the twelfth thoracic segment (longitudinal sections).

The single axone from the cell body of a Clarke's nucleus usually arises on the anterior or lateral margin of the cell, occasionally it comes off from the posterior margin. From its origin it runs ventralward, makes a hook-shaped bend, and becoming medullated, either just before or just after making the bend, runs as a transver-

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sal nerve fibre to the posterior periphery of the lateral funiculus, where it turns so as to run longitudinally toward the cerebrum in the direct cerebellar tract of Flechsig, the tract which I have designated the fasciculus spinocerebellaris dorsolateralis. These axones, in that horizontal part of their course which is situated between the dorsal horns and the dorsolateral periphery of the cord, make distinct bundles, spoken of as the "horizontal cerebellar bundle" by Flechsig, or as "Flechsig's bundle" by von Lenhossék. Collaterals do not appear to be given off from these axones, at any rate in their proximal portions. As we shall see later, these axones pass through the corpus restiforme of the medulla oblongata to terminate in the cerebellum.

The nerve cells in the caput of the posterior horn, that is, in the so-called *Kern des Dorsalhornes* of Waldeyer, are not well understood. Ziehen designates them *Innenzellen des Hinterhornkopfs.* These cells tend to be triangular in the anterior portion of the group, but become more spindle-shaped in the posterior portion. The smaller cells are partly spindle-shaped, partly polygonal. The size varies greatly. It is rare to find a cell with a diameter of more than 50 μ, while the smallest cells are almost as small as the minute nerve cells of the substantia gelatinosa. The axone passes in a straight line or in a curve lateralward and becomes a longitudinal fibre, usually ascending, of the lateral funiculus of the same side. Accordingly these cells are to be looked upon chiefly as tautomeric funicular neurones. An occasional axone may pass into the anterior or posterior funiculus, or rarely through the commissure to the opposite side of the cord.

The substantia gelatinosa (Rolandi) contains an enormous number of minute nerve cells, so small that for a long time these cells were believed to be glia cells until Weigert demonstrated that glia cells are really relatively rare in this situation, and Ramón y Cajal, with Golgi's method, demonstrated the exact characters of the nerve cells and their processes situated there. These cells have been very well described by Gierke, and have been referred to them as *Gierke's cells.* They are usually stellate, though sometimes more spindle-shaped. They are very small; it is rare to find an axone exceeding 20 μ in diameter. The size varies between 6 and 20 μ. The arrangement in rows is very well shown in Ramón y Cajal's drawings. Each cell has numerous dendrites which have no regular arrangement, though sometimes they form bush-like masses at two extremities of a spindle-shaped cell. The axone arises, nearly always, from the posterior pole of the cell and runs backward, but can seldom be followed beyond the so-called zonal layer, that is, the outermost portion of the substantia gelatinosa which stains less intensely in carmine preparations (*Zonalschicht* of Waldeyer). Ramón y Cajal believes that some of the axones go to form longitudinal fibres of the fasciculus of Lissauer; others to form endogenous fibres of the posterior funiculus; some, doubtless, run longitudinally in the posterior horn itself. Golgi cells of type II., so-called dendraxones, have been described by various authors in the substantia gelatinosa (Rolandi). The finer structure of the cells of the substance of Rolando has been studied by Levi, to whose article we refer for a description of the nucleus and nucleolus.

As early as 1859 Clarke drew attention to the peculiar position occupied by certain cells of the zonal layer of the substantia gelatinosa. These cells, which have been called *marginal cells* by von Lenhossék, and *cellules limitantes* by the French writers, form an uninterrupted row, closest together at the medial margin of the substantia gelatinosa of the posterior horn. Some of them can be followed beyond the substantia gelatinosa, along the medial margin of the posterior horn, even as far as Clarke's nucleus. The individual cells are spindle-shaped, the long axis of the cell running parallel to the margin of the substantia gelatinosa. A few pyramidal cells can be seen, the apex of the pyramid being turned toward the interior of the substantia gelatinosa. These

cells are larger by far than the Gierke cells of the substantia gelatinosa itself. The dendrites come off chiefly from the poles of the cells; the axone may arise from the cell body or from a dendrite. It usually passes ventralward through the substantia gelatinosa (Rolandi), where it gives off collaterals (Ramón y Cajal) and then bends lateralward to become a longitudinal fibre of the lateral funiculus. In animals like the chick, mouse, and pig, some axones bifurcate into two, both going to the lateral funiculus, or one going to the posterior root fibres which have not yet been followed in human beings.

A very careful study of the glia cells of the posterior horn has been made by Weigert. He it was who demonstrated the relatively small amount of glia in the substantia gelatinosa (Rolandi), a view quite opposed to the older descriptions. There is more glia in the caput of the posterior horn; the nucleus dorsalis is tolerably rich in glia cells. The appearances of the glia of the posterior horn and of the substantia gelatinosa (Rolandi), as revealed by Golgi's method, are well described and pictured by von Lenhossék, to whose article the reader is referred.

The study of the finer and coarser medullated fibres appearing in the posterior horn, made by von Lenhossék, is also one of the best at our disposal. Every one who has studied Weigert preparations of the posterior horn has been struck by the radial bundles of medullated fibres which pass through the substantia gelatinosa (Rolandi), and by the great number of fine fibres present in different parts of the posterior horn.

A large number of the fibres entering the posterior horn of the gray matter are to be looked upon as the terminals of the fibres of the posterior funiculi. As manifold observations have shown, the fibres coming into the posterior funiculus through any given posterior root, vary greatly in their length. Some run into the gray matter to terminate almost at the level of entrance; others run longitudinally in the posterior funiculus, to terminate at the level of entrance, while still others run for long distances lengthwise in the posterior funiculus, passing by a great many segments before terminating in the gray matter of the cord, some of them even passing the whole length of the spinal cord above the level of the entrance to find a termination first in the gray matter of the medulla oblongata. Accordingly the posterior root fibres seen terminating in the gray matter at any given level of the cord may have come in through a posterior root near this level, or through a number of posterior roots at variable distances below. A few posterior root fibres instead of running lengthwise in the posterior funiculus assume a longitudinal course within the gray matter of the posterior horn itself.

Much interest has been manifested with regard to the medullated fibres which run in from the fasciculus cuneatus to terminate in the nucleus dorsalis. Von Lenhossék and von Kölliker describe these fibres going to the nucleus dorsalis as collaterals of the posterior root fibres, though Schaffer, of Budapest, maintains that these fibres are the main fibres and not collaterals, and his observations, together with those of Redlich, indicate that it is the fibres from the sacral and lumbar nerve roots which chiefly end in the nucleus dorsalis. The number of fine medullated fibres to be seen in among the cell bodies of the nucleus dorsalis is a striking feature of Weigert preparations.

Whatever may be the facts in the dispute about the nature of the fine medullated fibres in the nucleus dorsalis, there can be no doubt that in addition to the terminals of the stem fibres of the posterior root running into the gray substance, there are immense numbers of collaterals from the posterior root fibres and their limbs of bifurcation passing into the dorsal horn, some of them to end there, others to pass through it and to terminate in the anterior horn. These collaterals are most numerous on the fibres of the fasciculus cuneatus; but they rarely come from the fibres of the fasciculus gracilis; in other

words, the collaterals are given off from the proximal portions of the posterior root fibres rather than from their distal portions.

A group of these collaterals about which we know most is that of the reflex collaterals which come off in a flat curve, slightly convex lateralward, from the root entrance zone and enter the gray matter at the medial margin of the head of the posterior horn, some of them passing through the most medial portion of the substantia gelatinosa (Rolandi). These fibres lie lateral from Clarke's nucleus and pass into the posterior root fibres which run into the nucleus dorsalis to terminate there. Once inside the posterior horn these reflex collaterals run either straight ventralward or ventralward and slightly lateralward, sometimes forming a second slight curve, the concavity of which is directed medialward. In the anterior horn the collaterals undergo fan-like dispersion and end in terminal arborizations upon the cell bodies and dendrites of the anterior horn cells.

A large number of the radial bundles passing through the substantia gelatinosa are terminals and collaterals from the fibres of Lissauer's fasciculus to the caput of the posterior horn. A certain number of terminals and collaterals from the fibres of the lateral funiculus have been shown by Golgi's method to run into the gray matter of the posterior horn and to end there.

Doubtless some of the medullated fibres seen in the posterior horn are the medullated axones of posterior horn cells on their way to the funiculus lateralis, the funiculus posterior, or the commissure. The horizontal cerebellar path of Flechsig met with at tolerably regular intervals and representing the medullated axones of the cells of the nucleus dorsalis belong to this category.

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Columna Grisea Lateralis seu Intermediolateralis.—This column, especially developed throughout the thoracic portions of the spinal cord, includes the nerve cells of the so-called "lateral horn" and of the adjacent reticular formation. J. Lockhart Clarke described it as the tractus intermediolateralis, and pointed out that it was most marked in the upper portion of the pars thoracica. Many authors have made the mistake of confusing the

cells of this lateral column of gray matter with those of the posterolateral group of the anterior horn, and in the cervical and lumbar regions there is still some ground for doubt as to which cells shall be counted as belonging to the columna lateralis and which to the column anterior.

The bodies of the nerve cells tend to lie in compact groups; the individual cells are usually multipolar, sometimes spindle-shaped. The measurements in the long axis of the cell body are given as varying between 12 and 45 μ, those of the short axis between 5 and 15 μ. The dendrites which often run far out into the white substance tend to be arranged in oppositipolar groups corresponding to the spindle shape of many of these cells. The single axone goes as a rule to become a longitudinal (ascending or descending) fibre of the lateral funiculus of the same side. The cell bodies of the columna lateralis must therefore be regarded as being those of tautomeric neurones. A few axones probably go to the anterior funiculus of the same side. It has been suggested that some of these cells become anterior root fibres, which go to innervate the abdominal and perineal muscles; but the results of studies by the method of Golgi are opposed to such a view.

Columna Intermedia.—I use this term to designate an important area of gray substance situated between the anterior and posterior horns, and variously named by different authors (*Mittelzone der grauen Substans,* von Lenhossék; *Zwischentheil* or *Zwischenzone der grauen Substanz,* Ziehen). Here are situated groups of nerve cells which may be called intermediate cells (*Mittelzellen* of Waldeyer, *Zwischenzellen* of Ziehen). They lie anterolateralward from the nucleus dorsalis Clarkii. The arrangement of these cells is more regular and continuous in the upper part of the spinal cord, while in the lower part it is far less regular, the cells being scattered. Arginsky has described and pictured peculiar aggregations of these cells, which have, however, as he maintains, no segmental significance. The cell bodies are, as a rule, polygonal in shape and vary in size between about 10 and 24 μ in the long diameter. The axones of these cells go chiefly to become fibres of the lateral funiculus, though some have been followed into the anterior funiculus and others into the commissura anterior alba. The corresponding neurones are therefore to be regarded as tautomeric and heteromeric respectively.

Substantia Grisea Centralis.—This includes the gelatinous gray matter surrounding the central canal. The ependymal cells which line the central canal play a large part in the formation of this portion of the gray matter. Some one hundred ependymal cells are required to build up the circumference of the central canal at any one level (Stilling). These cells vary from 10 to 25 μ in breadth, and from 25 to 55 μ in length; these figures refer to the swollen main portion of the cell body and do not, of course, include the long processes (ependymal fibres). The cells are ciliated at their distal end; these cilia are much easier to make out in the embryo than in the adult. The so-called ependymal fibres are really the distal processes of the ependymal cells. The appearance of these fibres in embryonic tissues, stained by the method of Golgi, is very remarkable. The careful descriptions of von Lenhossék and Ramón y Cajal may be consulted in this connection.

In addition to the ependymal cells a larger number of glia cells exists in this region than in the more peripheral parts of the gray matter. The large number of nuclei visible in this region in iron-hematoxylin preparations probably accounted for by the presence of large numbers of glia cells, and the gelatinous appearance around the central canal is due to the large number of ependymal glia cells in the neighborhood. Weigert's glia stain demonstrates an extraordinary richness in glia in this region, the whole area coming out dark blue in the section.

The mode of obliteration of the central canal has been described in detail by Weigert and by Brissaud, to whose descriptions the reader is referred.

True nerve cells would appear to be absent in the immediate neighborhood of the central canal. In the more

peripheral portions of the substantia grisea centralis a few cell bodies can be found, part of them those of neurones whose axones go to the lateral funiculus, others those of intracommissural neurones.

In the gray commissure there are many white fibres which appear to be independent of the commissura anterior alba. These tend to be combined into two delicate white commissures which run in the gray commissure, one in front of the central canal (commissura intracentralis anterior), and one behind the central canal (commissura intracentralis posterior).

The commissura intracentralis anterior, identical with Stilling's commissura anterior accessoria, is sharply separable from the commissura anterior alba, lying as it does behind the latter in the gray matter. Its constituent fibres are very much finer than those of the anterior white commissure. The bundle is most marked in the intumescentia lumbalis and in the conus terminalis. According to Ziehen, the majority of the fibres, namely, those more anteriorly situated, are connected (by origin or termination) with the anteromedial group of nerve cells in the anterior horn. The more posterior fibres of this little commissure he follows to the junction of the columna intermedia with the substantia grisea centralis, and concludes that they here assume a longitudinal direction.

The commissura intracentralis posterior consists of very fine fibres, and is best developed in the proximal portion of the pars cervicalis and in the conus medullaris, being only feebly represented in the thoracic cord and in the intumescentiæ. Exact measurements of the sagittal diameter are given by Stilling.

Much work has been done upon the origin and termination of the fibres of this posterior intracentral commissure. The view now held is that many of them represent reflex collaterals from the posterior root fibres of one side of the cord, which go through this commissure to terminate in the opposite anterior horn. In addition, some collaterals from fibres of the lateral and posterior funiculi pass through this commissure to end in the posterior horn. Again, some of the cells in the posterior horn give off axones which, becoming medulated, pass through this commissure to the opposite posterior horn, to end there, or to become endogenous fibres of the opposite posterior funiculus. Ziehen also describes in the commissure fibres which arise from the cells of the columna intermedia and from the cells of the columna intermediolateralis, but the termination of these fibres he could not ascertain.

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THE CONDUCTION PATHS OF THE SPINAL CORD.

We have thus far considered the white matter and the gray matter more or less separately without any special reference to the interrelations of the nerve cells to the nerve fibres. Investigations have shown that functionally similar nerve fibres tend to run in definite bundles of the white matter, and that functionally similar groups of nerve cells tend to lie in common masses or columns in the gray matter. The bundles of fibres of common function are known as fibre systems. The functional groups of nerve cells are known as nerve centres or nuclei. Histological examination proves that these nerve centres or nuclei are connected with specific fibre systems. Each

nerve cell of a particular nucleus gives off an axone, which becomes the medulated nerve fibre of a definite fibre system. Since the nerve-cell body or perikaryon with its dendrites and axone, the collaterals and termination of the latter, is, as a whole, known as a neurone, it is obvious that we may speak of a nerve centre, or nucleus, together with its corresponding fibre system, as a neurone system (systema neuronicum). It is to the various neurone systems and the modes of localizing them in the spinal cord that it is our intention next to turn. We shall see that the term conduction path is used in a wider sense to include a chain of superimposed or subimposed neurone systems, the end arborizations of the axones of one neurone system transferring the nerve impulses to the dendrites and cell bodies of the next neurone system in the chain. A good spatial sense is necessary for the proper understanding of the conduction paths; unless one is capable of thinking of the three dimensional relations inside the central nervous system, he will have great difficulty in understanding the problems connected with them.

While, as we have said, there is a marked tendency to aggregation of fibres of similar function in localized areas of the white matter of the cord, it must not be thought that this localization is as sharp as many of the diagrams in the text-books would lead one to believe. Indeed, there is undoubtedly much mixing of fibre systems in given areas of a cross-section, and when we designate a certain area as that of the lateral pyramidal tract, for example, it must be understood that this nomenclature is employed for a fortiori reasons, for we know that in the area a few fibres other than those belonging to the pyramidal tract exist.

The methods which are employed for the localization of the conduction paths are as follows:

1. Weigert's Myelin-Sheath Method.—This method, described in the article Brain, Histology of, permits one in serial sections to follow medulated axones for very considerable distances. Unfortunately, it is not of great service in demonstrating the connection of the nerve cells with the nerve fibres, for even when carmine or other dyes are used as a contrast stain for the cell body and axones, it is often very difficult to follow an axone into its corresponding medullary sheath.

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2. Method of Golgi.—This method, chiefly applicable to embryonic tissues, has proved to be of extraordinary value in demonstrating developing dendrites, axones, collaterals, and telodendrions. It permits us to follow the axones of the various anterior horn cells to the anterior roots or to the anterior white commissure, or to the funiculi. It, more than any other method, has permitted the determination of the funicular relations of the axones of the posterior horn cells, and has given us most precise information regarding the intramedullary course of the axones of the fibres of the posterior roots. Finally, by means of this method, we have gained an entirely new conception of the relations of the axones of the terminals of one neurone system to the cell bodies and dendrites of the next neurone system in given conduction paths. The method has, unfortunately, a limited application in the study of the adult spinal cord.

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I have references to no less than nine articles on the nervous system bearing his name, published during the year 1890 alone. It would occupy too much space to give here a complete list of his publications. An epitome of his views is to be found in "Les nouvelles idées sur la structure du système nerveux chez l'homme et chez les vertébrés," French by Azoulay, Paris, 1894; and in the Croonian Lecture, "La fine structure des centres nerveux," Proceedings of the Royal Society, London, vol. lv., 1894, pp. 444-468. This lecture was delivered in French and published in the same language. A brief but inaccurate abstract of it in English was printed in the British Medical Journal, 1894, i., p. 543.
Weigert, C.: Die Golgische Methode. Ergebn. d. Anat. u. Entwickelungsgesch., Wiesb., Bd. v., 1896, S. 7-29.

3. Method of Flechsig (Observations of Serial Medulation).—Though a number of investigators before Flechsig had observed that different portions of the white substance developed their myelin sheaths at different periods, it was Flechsig who first took advantage of this fact in a large way for determining the serial sequence of medulation. He also utilized the facts discovered for drawing inferences with regard to the topographical localization of conduction paths. Flechsig's studies proved that in human embryos of the same age the same groups of nerve fibres are medulated in the white substance, while embryos at different ages reveal an entirely different grouping of the medulated fibres. In other words, the medulation of the different fasciculi is temporarily constant and follows a definite law. After studying a series of embryos, one can, if he knows the age of the embryo, say off-hand what bundles of fibres in the cord will on examination be found to be medulated, and what bundles will still lack myelin sheaths. Flechsig further found that nerve fibres having the same origin and termination, that is, nerve fibres of the same fibre system, and which therefore probably have the same function, become medulated at the same period, while other fibres, with different anatomical connections and different functions, become medulated at other times.

Flechsig, by this method, was able to distinguish easily in the funiculus anterior two parts: (1) the pyramidal tract of the funiculus anterior; and (2) the ground bundle or fasciculus lateralis proprius of this funiculus. In the lateral funiculus a study of the medullation separates sharply (a) the pyramidal tract of the lateral funiculus

(fasciculus cerebrospinalis lateralis); (b) the direct cerebellar tract (fasciculus cerebrospinalis), or, better, fasciculus spinocerebellaris dorsolateralis); and (c) the ground bundle of the lateral funiculus (fasciculus lateralis proprius). This embryological method goes even further and divides the fasciculus lateralis proprius into an internal part, the lateral limiting layer of the gray matter (seitliche Grenzschicht der grauen Substanz), and an external part, the anterior mixed zone of the lateral funiculus (vordere gemischte Seitenstrangzone). In the posterior funiculus the fasciculus gracilis (Golli) becomes medulated, on the whole, at a different period from that for the fas-
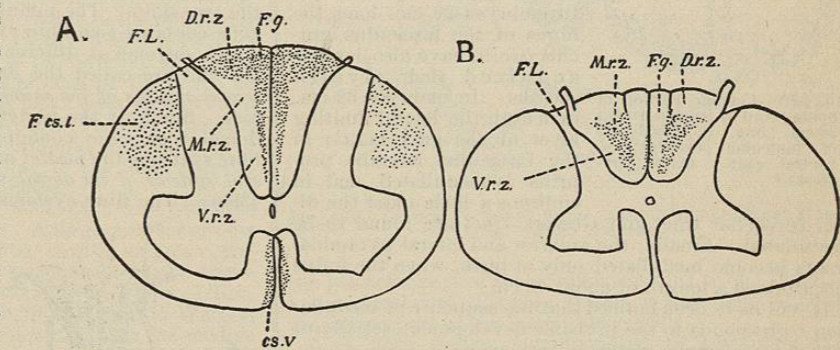

FIG. 4393.—Middle of Intumescentia Cervicalis. A, Memberment of dorsal funiculi as revealed by study of myelinization; B, lesion in a case of incipient tabes.
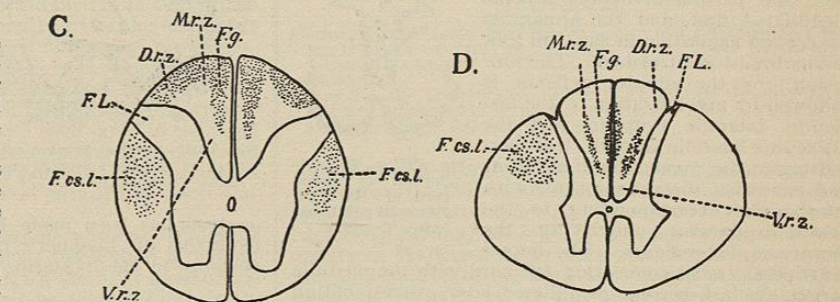
FIG. 4394.—Pars Thoracalis. C, Section through midthoracic region illustrating myelinization memberment; D, section through upper thoracic region showing lesion in a case of incipient tabes.
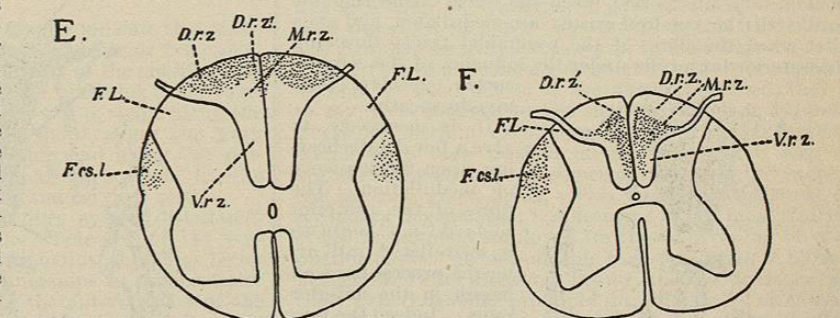
FIG. 4395.—Intumescentia Lumbalis. E, Memberment as revealed by study of myelinization; F, lesion in a case of incipient tabes.

FIGS. 4393, 4394, and 4395.—Figures Illustrating the Dorsal Funiculi in the Cervical, Thoracic, and Lumbar Regions of the Spinal Cord. Those on the left side illustrate the embryological memberment, those on the right side the lesions in cases of incipient tabes. (After P. Flechsig, Neurolog. Centralbl., Leipzig, Bd. ix., 1890, S. 73.) Lettering explained in text.

ciculus cuneatus (Burdachi). The embryological method, however, permits of a much finer analysis still of the posterior funiculus, as we shall have occasion to point out later on.

In general it may be said that a study of embryos in four stages, at lengths of 25 cm., 28 cm., 32 cm., and