50 cm. respectively, gives a tolerably clear idea of the medullation sequence in the spinal cord. Thus, in human embryos 25 cm. long, there are myelin sheaths upon the fibres of (1) the commissura anterior alba; (2) the fibres of the anterior roots and some of the fibres of the posterior roots; (3) the fibres of the fasciculus anterior proprius; (4) the fibres of the anterior mixed zone of the lateral funiculus; and (5) many of the fibres of the fasciculus cuneatus (Burdachi). In embryos 28 cm. long the fibres of the fasciculus gracilis (Golli) have also largely acquired their myelin sheaths. In embryos 32 cm. in length the lateral limiting layer of the gray matter in the fasciculus lateralis proprius is medullated, and in embryos a little older the direct cerebellar tract and Gowers' tract are found to be medullated. Finally, the anterior and lateral pyramidal tracts become medullated only at birth, when the fœtus has attained a length of about 50 cm.

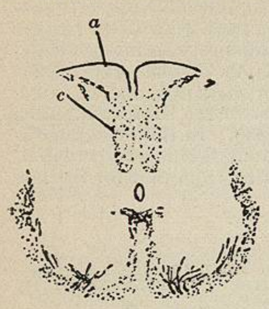

Fig. 4396.—Lumbar Portion of Spinal Cord of Human Fœtus 24 cm. Long. *a*, Dorsal part of funiculus posterior; *c*, ventral part. (After Trepinski.)

It will have been noticed that the sequence of medullation corresponds to the probable development serially of the more sharply defined nervous functions. Thus, as we should expect, the peripheral nerves become medullated first, and the apparatus for central excitation in the cord (not in the brain) is furnished. The provision for the simpler reflexes is followed by myelinization of the fasciculus lateralis proprius and the fasciculus lateralis anterior, thus permitting of the connection of adjacent and somewhat distant segments with one another corresponding to the neural apparatus underlying the more complex reflexes. The longer centripetal tracts connecting the cord with the medulla and cerebellum become medullated later, corresponding to still more complex reflexes and to the coördination of movements and the maintenance of equilibrium. It is at a very late period when the fibres connecting the cord with the cerebral cortex are medullated, and even later when the fibres of the pyramidal tracts, throwing the anterior horn cells under the influence of the cerebral cortex, receive their myelin sheaths.

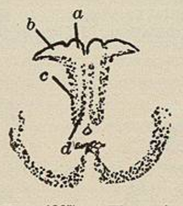

Fig. 4397. — Thoracic Portion of Spinal Cord of Human Fœtus 24 cm. Long. (After Trepinski.)

It is necessary to give a few details bearing upon the sequence of medullation. The fibres of the posterior roots do not begin to be medullated until after the process has well begun in the anterior roots. Indeed the myelinization of the posterior root remains, on the whole, dilatory as compared with that of the anterior root. Von Bechterew has divided the posterior roots into two fibre systems, the first corresponding to medullation at the fourth month of fœtal life, the second to a medullation process most marked near the end of intra-uterine life. Later studies by Flechsig and Trepinski make it seem certain that at least five fibre systems are to be distinguished in the posterior roots. As they correspond to five similar systems in the posterior funiculus, they need no further description.

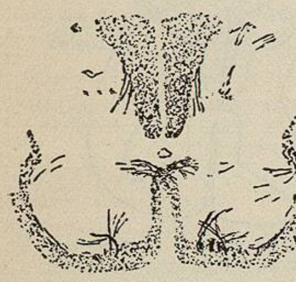
Fig. 4398.—Lumbar Portion of Spinal Cord of Human Fœtus 28 cm. Long. (After Trepinski.)

Flechsig divided each funiculus posterior, exclusive of the fasciculus gracilis (Golli), into the following areas: (1) the anterior root zone (*vordere Wurzelzone*); (2) the middle root zone (*mittlere Wurzelzone*); (3) the posterior or dorsal root zone (*hintere Wurzelzone*); (4) the median zone (*mediane Zone der Hinterstränge*). Flechsig gives the name *ovales Centrum* to the oval area in the lumbar region made up of the median zones of the two sides. The middle root zone contains two fibre systems which develop at different periods and are called the *first and second systems of the middle root zone.* Similarly the posterior or dorsal root zone contains two fibre systems, the *medial and lateral systems of the dorsal root zone* (Figs. 4393, 4394, and 4395). The fibre systems receive their myelin sheaths in the following sequence: (1) the anterior or ventral root zone (*V.r.z.*); (2) the first system of the middle root zone (*M.r.z.*) and the median zone; (3) the fasciculus gracilis (Golli), the second system of the middle root zone and the medial portion of the posterior or dorsal root zone (*D.r.s.*); (4) lastly, the lateral portion of the dorsal root zone, namely, Lissauer's fasciculus.

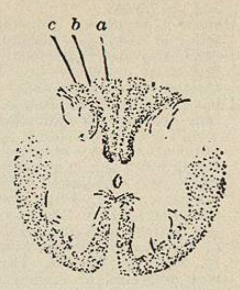

Fig. 4399.—Thoracic Portion of Spinal Cord of Human Fœtus 28 cm. Long. (After Trepinski.)

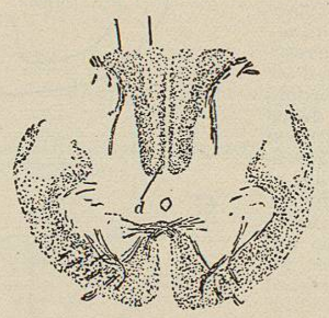

Fig. 4400.—Cervical Portion of Spinal Cord of Human Fœtus 28 cm. Long. (After Trepinski.)

A still more careful analysis has been made by Trepinski, who makes out, exclusive of Lissauer's fasciculus, four distinct fibre systems in the posterior funiculus. These fibre systems are medullated in fœtuses 24 cm., 28 cm., 35 cm., and 42 cm. long respectively. The areas of the different systems overlap somewhat.

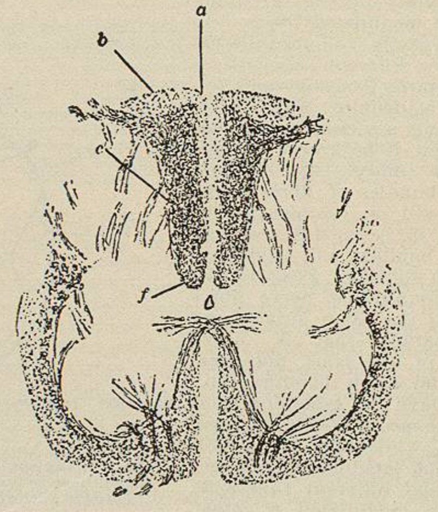

Fig. 4401.—Lumbar Region of Spinal Cord of Human Fœtus 35 cm. Long. (After Trepinski.)

In fœtuses 24 cm. long (Figs. 4396 and 4397) the posterior part of the funiculus in the lumbar region shows no medullated fibres, though the more ventral parts show evenly scattered medullated fibres. In the pars thoracalis and pars cervicalis the medullated fibres form a narrow stripe along the septum medianum posterius (Flechsig's median zone) and a somewhat broader stripe along the posterior horn (Flechsig's anterior root zone). These medullated stripes go over into one another in the most anterior region of the funiculus.

In fœtuses 28 cm. long (Figs. 4398, 4399, and 4400) the posterior funiculus in the lumbar region is medullated throughout, the second fibre system obviously being distributed over the whole cross-section. In the thoracic cord medullated fibres have appeared throughout the cross-section, but a light area is visible in the middle region of the funiculus, forming a stripe which goes from the posterior periphery almost to the anterior extremity of the funiculus. In the cervical cord of the fœtus 28 cm. long, the fasciculus gracilis looks pale, except for a narrow stripe near the median septum (Flechsig's median zone). This darker area is continuous anteriorly with the medullated area corresponding to the fasciculus cuneatus which is now well medullated.

In fœtuses 35 cm. long (Figs. 4401, 4402, and 4403) the third fibre system is medullated. A large number of new fibres have appeared in the lumbar cord in an area corresponding to Flechsig's middle root zone. In the cross-section this area is limited posteriorly by a curved line, behind which the posterior funiculus is pale in Weigert sections. There is another light stripe near the median septum, and a third light area in the most anterior part of the funiculus. The thoracic cord of the 35 cm. fœtus presents an entirely different appearance from that of the fœtus of 28 cm. The anterolateral part of the fasciculus cuneatus has received many new fibres; the posterolateral part of this fasciculus looks light in Weigert preparations. In the cervical cord at this stage the third fibre system is seen to be distributed throughout the greater part of the fasciculus cuneatus; a small area in the most posterior region of the funiculus shows no increase in fibres. The fibres in the medial portion of the fasciculus gracilis are increased. The lateral part of this fasciculus now looks light.

In fœtuses 42 cm. long the whole posterior funiculus (with the exception of Lissauer's fasciculus) is evenly medullated; the fibres which fill up the light areas of the fœtus 35 cm. long may therefore be regarded as belonging to Trepinski's fourth fœtal system. Lissauer's fasciculus is not wholly medullated even in fœtuses 47 cm. long.

To recapitulate, Trepinski's studies indicate that there are at least five fibre systems in the posterior funiculus.

1. A fibre system, including a part of the anterior portion of the funiculus in the lumbar cord, and a stripe along the posterior horn, along the gray commissure and along the posterior median septum in the thoracic and cervical cord.

2. A fibre system distributed over the whole area of the posterior funiculus, the fibres being more numerous in the posterior than in the anterior part of the lumbar cord, most scanty near the septum intermedium in the thoracic cord and in the fasciculus gracilis in the cervical cord, though the median zone of Flechsig is well medullated.

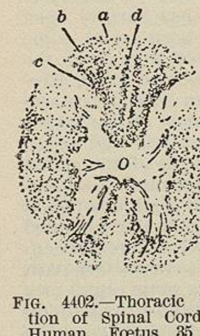

Fig. 4402.—Thoracic Portion of Spinal Cord of Human Fœtus 35 cm. Long. (After Trepinski.)

3. A fibre system distributed over the whole funiculus in the lumbar cord, except in Flechsig's median zone and the medial part of his posterior zone; spread all over the thoracic and cervical posterior funiculus with the exception of Flechsig's median zone, the medial part of his posterior zone, and the lateral part of the fasciculus gracilis.

4. A fibre system distributed in the posterior portion of the lumbar cord (medial posterior root zone of Flechsig), the anterior part of the funiculus and a stripe along the posterior part of the median septum; in the thoracic and cervical cord this fibre system is also distributed in the lateral part of the fasciculus gracilis.

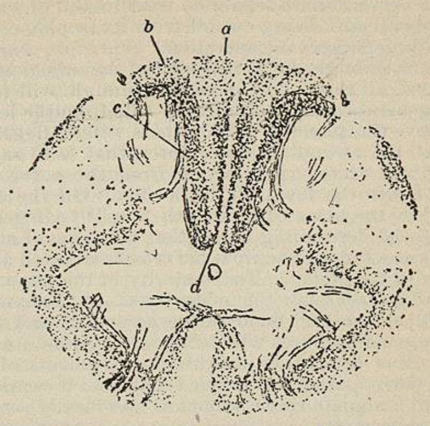

Fig. 4403.—Cervical Portion of Spinal Cord of Human Fœtus 35 cm. Long. (After Trepinski.)

5. A fibre system corresponding to Lissauer's fasciculus.

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Flechsig, P.: Die Leitungsbahnen im Gehirn und Rückenmark, Leipzig, 1876, and especially in his article, Ist die Tabes dorsalis eine "System-Erkrankung"? Neurol. Centralbl., Leipz., Bd. ix., 1890, SS. 33, 72.
Trepinski: Die embryonalen Fasersysteme in den Hintersträngen und ihre Degeneration bei der Tabes dorsalis. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xxx., 1897, SS. 54-81.

4. *Method of Waller or Türck* (Study of Secondary Degenerations).—This method takes advantage of the fact that if a medullated axone be interrupted anywhere in its course by cutting, pressure of a tumor or the like, secondary or Wallerian degeneration takes place in the cellulifugal portion of the fibre, the portion of the fibre between the point of injury and the cell body which gives origin to the axone remaining uninjured for a considerable period of time. The finer changes characterizing this secondary or Wallerian degeneration have already been described in a previous article in this Handbook (see *Neurone, General Pathology of,* in Vol. VI.).

As a rule, the secondary degeneration does not extend beyond the telodendrion of the axone concerned, that is to say, it is confined to the neurone which is injured. There are certain exceptions to this rule, exceptions which have been used in an absurdly unfair way as arguments against the existence of neurones, but in general the rule given holds. This method of the study of secondary degeneration has been one of the most fruitful of all the methods employed for the unravelling of conduction paths. It is applicable to degeneration in human beings, following disease or injury, and also to degenerations experimentally produced in animals by section or other modes of experimental injury. For a long time the application of this method was confined to cases in which the degeneration had gone far enough and was extensive enough to be studied by Weigert's myelin-sheath method, but more recently much greater advances have been made through the application of the extremely delicate method of Marchi, which permits of the detection of small groups of fibres, and even of single degenerated fibres a very short time (twelve to fifteen days) after the injury.

The method of secondary degenerations permits us, for example, to make out, at any given level of the cord, the number of fibres which are passing centripetally at that point, that is, ascending, and the number of fibres which are passing centrifugally at that level, that is, descending. Since every nerve fibre is dependent somewhere upon the nutritive influence of a nucleus in the cell body or perikaryon, that is to say, is a prolongation of a cell, when the nerve fibre is separated from its cell of origin, the peripheral part, being cut off from its trophic centre, necessarily undergoes degeneration.

If we cut through the spinal cord of an animal at any given level, all the nerve fibres cut through will inevitably degenerate on the cellulifugal side from the lesion. Thus above the plane of section there will be degeneration of all the ascending nerve fibres, that is to say, of all the fibres whose axones come from the nerve cells situated below the level of the section. On the other hand, below the plane of section there will be degeneration of all the descending fibres, that is to say, of all the fibres whose axones come from nerve cells situated above the plane of the lesion. The majority of the ascending fibres will be sensory; the majority of the descending fibres will be motor. Some of the ascending and some of the descending fibres will belong to neurones whose function it is to connect neighboring segments of the cord for participation in complex reflexes; it would be difficult to designate these axones as specifically sensory or specifically motor.

An excellent list of the most important observations on degeneration after transverse lesions of the human spinal cord is given by Ziehen on pages 246 and 247 of his monograph. There are observations for nearly every segment down as far as the second lumbar. The list is too long to be included here, but it will be found convenient for reference.

If transverse lesion of the human spinal cord has taken place in the pars thoracalis, there will, in general, be found degeneration, above the plane of the lesion, of the following centripetal bundles:

1. The whole of the posterior funiculus, including Lissauer's fasciculus, with the exception of a few centrifugal fibres to be described among the descending degenerations.
2. The peripheral zone of the lateral funiculus, including the direct cerebellar tract (fasciculus cerebellospinalis) in the dorsolateral periphery and Gowers's tract (fasciculus anterolateralis superficialis) in the ventrolateral periphery.
3. A part of the fibres of the lateral limiting layer of the gray matter (*zone cornumarginale* of French authors).
4. A part of the fibres of the anterior mixed zone of the lateral funiculus (funiculus lateralis proprius).
5. A large part of the fibres of the anterior ground bundle (fasciculus anterior proprius).
6. A large part of the fibres of the peripheral zone of the anterior funiculus, not only on the surface, but also along the fissura mediana anterior.
7. A few fibres scattered throughout the region occupied by the fasciculus cerebrospinalis lateralis or lateral pyramidal tract.

Below the level of the lesion there will be found degenerated the following:

1. The lateral pyramidal tract in the lateral funiculus (fasciculus cerebrospinalis lateralis).
2. A part of the fibres of the peripheral zone of the more ventral portion of the lateral funiculus.
3. A few of the fibres of the lateral limiting layer of the gray matter.
4. A part of the fibres of the anterior mixed zone of the lateral funiculus (fasciculus lateralis proprius).
5. A few of the fibres of the anterior ground bundle (fasciculus anterior proprius).
6. A few of the fibres of the peripheral zone of the anterior funiculus (Loewenthal's tract) from the cerebellum to the cord.
7. The pyramidal tract of the anterior funiculus (fasciculus cerebrospinalis anterior).
8. A comma-shaped layer of fibres at the junction of the fasciculus gracilis (Golli) with the fasciculus cuneatus (Burdachi) in the posterior funiculus.
9. A narrow layer near the septum medianum posterius (Flechsig's centrum ovale).
10. Lower down, a triangular field in the posteromedial portion of the posterior funiculus (dorsomedial sacral bundle of Obersteiner, *triangle médian* of Gombault et Philippe).
11. A few fibres in the most anterior portion of the posterior funiculus (*zone cornucommissurale* of Marie).

The method of the study of secondary degenerations has also been most useful in determining the exact intramedullary distribution of the fibres of the posterior roots of spinal nerves. Further reference to this fact will be made when the individual conduction paths are taken up.

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Singer, J., und Münzer, E.: Beiträge zur Anatomie des Centralnervensystems insbesondere des Rückenmarkes. Denkschr. der Wiener Akad., Bd. lvii., 1890–91, S. 569.
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Waller, A.: Experiments on the Section of the Glossopharyngeal and Hypoglossal Nerves of the Frog, and Observations of the Alterations Produced thereby in the Structure of their Primitive Fibres. London, Edinburgh, and Dublin Philosophical Magazine, vol. xxxvii., No. 247, p. 65, July, 1850. Also in Philosophical Transactions of the Royal Society of London, 1850, p. 423, and in the Edinb. Med. and Surg. Journ., vol. lxxvi., 1851, pp. 369–376.—Sur la reproduction des nerfs et sur la structure et les fonctions des ganglions spinaux. Arch. f. Anat., Physiol. u. wissensch. Med., Berl., 1852, SS. 392–401: Compt. rend. hebd. des séances de l'Acad. des sc., Par., t. xxxiv., p. 675.—Nouvelle méthode pour l'étude du système nerveux applicable à l'investigation de la distribution anatomique des cordons nerveux, et au diagnostic des maladies du système nerveux, pendant la vie et après la mort. Compt. rend. hebd. des séances de l'Acad. des sc., Par., t. xxxiii., 1851, p. 606.—Expérience sur les sections des nerfs et les altérations. Compt. rend. Soc. de biol., Par., 2me s., t. iii., 1857, pp. 6–8.

5. *Method of von Gudden* (Method of Development Inhibition).—Von Gudden's observations led him to believe that in a new-born animal a fibre system extending between two centres would atrophy if either centre were destroyed. But while the fibre system atrophies in either case, if one of the two centres be destroyed, the other will atrophy, not if it be the exciting one, but only if it be the one excited. For example, destruction of the retina, he maintained, would lead to an inhibition of the development of the whole visual path as far as the colliculus superior and the lateral geniculate body, but destruction of the superior colliculus itself would not inhibit the development of the retina, and destruction of the cortical visual area would not hinder the development of the superior colliculus, or the optic nerve or the retina. Observations and experiments since his time indicate that sometimes, at least, the extirpation of the centre excited is followed by an inhibition of the development of the exciting centre; thus the extirpation of the visual area in the cortex may be followed by imperfect development of the optic nerve. It has further been shown that amputations in the new-born cause some inhibition of development of the motor regions of the cortex and of the pyramidal tract, besides causing atrophy of the corresponding anterior horn cells in the spinal cord. On the other hand, extirpation of the motor area of the cortex in the new-born does not lead necessarily to atrophy of the anterior horn cells of the spinal cord, as von Gudden believed, but clinical and pathological observations render it probable that such atrophy is sometimes produced. Ziehen formulates the modified law as follows: If, in a new-born animal, before the central nervous system is fully developed, a conduction path be cut through, a centre destroyed, or a sense organ or a muscle extirpated, the conduction paths and centres therewith connected suffer an inhibition of development in so far as and in the degree that they are deprived of excitations. Thus centres and tracts which, as a result of the injury, receive no impulses, or almost none, fail to develop. This explains why the motor cells of the anterior horn often remain intact after cortical lesions, for even after the cortical injury they receive impulses continuously by way of the reflex collaterals from the posterior root fibres. The occasional occurrence of inhibited

development of sensory nerves after cortical extirpation might be explained on the theory that as a result of the loss of conscious sensations, for example from the eye, conscious movements of the same, on account of their uselessness, would gradually cease to occur, and with the limitation of the movements an important nutritive stimulus would disappear. Whether an inhibition of development would then occur, and in what degree, would depend upon the number of accidental circumstances (number of stimuli of reflex movements, etc.) (Ziehen).

In the application of the method Weigert's myeline-sheath procedure and carmine staining are to be employed. A reduction in size of one-third on one side of the nervous system, as compared with the normal opposite side, traceable through a series of sections, is the criterion to be observed.

By this method most important information has been gained with regard to the visual conduction paths, the auditory conduction paths, the lemniscus, and the pyramidal tract.

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Monakow, C. von: Gehirnpathologie, Wien, 1897.

6. *Method of Gotch and Horsley* (Electrophysiological Method).—This method is a physiological one and depends upon the variation of the electrical current on excitation of a conduction path; it determines the path followed by the impulses and hence the course followed by the axones of the fibre systems themselves.

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Gotch, F., and Horsley, V.: On the Mammalian Nervous System, its Functions and their Localization Determined by an Electrical Method. Phil. Tr., 1891, London, 1892, vol. clxxxii. (B.), pp. 267–526.

By means of these various methods the centripetal and centrifugal conduction paths of the spinal cord have been and are being worked out. The centripetal paths include the paths carrying sensory impulses to cerebellar and cerebral centres, the sensory limbs of reflex arcs in the cord and the centripetal intersegmental paths. The centrifugal paths include the pyramidal tracts, the cerebello-spinal paths, and other centrifugal paths connecting the infracortical nuclei of the cerebrum with spinal centres, as well as the centrifugal intersegmental paths of the cord itself. To a description of some of the principal paths here mentioned we shall now turn.

A. The General Sensory or Centripetal Paths in the Spinal Cord.

It seems natural to begin with a description of the neurone systems concerned in the construction of the general sensory conduction paths from the skin, muscles, and organs to the nerve centres of the cord and to the higher centres in the brain. The conduction paths here concerned are very complex, but this is not to be wondered at when one recalls the complexity of reflex, instinctive, and voluntary reactions in which they participate, and when he remembers that these paths are the recipients of all the impulses from the skin, mucous membranes, and muscles below the head—impulses which probably vary in origin and character according as they are interpreted in consciousness, as touch, muscle sense, heat, cold, or pain. We might, from physiological observations, expect to find anatomically in the spinal cord separate conduction paths for touch, for heat, for cold, for muscle sense, and for pain. It is easy to demonstrate anatomically a large number of different centripetal fibre systems in the cord, but as to just how these differ in function and as to just what paths subserve the various modalities of sensation we are very poorly informed. It is true that there is some evidence for the view that tactile sensory impulses run in the lateral funiculi, and preferably though not exclusively, after crossing from the side of the cord in which they enter to the opposite side; and, further, that the muscle-sense impulses (kinæsthetic excitations) run in the posterior funiculi, chiefly on the side of entrance. Anatomy teaches that all the centripetal impulses, no matter the sensation modality to which they correspond, enter the spinal cord through the fibres of the posterior roots. Most of the fibres of the posterior roots terminate at some level or another in the spinal cord or medulla oblongata. These fibres we know to be the axones of neurones, the cell bodies of which are situated in the spinal ganglia. By means of the terminals and collaterals of these axones the impulses arriving along them in the spinal cord may be transferred to several sets of central neurones; these latter carry the impulses farther and are designated as neurones of the second order in the general centripetal path. On the way from the periphery to the cortex of the brain the centripetal impulses have to pass through a chain of at least three superimposed neurone systems. and in many instances a very much larger number of neurone systems may take part in the concatenation.

It will be convenient to describe, first, the centripetal neurone systems of the first order, and to go on afterward with the description of the sensory neurone systems of the second and of higher orders, as far as these are present in the spinal cord.

1. *Peripheral Sensory Neurone Systems* (Centripetal Neurone Systems of the First Order).—These neurone systems include all the neurones which send processes to the periphery of the body below the head, to receive impulses from the skin, mucous membranes, muscles, tendons, and joints, and which send their central axones through the posterior roots of the spinal nerves into the posterior funiculi of the spinal cord. The cell bodies of these neurone systems are all situated in the spinal ganglia. The proximal portions of the central axones as well as the whole extent of the peripheral axones of these neurones are situated outside the spinal cord. Only those portions of the central axones which extend from the pia onward are intramedullary; the intramedullary axones, being derived from cell bodies extramedullary in situation, are designated "exogenous fibres of the spinal cord."

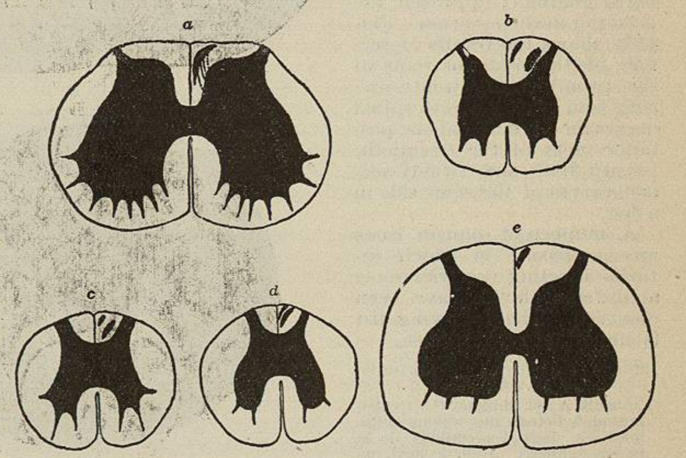

FIG. 4404.—Secondary Degenerations in the Spinal Cord after Experimental Section of Dorsal Root. (After Singer and Munzer, from A. van Gehuchten, "Anatomie du système nerveux de l'homme," Louvain, 1897, pp. 305 and 306, Figs. 208 to 212.) *a*, Level of the twenty-second spinal nerve; *b*, cross-section of the cord between the level of the twentieth and twenty-second spinal nerves; *c*, transverse section through the cord at the level of the eighteenth spinal nerve; *d*, transverse section of the cord in the thoracic region; *e*, transverse section of the cord at the level of the intumescentia cervicalis.

The study of secondary degenerations occurring in disease in human beings, or produced experimentally in animals, has thrown much light upon the distribution of the intramedullary continuations of the posterior root fibres, particularly since the method of Marchi has been applicable. Section of a posterior root in an animal causes complete degeneration of the intramedullary continuation of the fibres of that root to their termination. Serial sections show a progressive diminution in the number of fibres which are the continuations of the fibres of a given root as the cord is ascended, owing partly to a progressive diminution in the calibre of the fibres, but chiefly to the fact that the fibres of each root as they ascend stop at different levels to end in the gray matter. Moreover, there is a gradual change in the position occupied by the degenerated fibres as the cord is ascended. Thus fibres which low down in the cord are situated in the "entry zone" near the gray matter, come, higher up, to occupy a more medial and more posterior position; they pass gradually medialward through the fasciculus cuneatus until finally they come to lie, at higher levels, in the fasciculus gracilis. Each posterior root as it enters the spinal cord displaces the fibres of the fasciculus cuneatus in a posterior and medial direction, so that the long ascending fibres gradually approach the posterior median septum. Fig. 4404 shows the results of section of the posterior roots of the twenty-sixth, twenty-seventh, and twenty-eighth spinal nerves on one side and the posterior roots of the twentieth, twenty-first, and twenty-second nerves of the same side in a dog.

A number of human cases are on record in which injuries affecting posterior roots at different levels have been observed. The following list is important for reference:

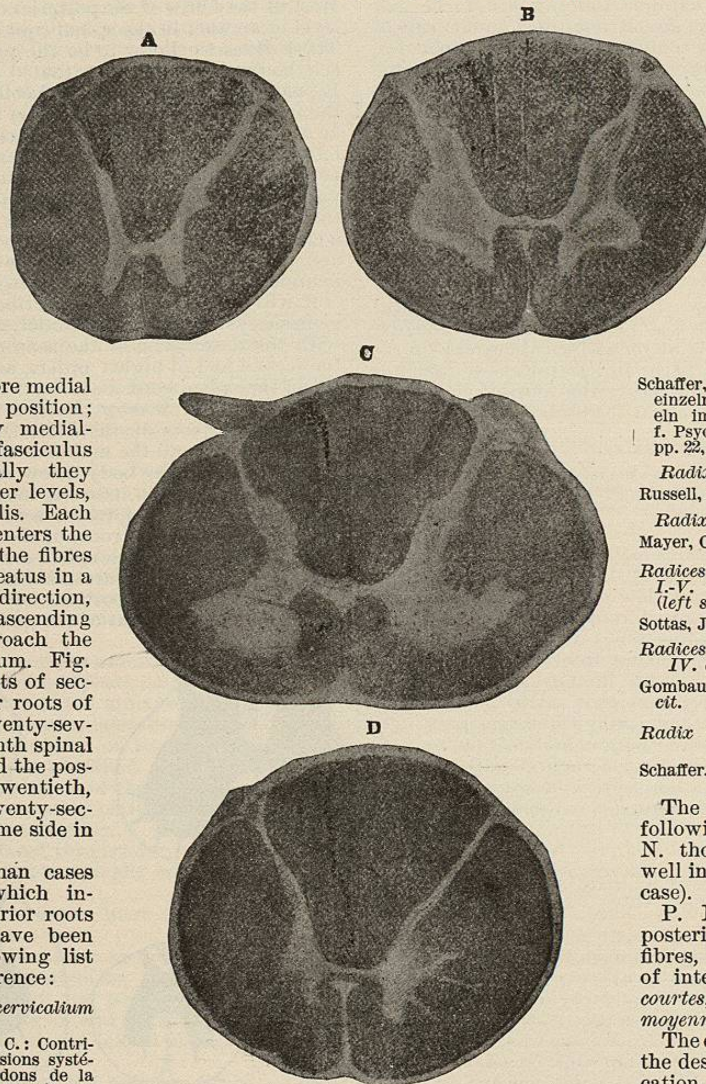

FIG. 4405.—Transverse Section of the Human Spinal Cord, showing Secondary Degenerations Following Isolated Lesion of the Sixth Thoracic Spinal Nerve. (After A. Marguliés, "Neurol. Centralbl.," Leipz., Bd. xv., 1896, SS. 348 and 349, Figs. 1-4.) *A*, Transverse section at the level of the sixth thoracic root; *B*, transverse section at the level of the first thoracic root; *C*, transverse section at the level of the seventh cervical root; *D*, transverse section at the level of entrance of the third cervical root.

Radices posteriores Nn. cervicalium IV. and V.

Gombault, A., et Philippe, C.: Contribution à l'étude des lésions systématisées dans les cordons de la moelle épinière. Arch. de méd. expér. et d'anat. path., Par., t. vi., 1894, pp. 365, 538.

Radix posterior Nn. cervicalium VI. and VII.

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Radix posterior N. cervicalis VII.

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Marguliés, A.: Zur Lehre vom Verlaufe der hinteren Wurzeln beim Menschen. Neurol. Centralbl., Leipz., Bd. xv., 1896, SS. 347-351.

Radices posteriores Nn. lumbalis IV. et N. sacralis II. (III?).

Mayer, C.: Zur pathologischen Anatomie der Rückenmarkshinterstränge. Jahrb. f. Psychiat., Leipz., u. Wien, Bd. xiii., 1894, SS. 57-107.

Radix posterior N. lumbalis V.

Schaffer, K.: Ueber Faserverlauf einzelner Lumbal- und Sacralwurzeln im Hinterstrang. Monatschr. f. Psychiat. u. Neurol., vol. v., 1899, pp. 22, 95.

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Russell, J. S. R.: *Loc. cit.*

Radix posterior N. sacralis II.

Mayer, C.: *Loc. cit.*

Radices posteriores Nn. sacralium I.-V. (right side), III. and IV. (left side).

Sottas, J.: *Loc. cit.*

Radices posteriores Nn. sacralium IV. and V. and N. coccygei.

Gombault, A., et Philippe, C.: *Loc. cit.*

Radix posterior N. Sacralis V. et N. coccygei.

Schaffer, K.: *Loc. cit.*

The lesions at various levels following an isolated lesion of N. thoracalis VI. are shown well in Fig. 4405, *A* (Marguliés' case).

P. Marie has divided the posterior root fibres into short fibres, long fibres, and fibres of intermediate length (*fibres courtes, fibres longues, et fibres moyennes*).

The exact course followed by the descending limbs of bifurcation of the posterior root fibres has not been ascertained satisfactorily as yet in any human case. Experiments on animals indicate that the descending limbs of bifurcation are short, running in to terminate in the gray matter within one or two segments of the level of entrance of the corresponding posterior root.

By Marchi's method it has been demonstrated that the fibres of the fasciculus gracilis which reach the medulla oblongata, nearly all turn in to end in the nucleus funiculi gracilis, while those of the fasciculus cuneatus which reach the medulla oblongata turn in to end in the

nucleus funiculi cuneati. A certain number, however, of those fibres which ascend in the fasciculus gracilis are continued as posterior external arcuate fibres into the restiform body to end in the cerebellum, while others go as internal arcuate fibres to decussate in the raphe. Some of the fibres of the fasciculus cuneatus also go by way of the retiform body to end in the cerebellum without being interrupted in the nucleus funiculi cuneati.

Sections of the spinal cord stained by Weigert's myeline sheath method show many fibres extending from the posterior funiculi into the gray matter of the cord. These have been proven by other methods to be partly terminals, partly collaterals of the posterior root fibres.

Golgi's method has helped us a great deal in the interpretation of these fine medullated fibres of the Weigert's specimens, and indeed has revolutionized our conception of the mode of branching and termination of the posterior root fibres in general. By Golgi's method it is very easy to demonstrate the Y-shaped bifurcation of each posterior root fibre, soon after its entrance into the cord, into an ascending and a descending limb, each of which turns to run in the longitudinal direction, the ascending limb for a long distance, the posterior limb for a short distance, both ultimately terminating in the gray matter (Fig. 4406). This method, too, has revealed the large number of collaterals given off by the stem fibres, by the descending limb of bifurcation, and by the proximal portion of the ascending limb of bifurcation; it has also shown us how the terminals of the limbs of bifurcation themselves as well as the collaterals come into relation with the dendrites and cell bodies of the centripetal neurones of the second order, situated in the various groups of nerve cells of that gray matter.

It is very hard to state definitely in all cases how many of the fine fibres going from the posterior funiculi into the gray matter of the cord, as seen in Weigert preparations, are collaterals and how many are terminals of posterior root fibres. Of the groups to be immediately considered the reflex bundles appear to be made up chiefly of medullated collaterals, while the fine fibres going to end in the nucleus dorsalis are probably chiefly terminals of ascending limbs of bifurcation of posterior root fibres.

The fine medullated fibres going into the gray matter are divisible into at least four principal groups: (1) those ending in the columna grisea posterior and in the columna grisea intermedia; (2) those passing from the fasciculus cuneatus partly through the substantia gelatinosa, partly medial from it, forming S-shaped curves and ending in the anterior horns; these bundles, largest in the intumescentiæ, make up the reflex collaterals, each of which terminates by multiple division in among the cell bodies and dendrites of the lower motor neurones of the anterior horn; (3) those coming from the middle area of the fasciculus cuneatus and ending in the nucleus dorsalis (Clarkii); the bundles, reaching the posterior surface of the gray column, split into two divisions, one of which passes to each side of the nucleus, so that in cross-sections the nucleus dorsalis reminds one of a berry on a stem; (4) those running into the posterior intracentral commissure and ending chiefly in the opposite posterior horn.

The studies of Flechsig and Trepinski on the successive medullation of the intramedullary continuations of the posterior root fibres have already been referred to. We know that the fibres of a given root are not medullated all at once, but we are not sure in how far the differentiation of the posterior funiculus, yielded by Flechsig's method of study, is due to the successive medullation of groups of fibres as wholes, and how much of it is due to the successive medullation of different parts of the same fibres. It might very well be that the proximal portion of the posterior root fibres are medullated earlier than the distal portions; or, again, it is easily conceivable that the stem fibres and the two limbs of bifurcation may become medullated before the collaterals, or that some collaterals from one fibre become medullated before other collaterals from the same fibre. Until we are better informed upon these points we shall be at a loss in the making of classifications for the subdivisions of the peripheral neurone systems now under consideration.

At present two subdivisions are justifiable, but in how far one corresponds to the other we do not know. The

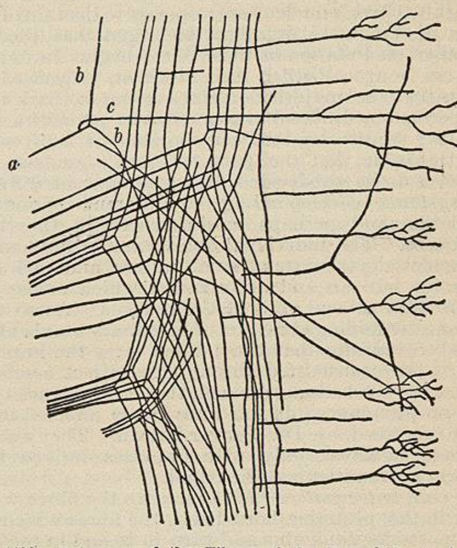

FIG. 4406.—Entrance of the Fibres of the Dorsal Roots into the Dorsal Funiculus of the Spinal Cord of an Embryo Calf. (After A. van Gehuchten, "Anatomie du système nerveux de l'homme," Louv., 2 ed, 1897, p. 302, Fig. 205.) A stem fibre, *a*, is seen dividing into two branches, *b*, *b*, the ascending and descending limbs of bifurcation. From the stem fibre, *a*, a collateral, *c*, is seen to arise. A number of collaterals arising from the limbs of bifurcation of other fibres are illustrated.

first subdivision, based upon successive medullation, has already been discussed. The second subdivision, that usually given in the text-books, is based upon the distribution of the terminals and collaterals of the posterior root fibres in different gray centres (*nuclei terminales*). Thus there may be distinguished (1) a direct ascending posterior funicular path (*direkte aufsteigende Hinterstrangbahn* of the Germans), including the long fibres of the fasciculus gracilis and fasciculus cuneatus which terminate in the rhombencephalon, chiefly in the nucleus funiculi gracilis and nucleus funiculi cuneati; (2) the path ending in the nucleus dorsalis (Clarkii); (3) the path ending in the posterior horn; (4) the reflex path ending in the anterior horn.

The *direct ascending path of the posterior funiculus* probably corresponds to several of Flechsig's fibre systems, not to any one of them. It is quite possible, therefore, that this path will, in the future, be further subdivided, inasmuch as its fibres are being medullated throughout the whole latter half of intra-uterine life. Clinical observations in tabes dorsalis and in transverse myelitis indicate that the muscle sense of the corresponding half of the body runs in the direct ascending path of each posterior funiculus—a view quite in accord with the observations in Brown-Séquard's paralysis, and with Mott's experimental hemisections in monkeys.

The *fibres running in to end in the nucleus dorsalis* (*Clarkii*) are, as Schaffer has shown, in all probability the terminals of ascending limbs of bifurcation of posterior root fibres rather than collaterals, although both may be concerned. Weigert preparations and Golgi preparations indicate that these fibres, as they ascend in the posterior funiculus, tend to run in Flechsig's middle root zone. My studies on hereditary ataxia lead me to think that at any rate a large part of these fibres correspond to the third fœtal system of Trepinski. Since the funiculus dorsalis is largely confined to the thoracic levels of the cord, it seems very likely that the fibres of the posterior funiculi which terminate in this nucleus are