gray matter is called the posterior or dorsal horn of the gray matter, or posterior column (*columna posterior*). The lateral projection of gray matter is known as the lateral horn, or lateral column (*columna lateralis*). These three gray columns (*columnæ griseæ*) on each side, together with the gray commissures, make up the whole extent of the gray matter of the cord, with the exception of a few strands of gray matter which mix in with the white matter in the form of a network at the angle between the lateral column and posterior column of gray matter. This network of gray matter is the so-called reticular formation (*formatio reticularis*). Elsewhere the gray matter is sharply marked off on all sides from the white matter which surrounds it.

The anterior horn, or anterior column of gray matter, is separated from the periphery of the cord by a thick layer of white matter. The posterior horn, or posterior column of gray matter, arrives much nearer to the surface in the region of the sulcus lateralis posterior. It does not, however, reach the surface of the cord, being separated from it by a narrow zone of white matter, known as the fasciculus of Lissauer.

On looking more closely at the posterior horn or posterior column of gray matter, it will be seen to be somewhat constricted in the cross-section, a little behind the gray commissure. This constriction is known as the neck of the posterior column (*cervix columnæ posterioris*). The tip of the posterior column behind is called the apex (*apex columnæ posterioris*). It is sometimes capped, more often crossed, by a somewhat expanded mass of unusually transparent gray matter known as the gelatinous substance of Rolando (*substantia gelatinosa* [*Rolandi*]).

On the surface of the cord the fila radicularia of the radix anterior of the spinal nerve on each side have been seen emerging from the area corresponding to the sulcus lateralis anterior. In the cross-section, fibres running out from the anterior horn or anterior column of gray matter can be traced horizontally, or somewhat obliquely, through the white matter between the anterior column and the sulcus lateralis anterior. Reaching the surface of the cord they form the fila radicularia of the anterior root.

On the surface of the cord behind, along the sulcus lateralis posterior, the fila radicularia of the posterior root have already been seen. An examination of the sections shows that, on entrance into the cord, the fibres of these fila do not penetrate into the gray matter of the posterior horn, but enter directly the white matter of the funiculus posterior.

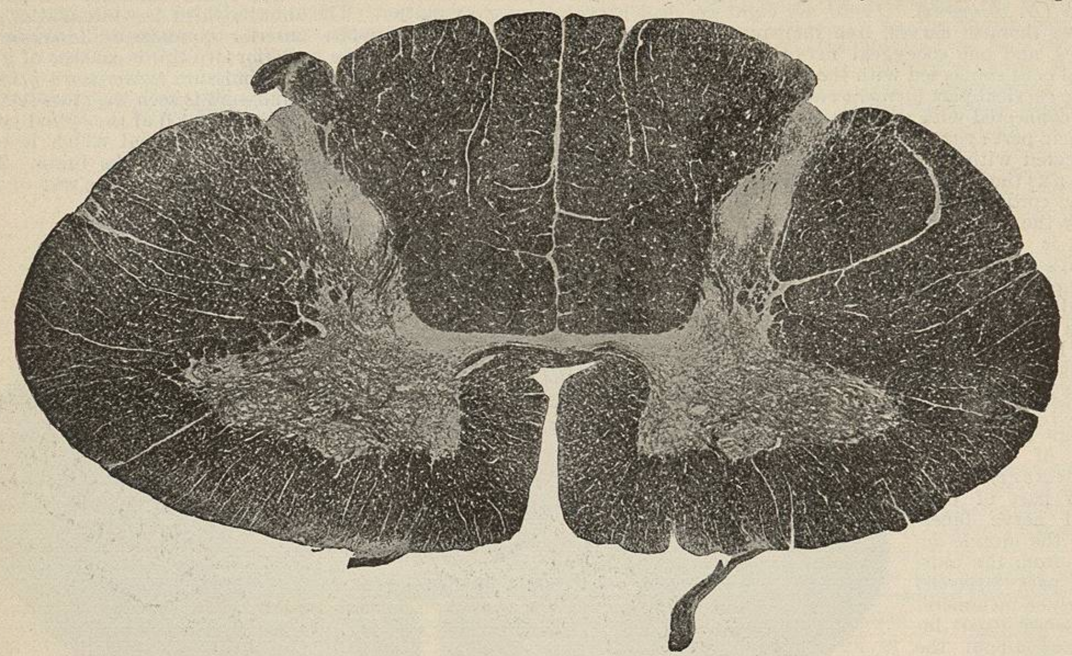

FIG. 4377.—Transverse Section Through the Sixth Cervical Segment of the Human Spinal Cord. Weigert myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

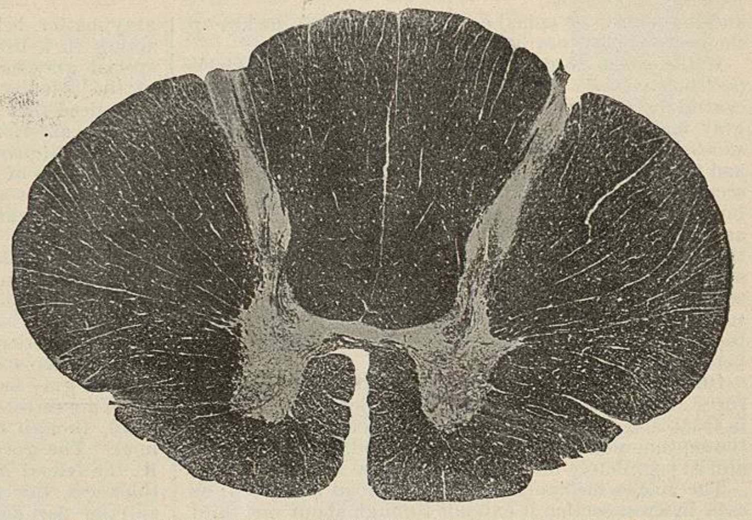

FIG. 4378.—Transverse Section Through the Third Thoracic Segment of the Human Spinal Cord. Weigert's myelin stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

The subdivision of the white matter in each half of the cord into three funiculi is well shown in the cross-section. The position of the fila radicularia of the anterior roots of the spinal nerves serves to separate the *funiculus anterior* from the *funiculus lateralis* much better than does the shallow sulcus lateralis anterior. Indeed some will have it that no sulcus lateralis anterior exists; it is therefore common to hear the anterior and lateral funiculi grouped together as a single mass of white matter, called the *fasciculus anterolateralis*. The *funiculus posterior* is sharply separated, however, from the funiculus lateralis in the section, by the sulcus lateralis posterior, and in the depth the white masses of the two funiculi are separated from one another by the columna posterior grisea.

The large posterior funiculus, situated between the sulcus lateralis posterior and the sulcus medianus posterior, is subdivided at this level by the sulcus intermedius posterior. Extending into the white substance from this sulcus is a septum of supporting substance known as the *dorsal paramedian septum*. The portion of white matter of the posterior funiculus medial from this septum is called the delicate fasciculus or bundle of Goll (*fasciculus gracilis* [*Golli*]), while the portion laterad from it is known as the wedge-shaped fasciculus or bundle of Burdach (*fasciculus cuneatus* [*Burdachi*]).

The relative distribution of gray and white matter may next be studied in a transverse section, taken at the *level of the sixth cervical nerve*, that is, through the cervical enlargement (*intumescentia cervicalis*) (Fig. 4377). The cord is here seen to be much larger than in the previous section, and the shape of the gray matter is considerably altered. The anterior horn or columna anterior is much larger, and has fused with the lateral horn or columna lateralis so that the latter does not exist at this level as an independent column. The posterior horn or columna posterior of gray matter is a little larger than at the higher level. The formatio reticularis is less pronounced. The frontal diameter of the cord is increased much more than the sagittal. The subdivision of the funiculus posterior into the fasciculus gracilis (Golli) and the fasciculus cuneatus (Burdachi) is still well marked.

At the *level of the third thoracic nerve* (Fig. 4378) the size of the cord has become much reduced, and the sagittal diameter is now much more nearly equal to that of the frontal diameter. The gray matter is present in much smaller amount, the anterior horn or columna anterior has been greatly reduced in size, the lateral horn or columna lateralis is small, and the posterior horn or columna posterior, slender and long. On the medial side of the columna posterior, just in front of its neck in the angle formed by it with the gray commissure, there is an expansion of the gray matter which was not visible in the two sections previously examined. This mass of gray matter contains large cells and is known as the dorsal nucleus of Clarke (*nucleus dorsalis* [*Clarkii*]). It is sometimes known as the column of Clarke or of Stilling. It is present on each side for a long distance in the cord; thus it extends throughout the whole thoracic part of the spinal cord and into the pars cervicalis as far as the level of the eighth or seventh cervical nerve; below, it extends into the pars lumbalis as far as the first or second lumbar nerve. The beginner will find in it a useful landmark for the recognition of sections derived from the pars thoracalis.

The dorsal paramedian septum, separating the fasciculus gracilis from the fasciculus cuneatus, is still present at this level, but it is less distinct than at higher levels, and is placed much nearer the middle line. The fasciculus gracilis is seen to be, accordingly, much smaller in volume than at higher levels. The septum grows less and less distinct as the pars thoracalis is descended, until at about the level of the eighth thoracic nerve it has entirely disappeared and the posterior funiculus is no longer subdivided into two fasciculi.

Sections of the thoracic cord below the eighth thoracic nerve show no marked alterations in the disposition of

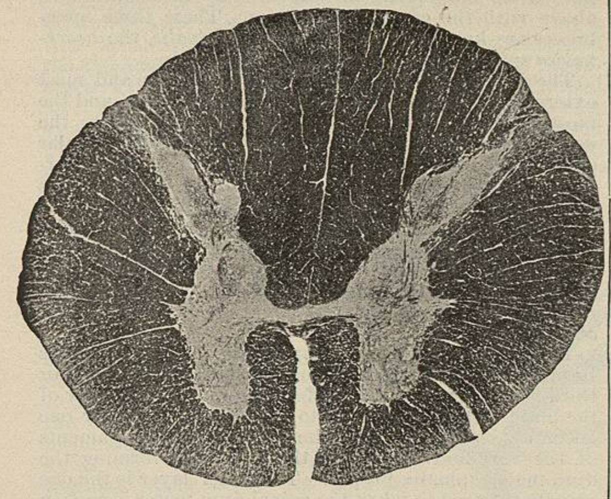

FIG. 4379.—Transverse Section Through the Twelfth Thoracic Segment of the Human Spinal Cord. Weigert's myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

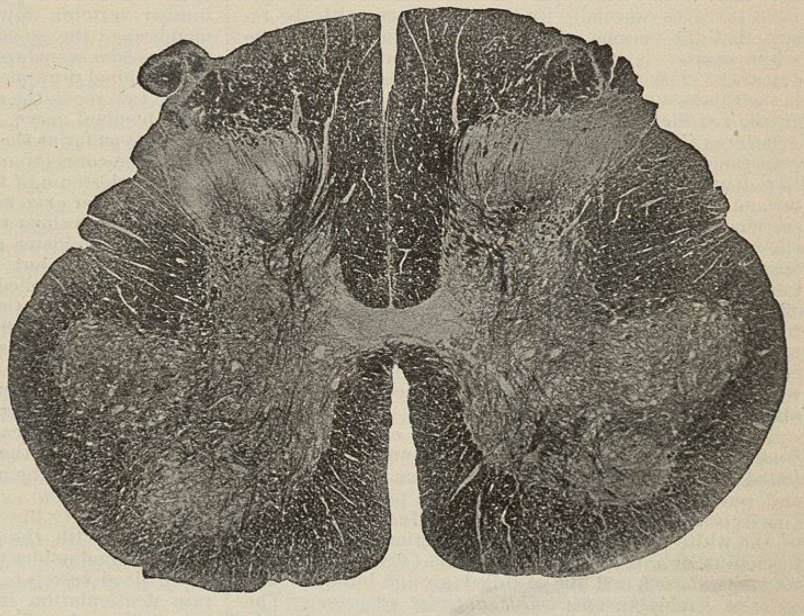

FIG. 4380.—Transverse Section Through the Fifth Lumbar Segment of the Human Spinal Cord. Weigert's myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

the white and gray matter until the lumbar enlargement (*intumescentia lumbalis*) is approached. Then the whole cord grows larger, both the gray matter and the white matter increasing in amount, the gray matter, however, to a greater extent than the white matter.

At the *level of the twelfth thoracic nerve* (Fig. 4379) a transverse section of the cord shows the beginning expansion of the gray matter. The nucleus dorsalis

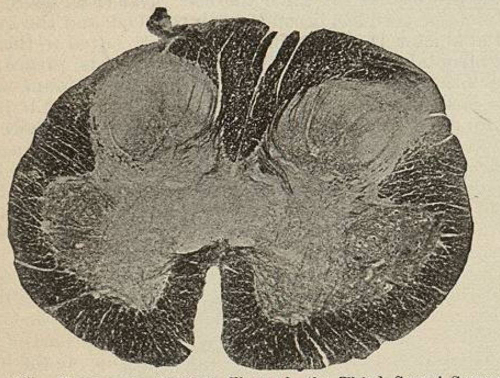

FIG. 4381.—Transverse Section Through the Third Sacral Segment of the Human Spinal Cord. Weigert's myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

(Clarkii) is here very distinct. From this level on, the gray matter increases very rapidly in amount, until the maximum expansion is reached in the largest part of the intumescentia lumbalis.

The relations at the *level of the fifth lumbar nerve* are well shown in Fig. 4380. The anterior and lateral columns of gray matter are again fused and form a much expanded mass in the anterior part of the cord. The posterior column or horn is enlarged to a greater extent here than in any other part of the cord. The enlargement involves especially its medial surface, with the result that the volume of the funiculus posterior of the white matter is relatively small. Indeed, a striking feature of cross-sections through the lumbar enlargement is the thinness of the white envelope and the marked expansion of the gray matter. In the latter the substantia gelatinosa (Rolandi) is especially prominent.

In the parts of the cord below the lumbar enlargement this disproportion between the volume of the gray matter and that of the white matter increases. A transverse section at the *level of the third sacral nerve* (Fig. 4381) shows this distinctly, and it is even more marked in a transverse section through the lower part of the conus medullaris at the *level of origin of the N. coccygeus* (Fig. 4382). Here the terminal mass of gray matter is surrounded only by a thin film of white matter. The filum terminale is so atrophic that sections of it reveal only the central canal, lined by ependymal epithelium and surrounded by a thin layer of gray substance, and outside of all the filum duræ matris spinalis.

To the naked eye the white matter of the different funiculi looks very much alike, and cannot be differentiated into the fasciculi, of which, from embryological and pathological studies, we know it to be composed. It will be seen later, however, that the funiculus anterior of the white matter contains the anterior cerebro-spinal fasciculus, or anterior pyramidal tract (*fasciculus cerebrospinalis anterior*) and the so-called ground bundle of the anterior funiculus (*fasciculus anterior proprius*). The funiculus lateralis of the white matter contains the lateral cerebro-spinal fasciculus or lateral pyramidal tract (*fasciculus cerebrospinalis lateralis*), the direct cerebellar tract (*fasciculus cerebellospinalis*), Gowers' tract (*fasciculus anterolateralis superficialis*), and the lateral ground bundle (*fasciculus lateralis proprius*). The funiculus posterior of the white matter contains the tracts of Goll and Burdach (*fasciculus gracilis Golli et fasciculus cuneatus [Burdachi]*). The exact location of these various fasciculi and the mode of determining their location will be described farther on in this article.

The Coverings of the Cord (Meninges).—The spinal cord is surrounded in the vertebral canal by three membranes known as the spinal meninges; they are continuous above with the cerebral meninges. These three membranes are known as the *dura mater spinalis*, the *arachnoidea spinalis*, and the *pia mater spinalis*.

The dura mater is the strongest of the three and most external. The pia mater is the most delicate and the most internal, being applied everywhere closely to the cord. Between the two is the delicate non-vascular arachnoid. Between the dura mater and the inner surface of the bony vertebral canal is a cavity known as the epidural cavity (*cavum epidurale*). Between the dura mater and the arachnoid is a space called the subdural cavity (*cavum subdurale*). More important, however, is the space between the arachnoid and the pia mater. This is the subarachnoid cavity (*cavum subarachnoideale*); it contains the cerebro-spinal fluid (*liquor cerebrospinalis*).

The spinal dura mater (*dura mater spinalis*) extends from the foramen magnum to the level of the second or third sacral vertebra. It differs from the dura mater of the brain in that it splits into two layers, the outer one becoming continuous with the periosteum and ligaments of the vertebral canal, and the inner one forming the dura mater spinalis proper. The latter layer is the one usually referred to when the spinal dura mater is spoken of, but it must be remembered that the outer layer must be added to it to make it homologous with the dura mater encephali. In the space between the outer layer and the dura mater spinalis proper, that is in the cavum epidurale, there are besides fatty tissue and some plexuses of veins and lymph channels. The thickness of the dura mater spinalis in the adult averages 0.5–0.6 mm.

Some fibrous filaments from the anterior middle line of the dura run obliquely downward and ventralward to be inserted into the posterior longitudinal ligament of the spine. These are especially developed from the fourth lumbar vertebra downward, where they fuse to form a membrane, the so-called anterior sacrodural ligament (*ligamentum sacrodurale anterius*).

The spinal dura mater forms a separate sheath for each of the two roots, the anterior root and the posterior root, of each spinal nerve. These sheaths are continued upon the roots as far as the spinal ganglia, where they become lost in the connective tissue of the peripheral nerves and in the periosteum of the bones.

At its lower extremity the dura mater spinalis forms a sac which envelops the nerve roots of the cauda equina. This sac terminates at the level of the second or third sacral vertebra, but the dura mater is continued as a sheath closely applied to the filum terminale. This portion of it, a long, tough thread, called the filum duræ matris spinalis, is finally inserted upon the posterior surface of the os coccygis.

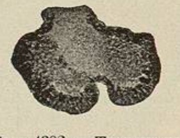

FIG. 4382.—Transverse Section Through the Coccygeal Segment of the Human Spinal Cord. Weigert's myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

The dura mater spinalis is connected with the arachnoidea by means of the so-called subdural threads and with the pia mater by the denticulate ligament (*ligamentum denticulatum*). The subdural threads are very fine and short, are connected with the outer surface of the arachnoidea, and usually carry blood-vessels. The ligamentum denticulatum is a membrane stretched out in a frontal or coronal plane between the dura mater and the pia mater, just midway between the anterior and posterior surfaces of the cord; it passes between the anterior and posterior roots of the spinal nerves. Its medial border is firmly attached to the pia mater. Its lateral border is toothed, the teeth being inserted at their summits into the dura mater midway between the exits of adjacent spinal nerves. Intermediate between the teeth

the lateral edge of the membrane forms free arcades. The number of teeth varies from eighteen to twenty-three. In the cervical region the N. accessorius runs behind the ligament.

The spinal arachnoid (*arachnoidea spinalis*) bounds the subdural cavity internally. It is to be noted that this is what is called by many anatomists the "visceral layer of the arachnoid"; below, it is reflected at the tip of the conus terminalis upon the dura mater to form the "parietal layer of the arachnoid" of various authors. This is why some writers call the cavum subdurale, situated between the parietal layer and the visceral layer of the arachnoid, the "arachnoid cavity." It is a serous cavity, like the pleura.

The arachnoid contains no blood-vessels; occasionally calcified plates are found in the membrane. The arachnoid is prolonged over the nerve roots, and over the summits of the teeth of the ligamentum denticulatum.

As a rule, it is very difficult to separate the arachnoid from the pia mater macroscopically. Key and Retzius describe the two together as the "meninx tenuis." These soft membranes, together, are also designated, the "leptomeninges," to distinguish them from the hard or tough membrane, the dura mater or "pachymeninx." If the visceral layer of the arachnoid be lifted carefully in the region of the cauda equina and cut through with fine scissors and then split longitudinally upward a little to one side of the median line, the space between the arachnoid and the pia mater, the subarachnoid cavity (*cavum subarachnoideale*), will be exposed. This space is not a free cavity, but really a communicating network of cavities, the walls of which are formed by delicate processes which extend between the arachnoidea and the pia mater. The meshes are filled with cerebro-spinal fluid. It is this cavum subarachnoideale which is tapped in Quincke's lumbar puncture when the needle is introduced opposite the interspace between the third and fourth lumbar vertebræ.

The spinal pia mater (*pia mater spinalis*), a very delicate membrane, closely envelops the spinal cord. It sends a fold into the depth of the fissura mediana anterior and elsewhere is intimately adherent to the external surface of the cord. It is extremely rich in blood-vessels, for it is in this membrane that the arteries which supply the cord undergo multiple subdivision before penetrating into the substance of the cord. When the pia mater is pulled off the cord, a number of minute arteries and capillaries are always torn out of the white substance; many of these are so small, however, that they cannot be made out with the naked eye.

The Blood-Vessels of the Spinal Cord (Fig. 4383).—The arterial supply of the spinal cord is derived from the vertebral arteries (*rami spinales Aa. vertebrales*), the ascending cervical arteries (*rami spinales Aa. cervicales ascendentes*), the posterior rami of the intercostal arteries (*rami spinales Rr. post. Aa. intercostales*), the posterior rami of the lumbar arteries (*rami spinales Rr. post. Aa. lumbales*), the ilio-lumbar arteries (*rami spinales Aa. iliolumbales*), and the lateral sacral arteries (*rami spinales Aa. sacrales laterales*).

Besides the rami spinales given off from the cervical portion of the A. vertebralis which pass through the foramina intervertebralia, each vertebral artery gives off an anterior spinal artery (*arteria spinalis anterior*) (O. T. A. vertebrospinalis anterior), and a posterior spinal artery (*A. spinalis posterior*) (O. T. A. vertebrospinalis posterior). The anterior spinal arteries of the two sides run medialward and caudalward and unite near the fissura mediana anterior somewhere between the foramen magnum and the level of the third cervical nerve. The trunk resulting from the fusion of the two, sometimes called the median anterior vertebro-spinal artery (*A. vertebrospinalis anterior mediana*), runs downward, unpaired on the anterior surface of the cord (not in the anterior median fissure), as far as the level of the fourth or fifth cervical nerve, where it ends by fusing with the *tractus arteriosus spinalis anterior*, the unpaired anterior median trunk resulting from anastomoses between the various spinal rami which come to the cord at the levels of the nerve roots all the way down as far as the filum terminale.

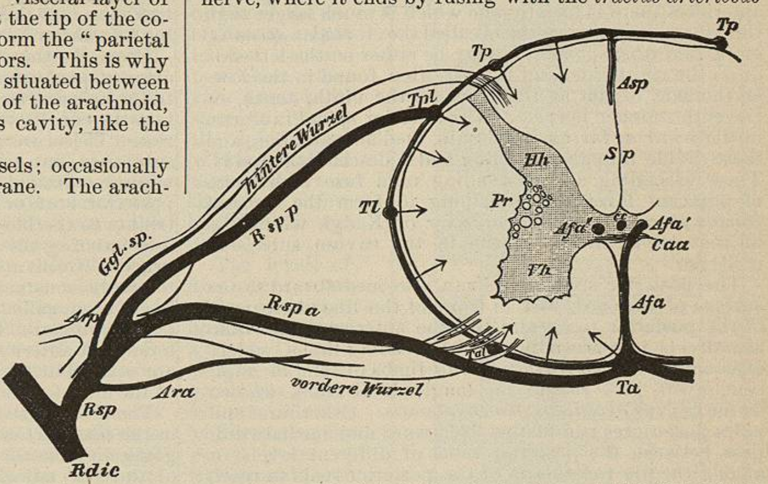

FIG. 4383.—Schematic Representation of the Arterial Vessels of a Segment of the Spinal Cord. For the sake of clearness the relative size relations of the vessels have been incorrectly drawn. *Afa*, Arteria fissuræ anterioris; *Afa'*, longitudinal central branch (ascending or descending) of *Afa*; *Afa"*, longitudinal central branch of the *Afa* next above or next below; *Ara*, arteria radicina anterior; *Arp*, arteria radicina posterior; *Asp*, arteria septi mediana posterior; *Caa*, commissura anterior alba; *Cc*, canalis centralis; *Ggl.sp.*, ganglion spinale: *Hh*, posterior horn of columna grisea posterior; *Vh*, anterior horn or columna grisea anterior; *Pr*, processus reticularis; *Rdic*, rhombus dorsalis seu posterior arteriæ intercostales; *Rsp*, ramus spinalis; *Rspa*, *Rspp*, ramus spinalis anterior, posterior; *Sp*, septum medianum posterius; *Ta*, *Tal*, *Tp*, *Tpl*, tractus arteriosus anterior, anterolateralis, lateralis, posterior, posterolateralis; *hintere Wurzel*, posterior root; *vordere Wurzel*, anterior root. (After T. Ziehen, in Bardeleben's "Handbuch der Anatomie des Menschen," Jena, 1899.)

The posterior spinal artery given off by the vertebral artery is delicate, bends around the lateral margin of the medulla oblongata and runs downward near the nervus accessorius on each side. Having reached the level of the fourth or fifth cervical nerve, it fuses with the longitudinal trunk, known as the *tractus arteriosus posterolateralis*. The latter is made up of ascending and descending branches of the spinal rami of the A. vertebralis, Aa. intercostales, lumbales, iliolumbales, and sacrales laterales.

Besides this tractus arteriosus posterolateralis the posterior spinal artery from the vertebral gives off segmental branches, the so-called penetrating arteries (*Aa. penetrantes*), which, passing medialward and joining with branches of the Aa. intercostales, give rise to another longitudinal trunk called the *tractus arteriosus spinalis posterior*. The latter does not run in the middle line, but runs lengthwise of the cord just behind the line of entrance of the posterior roots. The tractus arteriosus posterolateralis, on the other hand, runs anterior to and lateralward from the sulcus lateralis posterior or line of entrance of the posterior roots.

The rami spinales of the rami posteriores of the Aa. intercostales, the rami spinales of the Aa. lumbales, the A. iliolumbalis, the A. sacralis lateralis, as well as of the A. cervicis ascendens all run through the intervertebral foramina. On passing through the foramen, each ramus spinalis gives off two delicate branches, one to the anterior root (*A. radicina anterior*), the other to the posterior root (*A. radicina posterior*), and then, near the spinal ganglion, usually divides into two branches, one going to the front of the cord (*ramus spinalis anterior*), the other going to the postero-lateral surface of the cord (*ramus spinalis posterior*). It is to be noted that there is not a ramus spinalis for every nerve-root level; and further, that sometimes when a ramus spinalis is present, it does not divide into two branches but becomes entirely an anterior ramus or a posterior ramus, more often the latter. Thus, according to Kadyi, there are, as a rule, eight large rami spinales anteriores and as many as sixteen or seventeen rami spinales posteriores. Among the rami spinales anteriores there is usually one which is much larger than the others; this is sometimes called the *A. magna spinalis*, or *A. radicalis magna*. It may be either on the left side or on the right side, and is most often found in the lower thoracic region at the level of the ninth, tenth, or eleventh thoracic nerve. These anterior spinal rami run medialward as far as the fissura mediana anterior, and there divide into an ascending and a descending ramus. These ascending and descending rami fuse with those of adjacent levels, thus helping to form the general *tractus arteriosus spinalis anterior* of Kadyi, which lies in the epipial areolar tissue in the cavum subarachnoideale.

The posterior spinal rami run also medialward to the surface of the cord, just in front of the line of entrance of the posterior roots, and like the anterior spinal rami also divide into ascending and descending limbs, which, anastomosing with corresponding limbs of rami of adjacent levels, give rise to the longitudinal trunk known as the *tractus arteriosus posterolateralis*. Other rami spinales posteriores run farther backward and medialward, pass between the posterior roots of different levels, or among the fila radicularia of the posterior roots to reach a position just medial from the sulcus lateralis posterior, where they divide into ascending and descending limbs, which contribute to another longitudinal anastomosis known as the *tractus arteriosus posterior*, to which the Aa. penetrantes from the A. spinalis posterior of the A. vertebralis has above been seen to contribute.

The tractus arteriosus posterolateralis lies lateral from the posterior root and outside the pia mater. The tractus arteriosus posterior lies medial from the posterior root, but inside the pia mater. Between the tractus arteriosus posterior of one side and its fellow on the opposite side pass transverse anastomoses like the rungs of a rope ladder. These transverse rami are particularly noticeable opposite the cervical and lumbar enlargements.

About one-half a centimetre above the tip of the conus medullaris a large transverse anastomosing branch can be seen, connecting the tractus arteriosus posterolateralis with the tractus arteriosus anterior. The presence of this large branch, sometimes called the *ramus crucians*, explains why it is that fluid injected through the arteria spinalis magna may be distributed through the blood vascular network of the whole lower half of the cord on its posterior surface.

The anterior spinal artery and the tractus arteriosus spinalis anterior with which it is continuous give off two sets of branches. One set is central (*Aa. fissurales anteriores seu centrales*); the other set is lateral and peripheral (*rami laterales*).

The anterior fissural arteries (*Aa. fissurales anteriores seu centrales*), two hundred to two hundred and sixty in number, pass into the depth of the anterior median fissure and divide into two branches, one of the latter passing to the right, the other to the left. These branches go through the commissura anterior alba to the gray substance. They are known as the sulco-commissural arteries (*Aa. sulcocommissurales*). They often divide into ascending and descending branches which supply the whole of the gray matter of both the anterior and posterior horns, with the exception of the most peripheral part of the gray substance next to the white matter. The special branches going to the nucleus dorsalis are called the *arteriolæ columnarum Clarkii*.

The rami laterales go to the anterior roots and anastomose with the Aa. radicinæ anteriores; sometimes they form a longitudinal anastomotic chain called the *tractus arteriosus anterolateralis*. Other branches run backward to meet branches running forward from the tractus arteriosus posterolateralis and to form a lateral longitudinal anastomosis known as the *tractus arteriosus lateralis*.

The whole of the white matter and the most peripheral part of the gray matter get their blood supply from branches penetrating the cord from the tractus arteriosus anterolateralis, tractus lateralis, tractus posterolateralis, tractus posterior, and the Aa. radicinæ anteriores et posteriores. All these vessels have been grouped together by Adamkiewicz, under the name vasocorona.

From the transverse anastomoses between the tractus arteriosi posteriores of the two sides, certain unpaired posterior sulcal arteries (Aa. sulcales posteriores) penetrate into the cord in the region of the sulcus medianus posterior. These are much branched and supply the white substance, but scarcely go so deep as the posterior commissure. Branches from them may, however, reach the posterior horn or the nucleus dorsalis, and help to contribute to the blood supply of those parts. Minute vessels, entering the white substance between the fasciculus gracilis (Golli) and the fasciculus cuneatus (Burdachi), tolerably constant in the upper portions of the cord, have been called the interfunicular arteries (*Aa. interfuniculares*). The branches of the Aa. radicinæ posteriores et anteriores which reach the interior of the cord are small, but they play some part in the vascularization of the anterior and posterior horns of gray matter.

The arteries supplying the spinal cord are *end arteries* in the sense of Cohnheim. This is true of all the branches going in from the vasocorona as well as of the branches of the Aa. sulcales anteriores et posteriores. This explains the possibility of minute infarctions in the spinal cord. Despite the manifold longitudinal anastomoses throughout the whole length of the cord between the arteries of all levels, the cutting off of the blood supply through the lumbar and sacral vessels leads irrevocably to the death of the gray matter of the lower part of the cord, as has been over and again demonstrated by the experiment in which the abdominal aorta is compressed for half an hour.

The capillaries of the cord empty into the veins which form a network in the pia. Out of this network several large veins become differentiated, and these have been given special names. Thus, on the anterior surface of the cord are found: (1) *V. spinalis mediana anterior*; (2) *V. spinalis lateralis anterior dextra*; (3) *V. spinalis lateralis anterior sinistra*. On the posterior surface of the cord a median and two lateral veins can also be made out: (1) *V. spinalis mediana posterior*; (2) *V. spinalis lateralis posterior dextra*; and (3) *V. spinalis lateralis posterior sinistra*.

All these veins are devoid of valves. They empty through the *Vv. spinales anteriores et posteriores* largely into the *plexus venosi vertebrales interni*, and partly through the *Vv. intercostales* into the *V. azygos*. Some of the veins pass by way of the *Vv. lumbales* into the V. cava inferior. Other veins go by way of the *V. iliolumbalis* and the *Vv. sacrales laterales* into the V. hypogastrica, and so through the V. iliaca communis into the V. cava inferior.

The veins from the gray matter empty largely through the *Vv. fissurales anteriores* into the V. spinalis mediana anterior.

On Some Macroscopic Details.

Upper and Lower Limits of Cord.—The upper limit of the spinal cord in man and mammals corresponds to the lateral exit of the uppermost fila radicularia of the first cervical nerve. This point corresponds ventralward to the lowermost bundles of the decussatio pyramidum. The lower level of the cord, that is its junction with the filum terminale, nearly always lies on a level corresponding to the lower third of the first lumbar vertebra or the upper third of the second lumbar vertebra, though in forty per cent. of the cases it may lie opposite the upper two-thirds of the first lumbar or the lower two-thirds of the second lumbar vertebra. In one case it ended 5 mm. above the lower border of the twelfth thoracic vertebra,

and it has been found as far down as the lower margin of the second lumbar vertebra. (See report of Committee of Collective Investigation of Anatomical Society of Great Britain and Ireland for the year 1893–94, *Jour. Anat. and Physiol.*, vol. xxix., 1895, pp. 35–60.)

Length of Spinal Cord.—The extreme variations in the male are 44–50.6 cm.; in the female, between 39 and 47 cm. As to the relation of the length of the cord and the length of the vertebral column, measured from the foramen magnum to the basis ossis sacri, it may be stated that when the average length of the spinal column is designated 100, the length of the male spinal cord will be 64, that of the female spinal cord about the same. The average length of the vertebral column in the male is 70 cm.; in the female, 68 cm. (Ziehen).

Frontal and Sagittal Diameters.—The minimum measurements are met with in the middle of the thoracic cord, where the sagittal diameter measures about 8 mm., the frontal diameter about 10 mm. The maximum measurements in the intumescentia cervicalis are met with opposite the fifth or sixth cervical vertebra, where the sagittal diameter is 9 mm., the frontal diameter 13–14 mm. The maximum measurements in the lumbar enlargement are met with opposite the twelfth thoracic vertebra, where the sagittal diameter is about 8.5 mm., the frontal diameter 11–13 mm.

Upper Level of Conus Medullaris.—Charpy designates as the arbitrary upper limit of the conus medullaris a plane lying between the exit of the fifth sacral nerve and the nervus coccygeus. According to this the conus medullaris would measure about 10 mm. in length. Raymond states that clinicians usually regard the conus medullaris as extending farther up, usually to the plane between the third and fourth sacral nerve roots. This would make the conus medullaris considerably longer.

Swellings Other Than the Cervical and Lumbar Enlargements.—The segmental swellings observable in animals and corresponding to the origins of the nerve roots, despite the assertions of some authors, are not observable in the human spinal cord. Two slight enlargements, however, are to be made out in the human conus medullaris and filum terminale. One is situated at the region of transition of the conus medullaris into the filum terminale and corresponds to the ventriculus terminalis; the other enlargement is situated about 1 cm. farther caudalward.

Weight of Spinal Cord.—The average weight has been given above. The weighings of Meckel are of interest. For the three-months' fœtus, 0.12 gm. ($=\frac{1}{8}$ of brain weight); for the five-months' fœtus, 0.36 gm. ($=\frac{1}{63}$ of brain weight); for the nine-months' fœtus, 2.7 gm. ($=\frac{1}{107}$ of brain weight); for a five-months' child, 5.4 gm.

The relative weight of the human spinal cord compared with the body weight is as 1:1849.5 in the adult; in the new-born as 1:851.4. The relation of the human spinal-cord weight to body weight in a whole series of animals is given in Ziehen (*loc. cit.*). Keith has made many such measurements. Ziehen also gives a long table in which the relative weight of the spinal cord to the brain weight in animals is given. It is smallest in man and increases in the animal series steadily downward until fish are reached. In the adult human being the relation has been variously estimated from as 1:19 to as 1:51.13. The latest figures are those of Mies, who gives the relative weight of the cord to the brain as 1:49.80 in the female and 1:51.13 in the male.

Relation of Individual Spinal-Cord Segments (Root Levels) to Spinous Processes.—A number of researches dealing with the problem are available. In general it may be said that in the cervical region of the vertebral column the ordinal numeral of the spinous process is to be increased by one in order to give the ordinal numeral of the cervical nerve root arising at the level of that spinous process. In the region of the thoracic vertebræ two is to be added to the number of the spinous process in the upper half, while from the sixth to the eleventh thoracic vertebræ one must add three. The lower part of the spinous process of the eleventh thoracic vertebra and the interspace between this spine and the next lower corresponds to the origin of the third to the fifth lumbar roots; the spinous process of the twelfth thoracic vertebra and the interspace between it and the spinous process of the first lumbar vertebra correspond to the origin of the sacral roots. It is to be remembered that when the trunk is strongly flexed, the spinal cord with attached nerve roots is displaced a few millimetres upward.

The levels of the nerve roots differ somewhat in the child from those in the adult, as Chipault has pointed out. Thus in children under seven years of age we add three to the ordinal numeral for the spinous process in the region of the first four thoracic vertebræ to get the number of the nerve root of corresponding level; and in the region of the fifth to ninth thoracic vertebræ four must be added.

The lower level of the dural sac in the adult corresponds about to the level of the spinous process of the first sacral vertebra.

The topographical relations between the spinous processes and the roots of the spinal nerves are well shown in the accompanying figure copied from Reid (Fig. 4384).

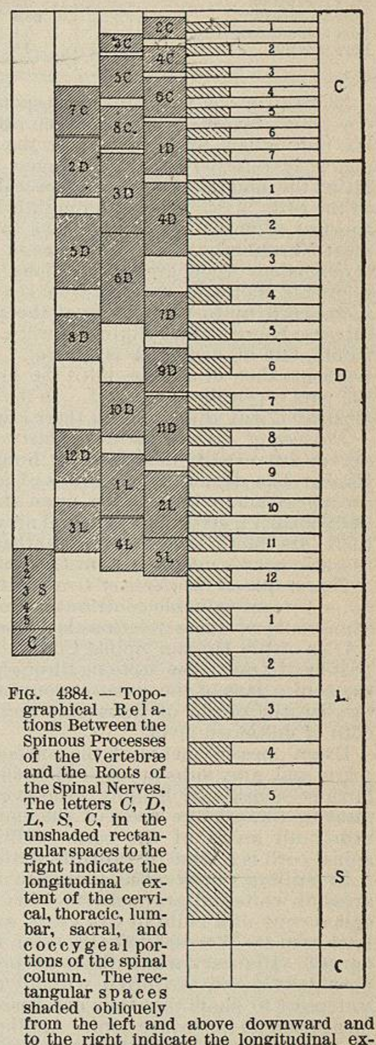

FIG. 4384. — Topographical Relations Between the Spinous Processes of the Vertebræ and the Roots of the Spinal Nerves. The letters *C*, *D*, *L*, *S*, *C*, in the unshaded rectangular spaces to the right indicate the longitudinal extent of the cervical, thoracic, lumbar, sacral, and coccygeal portions of the spinal column. The rectangular spaces shaded obliquely from the left and above downward and to the right indicate the longitudinal extent of the spinous processes of the individual vertebræ, while the rectangular spaces shaded obliquely from the right and above downward and to the left, indicate the region within which the origin of the individual roots of the spinal nerves is to be sought. The horizontal extent of the rectangular space has no significance. (After Reid, *Journ. Anat. and Physiol.*, Lond., 1889, p. 341.)

Cauda Equina.—Exact measurements have been made in an eighteen-year old individual of the distances between the root origins of the lumbar and sacral nerves and their foramina intervertebralia of exit by Testut. The distances measured are as follows:

N. lumbalis I........	114 mm.	N. lumbalis V.......	181 mm.
N. lumbalis II.......	138 "	N. sacralis I.........	188 "
N. lumbalis III......	151 "	N. sacralis V..	280 "
N. lumbalis IV......	163 "		

The filum terminale measures 16 cm. in length and extends from the third lumbar vertebra to the second coccygeal vertebra.