age. However, out of eight adults and three children in whom the tumor persisted untreated there was only one who could say that he had no ill effects from it. Spontaneous cure I have observed to take place after superficial ulcers on the surface of the sac had cicatrized; scar contraction seemed to be the chief factor in shrinking the tumor. Spontaneous cure has also followed rupture of the sac, but it is a surprising result, for this is usually a fatal accident. Spina bifida is very often associated with other malformations and deformities from paralysis, conditions not benefited by spontaneous cure.

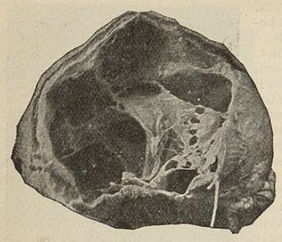

FIG. 4372.—Myelomeningocele; Sac much Subdivided. (Warren Museum.)

TREATMENT.—Without surgical intervention the chance of life for a young baby with spina bifida is small. His chance improves as he grows older, but his chance of living a useful, industrious life is slim; he will be an invalid nine times out of ten if he lives. Does surgery offer any better outlook? What is the mortality in cases which undergo operation? The recently compiled statistics of Swedish surgeons show that out of 229 cases which underwent operation 82 were fatal, a mortality of 35.8 per cent. Out of 21 cases over five years old but 1 was lost, while 43.3 per cent. of the cases under a week old ended in death. It is impossible to fix a mortality rate for the different forms of spina bifida, because clinical records have been made without reference to its division into varieties; for this reason some writers assert that about all children with spina bifida die before they are a year old; other surgeons whose experience is limited to a few successful operations believe that it is a simple thing to cure them all. In a measure both are right.

Simple meningoceles if protected against rupture not infrequently get well by gradual obliteration of the pedicle with fibrous tissue and subsequent shrinkage from absorption of fluid. If the meningocele is ruptured, whether during birth or afterward, convulsions and death from septic meningitis follow as a rule, unless the sac be ligatured and excised promptly to prevent the infection of the spinal canal. At least four cases, however, of rupture have been known to have healed without infection with a spontaneous cure. The fear of rupture often leads to excision of the sac, and the great majority of these cases make a perfectly good recovery. Nicoll, of Glasgow (*Lancet*, 1901, vol. i., p. 615), reports a good result in three cases, all in the cervical region, operated in the outpatient department and sent to their homes where a trained nurse attended them. The children were treated in this way rather than in the hospital ward because they were nursing and their mothers could not be admitted with them. A recent Italian writer reports a cure following repeated aspirations of a lumbar case. Hydrocephalus sometimes makes its appearance in a few weeks after operation and is a very unfavorable prognostic sign, just as it is in the other forms of spina bifida. The surgical technique for excision of a simple spinal meningocele presents no difficulties. The skin, subcutaneous fat, and fascia are divided on the tumor about an inch above the true pedicle, and the dissection is carried down to where the pedicle emerges and a ligature of silk or catgut loosely placed around it; the sac is then opened by a median incision and part of the fluid in it emptied in order to see if the cord or nerves are looped into the sac where the ligature might constrict them; if so, they should be gently tucked back into the canal with a probe or the ligature raised upon the pedicle sufficiently to avoid them before tying and excising the sac. If more than one vertebral arch is deficient, flaps from the aponeurosis covering the muscles of the back should be turned up and stitched over the pedicle, then the skin is sutured and a sterilized gauze dressing applied. If the patient is a young baby, loss of heat is to be guarded against during the operation by laying the infant face downward on a couple of hot-water bottles at about 110° F., and extra care should be taken to guard against shock. Anæsthesia should not be pushed too far with young babies, as it is easy to produce profound narcosis.

In England twenty years ago the injection of Morton's iodoglycerin solution was extensively employed. Dr. James Morton, the inventor, claimed to have obtained well-marked shrinkage and obliteration of the sac in forty out of fifty consecutive cases. The solution is made by dissolving ten grains of iodine and a drachm of iodide of potassium in an ounce of glycerin. One drachm of this is slowly injected with a hypodermic syringe into the sac; the child is held with the back down during operation and for several hours after, a precaution to prevent the fluid diffusing by gravity into the spinal canal. Sudden death followed occasionally; large clefts of the lumbosacral region were considered dangerous. The application of an elastic ligature has been abandoned in favor of cleaner and more modern methods.

Meningomyelocele is a much graver malformation, because with very few exceptions the cord is deformed where it is attached to the sac; the deformed region frequently involves the origins of six or more pairs of spinal roots; where the cord itself is not attached the nerve roots are adherent and are drawn out into long loops. Partial paraplegia and paralytic club-foot are commonly associated with it, as might be expected, and not infrequently congenital dislocation of the hip. No improvement of the paralytic condition has been obtained from operations upon the sac in this class of cases. Is it not wiser to refrain from operating? This question would certainly receive an affirmative answer were no other point of view obtainable. Most patients with meningomyelocele die during the first year of life; the chief causes are septic meningitis from rupture or ulceration, and hydrocephalus. Operation is justifiable if either of these causes of death can be eliminated. Hydrocephalus can neither be eliminated nor improved by operation, but a tight covering of healthy skin can be substituted for a thin ulcerating membrane in many cases and the danger of infection and rupture removed. Operations are often undertaken with only this end in view, and two methods have been successfully used—the injection of the sac with iodine and the cutting operation miscalled excision. The former method has just been described. The latter operation is performed somewhat differently from that employed for spinal meningocele. It consists in laying out as large skin flaps as possible from the base of the tumor and removing if possible the thin outer layer of membrane covering the vault of the tumor without opening the sac. The latter is then opened by a small incision somewhere on the side to avoid injuring the nerve roots and cord; the flaps are prepared from the muscle aponeurosis and tightly stitched over the collapsed sac; the skin is sutured over it with a layer of superficial stitches. In children of the age of puberty flaps of bone are often turned in to prevent the subsequent bulging which is bound to come on account of the large size of the cleft; foreign bodies have also been employed—pieces of gold or celluloid. The main object of the operation, however, must be to unite the divided sac and the skin flaps in such a way as to avoid leakage of cerebro-spinal fluid and not to injure the cord and nerves in replacing them in the canal. On account of these real difficulties the prognosis before operation must be much less favorable than in a case of simple meningocele. The after-care should also embrace every precaution to prevent leakage until union may take place. Little babies are best kept face down on the nurse's lap for six to ten hours, and then kept in bed still on the face with the hips raised for six days. Feeding

in this position is difficult, but may be accomplished by using the old-fashioned nursing-bottle with long flexible tube.

Myelocystocele pure and simple is fortunately a very rare deformity. Dr. Morton greatly improved one case by iodine injections. Aspiration alone or the evacuation of fluid by simple incision would inflict very little injury on the cord; but operators are wary of doing anything which might produce an increase of the paralysis, especially as a tough healthy skin covering, affording good protection against rupture, is usually found. After a small incision had been made, aponeurotic flaps could be turned back and closely sutured to prevent leakage of cerebrospinal fluid, as is done for meningomyelocele; the thickness of the skin flaps also would aid in preventing leakage. The myelocystomeningocele of Recklinghausen or myelocystocele complicated by meningomyelocele or by spinal meningocele is less common than either of those varieties. As the anatomical conditions vary widely treatment must be varied to suit the individual case. It was Mr. Clutton's intention, if he should find the sac becoming smaller, in a case in which a meningeal cyst was lying on the dorsal side of a myelocystocele, to inject Morton's solution. Excision of the meningocele could be performed in such a case, but the dilated cord would be too big to be replaced in the spinal canal.

In case the position is reversed and the hydromyelocele is on the dorsal side of a meningeal cyst, the same difficulty renders replacement of the cord into the canal impossible, although if impending rupture or danger of septic meningitis make operation imperative, an operation similar to that described for meningomyeloceles may be performed, the surgeon taking large enough flaps from the muscle aponeurosis to cover in the collapsed cysts which would probably be too voluminous to re-enter the canal. Unless these dangers threaten, however, cases are better unoperated, especially if the healthy skin covers the sac. A shield of metal, hard rubber, or stiffened leather should be worn to protect the sac from pressure. In case we have to deal with a myelocystocele which has ruptured on its ventral side into a subjacent meningeal cyst, the condition cannot be differentiated clinically from meningomyelocele and the treatment should be the same. In case the rupture has come on the dorsal side, leaving the sinus connecting the central canal of the cord with the external surface of the sac, it would seem rational first to explore, lay open, and obliterate the sinus, provided it is not too long, before attempting to deal with the sac itself. Curiously enough, several cases have been reported of adults who have borne these sinuses all their lives; it is probable that in these cases the sinus is limited by a closure of the central canal not far from the orifice.

In deciding on the treatment for a case it is well for the surgeon to ask himself three questions: Is this a case in which no operation should be done, or is it one in which a successful operation is possible, or one in which operation has to be done as a life-saving measure? No operation should be performed if the tumor is decreasing in size without leaking, unless meningitis is feared from the presence of deep ulcers; because a natural spontaneous cure offers just as good a result to the patient as does an operation. No operation should be performed if hydrocephalus be present, except with the distinct understanding that it is undertaken to avert for a short time death from rupture or meningitis. No operation should be performed on a myelocystocele which has a thick covering of healthy skin unless it is rapidly enlarging. Operation may be successful in any other case, whether spinal meningocele, myelomeningocele, myelocystocele, or myelocystomeningocele. Simple spinal meningoceles are almost always much benefited by excision. Excision should be done as a life-saving measure in all cases of rupture, and it should be done as soon as possible after the rupture; it should be done as a life-saving measure whenever rupture seems imminent or the proximity of septic ulcers awakens just fears of septic infection spreading to the meninges.

Temporary relief from impending rupture may be obtained by aspiration if the child's condition renders operation unjustifiable.

Spina Bifida Occulta.—In the so-called spina bifida occulta there is no projecting sac; an abnormal hairy patch in the median line is usually the only external sign on the back. Some paralysis, or paresis, a paralytic club-foot, muscular atrophy of the limb, anæsthetic areas, or sphincter paralysis which cannot be logically accounted for in other ways, may lead to its recognition; in some cases peculiar ulcers of the foot of nervous origin are observed. The affection is frequently obscure unless the bare back is seen. Sometimes a soft mass like a diffused lipoma may be felt beneath the hairy patch.

Recklinghausen says, in explanation of this condition, that in fœtal life there was present a spina bifida which collapsed and shrivelled, leaving only a minute scar and the hypertrichosis to mark where it had once been. On dissection one, two, or three cleft vertebræ are found closed in with a thick, dense, fibrous membrane, like a drum head. This is perforated by a fibrous or fibromuscular band uniting the superficial part of the tumor with that lying within the spinal canal; for a tumor, usually a fibro-lipoma, has been found at autopsy in these cases, and not infrequently considerable softening or compression of the cord as a result of its growth. The removal of this tumor and of fibrous tissue bands has in a few instances been followed by a complete disappearance of paralysis. One case was reported by Robert Jones in 1889. The lumbar cord in spina bifida occulta extends in the spinal canal often to the lower part of the sacrum instead of ending opposite the first or second lumbar vertebra. No explanation has been offered for the cause of the hypertrichosis. The tumor is regarded by Recklinghausen as the growth of some embryonic cells which had been drawn into the spinal canal along with the collapsed spina bifida sac. These cells may at times belong to another embryo and give rise to cases of fœtal inclusion like that reported by Jones, who removed a third arm from between the scapulæ and in so doing opened the spinal canal. *Augustus Thorndike.*

SPINAL COCAINIZATION AND LUMBAR PUNCTURE.—Analgesia by the subarachnoid injection of cocaine was first demonstrated by Dr. J. Leonard Corning, of New York, in 1885, and since that date this method of inducing anæsthesia has been carefully elaborated and has been practised in several thousand recorded cases by numerous observers in various parts of the world.

The knowledge so far accumulated does not justify a strict comparison of this procedure with general anæsthesia by ether or chloroform inhalation, and its relative safety is not yet definitely determined, but the meagre and fragmentary statistical data at present available indicate a mortality considerably in excess of that attendant upon the use of chloroform, and it is more than probable that the vast majority of practical surgeons do not, for various reasons, indorse the procedure as a trustworthy expedient. The more conservative advocates of this measure, being mindful of the hazard, regard it, not as a substitute for other methods of producing anæsthesia, but rather as appropriate to cases in which local anæsthesia cannot be applied, or when general anæsthetic agents are clearly contraindicated in consequence of pulmonary, cardiac, or renal disease, in aged persons, in alcoholics, in operations of a class rendered extra-hazardous by the administration of a general anæsthetic, and in operations in which the concurrence or the consciousness of the patient is desirable or necessary.

In the hands of prudent men, immediately disastrous results have been few, although alarming symptoms and sudden death, inexplicable on any other hypothesis than that of shock or intoxication, have followed lumbar puncture, both without and after the cocaine injection, thus clearly establishing the fact that the procedure is by no means free from danger.

It is worthy of remark that a number of failures have been reported, but how far the negative or the unfavorable results have been influenced by faulty technique,

by impure cocaine, or by idiosyncrasy is not known, and the possibility of provoking by puncture remote pathological changes in the cord or in its membranes remains to be ascertained.

Spinal cocainization is commonly resorted to for the purpose of producing analgesia in those parts of the body which are below the diaphragm, but it is claimed that the effect may be extended to the upper part of the trunk, to the head, neck, and upper extremities, and that it is available for operations upon these parts as well as for major and minor abdominal and pelvic operations, and for other operations on the lower portions of the body.

Various substances possessing more or less analgesic power have been used in like manner for the same purpose. Among them, eucaine, antipyrin, nirvanin, and morphine; but cocaine is employed far more than all the others combined, and is decidedly to be preferred for this purpose to any known agent.

A drug introduced into the subarachnoid space should be absolutely sterile, as the risk of infection ranks among the prominent dangers of the practice. It should also be of pure quality and of definite strength. Several methods of rendering cocaine aseptic have been proposed and have proven satisfactory. Most operators who undertake to sterilize the drug depend upon heat applied to an aqueous solution, using a temperature of 180° to 212° F., for from one minute, which does not sterilize, to fifteen minutes, which is said to destroy much of the cocaine and seriously to impair the analgesic property of the solution thus treated. The method of fractional sterilization of a two-per-cent. solution by subjecting it, in glass capsules, to a heat of 176° F. for four hours, on four successive days, is efficient, but very troublesome, as the solution does not keep well and is generally regarded unfit for use after about two weeks, so that a fresh preparation of the drug becomes necessary. The dry method appears to be the most feasible. This consists in subjecting a chemically pure specimen of cocaine to a dry heat of 300° F. for ten minutes or longer. The powder is not decomposed or injuriously affected by this temperature, and if properly protected it will keep indefinitely and is always ready for use.

The usual dose for a robust adult is from one-quarter to one-half of a grain, dissolved either in sterile water or in the spinal fluid itself. Smaller doses are recommended for young, very old, or feeble subjects. A two-per-cent. solution is ordinarily employed—the smaller dose of a stronger solution being generally preferred to a corresponding dose of a weaker solution.

The use of cocaine by spinal injection is not restricted, exclusively, to surgical procedures. It has been successfully employed in obstetric practice for the purpose of lessening the pains of parturition. The injection is made during the second stage, and it is claimed that the pains are relieved, while at the same time the force of the uterine contractions is not diminished, but that voluntary effort, on the other hand, is increased—the suffering being absent—so that the duration of the labor is thereby actually decreased.

Some of the ardent supporters of medullary narcosis attribute to it, if promptly invoked, the power to limit or to arrest shock from violent injuries.

The anæsthetic effect of an average injection of cocaine is felt in the lower portions of the body after three or five to ten minutes. The upper portions of the body are affected in from twenty to thirty minutes, and the maximum dose is usually required to accomplish this result. Complete insensibility to pain may continue for from one hour to one hour and a half or two hours, and sometimes for three, four, or even five hours. In prolonged operations or in tedious labor, the injection may be repeated, in a slightly decreased dose, if necessary to maintain the anæsthesia.

A glass syringe which can be boiled and rendered thoroughly aseptic fulfils the requirements of a satisfactory instrument. The needle should not be less than three inches long, of small diameter, with a sharp point and a short bevel. It may be constructed of steel or of a composition of iridium and platinum, which is strong, not brittle, and is less likely to rust than steel.

Subarachnoid injection, whether with cocaine or with any other substance, is liable to be attended by more or less serious symptoms—by untoward phenomena associated either with the simple puncture or with the effect of the injected material. Among the most important manifestations are cardio-respiratory disturbances, asphyxia, panting, shock, headache, restlessness, delirium, rapid pulse, nausea, vomiting, sweating, cyanosis, collapse, cramps, rigors, transient paraplegia, sensations of heat, general depression, elevated temperature, subnormal temperature, fibrillary muscular contractions, relaxation of the sphincters with involuntary discharges, retention of urine, etc.

In very nervous and apprehensive patients, the eyes and ears should be closed during the operation, and a dose of morphine and strychnine, given as a preliminary safeguard, is sometimes advantageous. The instruments, the hands of the operator, and the skin over the entire back and loins of the patient should be prepared as carefully as for an abdominal section. Any of the lumbar interspaces may be selected for the puncture, though the third or fourth is usually chosen. It has been done as high as the sixth cervical vertebra, but it is generally conceded that under ordinary circumstances puncture in the lumbar region is safest and best, even when high analgesia is desired. The spinous process of the fourth lumbar vertebra can be located by drawing a transverse line to connect the two iliac crests. It may then be accurately defined by deep palpation. The seat of puncture should be frozen by ethyl chloride, and the skin—the only sensitive tissue—penetrated with the point of a bistoury. The patient should lie on either side, with the body well curved forward and a pillow under the hip. The needle may be entered just beneath the spine in the median line and pressed firmly a little upward and forward, or it may be entered a half-inch to the right or to the left of the median line and passed obliquely toward the spinal canal. When the point of the needle enters the space, which in a well-developed adult is about two and a half inches below the surface, a sense of diminished resistance will be noticed, and the spinal fluid, always clear and limpid, will flow from the outer end, drop by drop or in a steady stream. If the lumen of the needle should be obstructed or if from any cause the fluid does not appear after the point is supposed to have entered the space, a stylet may be passed, the patient may cough or make a slight straining effort, or gentle aspiration by means of a syringe will overcome the obstacle. When the fluid begins to flow, the finger should be placed over the end of the needle, and the syringe containing the warm solution or the sterilized crystals of cocaine should be attached. Operators of experience disagree as to the advisability of allowing a few drops of the fluid to escape before throwing in the cocaine solution, some alleging that the normal quantity of the fluid in the cavity should not be disturbed, but that the amount withdrawn should equal or slightly exceed the amount introduced, while others assert that severe headaches and other bad effects are infrequent if the spinal fluid is not wasted. If the solution is used, the piston should be slowly depressed, but if the powder is to be dissolved in the spinal fluid the piston, already closed, should first be withdrawn until the barrel is about half filled with the fluid, which readily dissolves the cocaine, and then the solution should be gradually returned into the space, the needle removed, and the puncture closed with collodion.

Emphasis is laid upon the importance of very deliberate introduction of the solution, and a little delay in withdrawing the needle is advised; if, however, analgesia of the upper parts of the body is desired, the very rapid and forcible depression of the piston is considered essential.

Lumbar puncture, as an independent procedure for the purpose of withdrawing cerebro-spinal fluid, was introduced to the profession by Quincke in 1890, and since

then it has been frequently practised as a diagnostic means and to lessen pressure in acute or chronic hydrocephalus.

It should be remembered that the spinal cord proper terminates at the first lumbar vertebra, and that the subarachnoid space is continuous with the ventricles of the brain through the foramina of Magendie, Key and Retzius. It is not certain, however, that these foramina are always sufficiently patent to allow the free passage of the fluid. The normal quantity of the cerebro-spinal fluid varies in different individuals. It has been estimated at from half an ounce to two ounces. It is more abundant in old than in young persons, and is quickly reproduced.

The operation of lumbar puncture is simple and easy of performance, but it is attended with considerable danger. The withdrawal of a very small amount of cerebro-spinal fluid has caused extremely grave symptoms, and has been followed in repeated instances by immediately fatal results. The puncture is usually made, with strict antiseptic precautions, at the third or fourth lumbar interspace as above described for spinal anæsthesia. *James B. Baird.*

SPINAL CORD.—*General Description of the Macroscopic Appearances.*—The spinal cord (*medulla spinalis*) (Figs. 4373, 4374, and 4375) is that portion of the central cerebro-spinal nervous system which is situated within the vertebral canal. In human beings it is a slightly flattened cylindrical strand, varying in calibre somewhat at different levels. It is markedly curved in its course, corresponding to the curvature of the vertebral column. The spinal cord measures from 43 to 45 cm. in length, being on the average somewhat longer in the male than in the female. It is continuous above, at the lower edge of the foramen magnum, with the medulla oblongata, and extends below into the lumbar part of the vertebral canal, where it is suddenly drawn out into a terminal filament (*filum terminale*). The lower limit of the cord is variable in position in human beings. Usually the junction with the terminal filament is met with opposite the lower third of the first lumbar vertebra, or opposite the upper third of the second lumbar vertebra, but it may be found even higher or lower than these levels. In the adult, therefore, the spinal cord does not extend throughout the whole length of the vertebral canal; the condition is very different from that found in the embryo (*vide infra*). Nor does the spinal cord come anywhere near filling up the lumen of the vertebral canal. A cross section through the vertebral canal with the cord *in situ* reveals a large space between the surface of the cord and the inner surface of the bony vertebral canal (Fig. 4374). This space is subdivided by the coverings of the cord into several spaces. One of these, between the arachnoid membrane and the pia mater, the so-called subarachnoid cavity (*cavum subarachnoidale*), is filled with the cerebro-spinal fluid (*liquor cerebrospinalis*). This disproportion between the size of the cord and that of the cavity of the vertebral canal is of great significance for the protection of the cord from injury during the various movements which the vertebral column undergoes.

The spinal cord, though in general of a cylindrical shape, is everywhere somewhat flattened from before backward; the sagittal diameter is always less than the frontal diameter. In the smallest portions of the cord the difference between the sagittal and frontal diameters may not exceed 1 or 2 mm., but in the two enlargements of the cord the difference may be much greater. The upper principal enlargement is situated at the junction of the neck and thorax, and is known as the cervical enlargement (*intumescentia cervicalis*); at the point of its maximal enlargement the frontal diameter exceeds the sagittal by 4–5 mm. The other principal enlargement, at the junction of the thoracic with the lumbar spine, is known as the lumbar enlargement (*intumescentia lumbalis*); the maximum of this enlargement is reached at the level of the twelfth thoracic vertebra, where the frontal diameter exceeds the sagittal by 2.5–4.5 mm. These two principal enlargements correspond to the places where the spinal cord gives off nerves to, and receives nerves from, the upper and lower extremities respectively.

Just below the intumescentia lumbalis the spinal cord diminishes very rapidly in calibre, giving rise to the so-

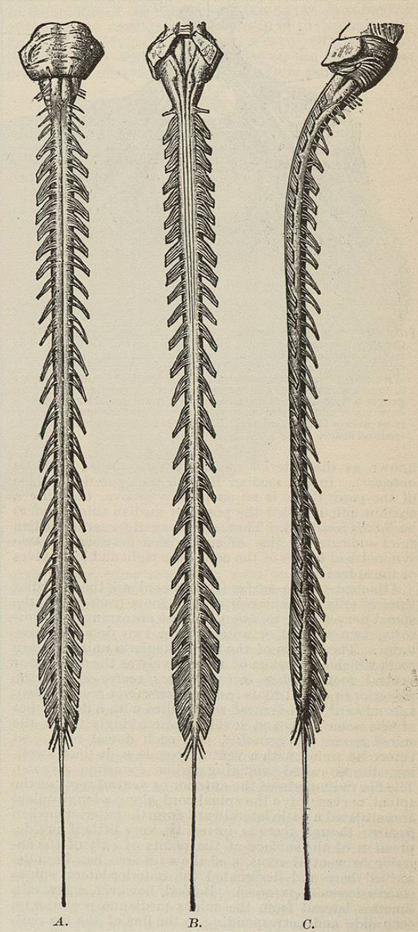

FIG. 4373.—Views of the Spinal Cord (Medulla spinalis). *A*, From in front; *B*, from behind; *C*, from the right side. (From Toldt.)

called medullary cone (*conus medullaris*). From the lower end of the conus medullaris the terminal thread (*filum terminale*) extends downward as a delicate strand for a distance of from 20 to 25 cm., to terminate upon the posterior surface of the os coccygis (Fig. 4375).

The spinal cord weighs on the average from 27 to 28

gm., but in individual cases the weight may be considerably above or below the average.

The external surface of the cord is not perfectly smooth. On examination, a deep longitudinal groove is seen in the median line upon the anterior surface. This is

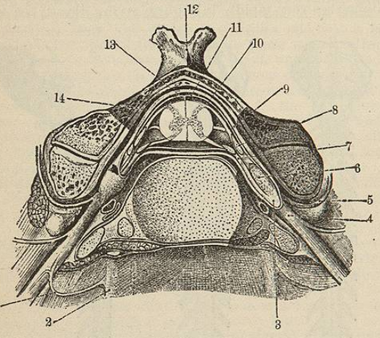

FIG. 4374.—Transverse Section Through the Intervertebral Fibro-Cartilage Between the Third and Fourth Cervical Vertebræ. The spinal meninges are shown in cross-section and their relations to the spinal nerves are indicated. (After C. Toldt, "Anatomischer Atlas," Wien, 1900.) 1, Ramus communicans; 2, trunk of the sympathetic; 3, fourth spinal nerve; 4, ramus anterior; 5, ramus posterior; 6, ganglion spinale; 7, radix anterior; 8, radix posterior; 9, spinal dura mater; 10, subarachnoid space; 11, spinal arachnoid; 12, spinous process of the third cervical vertebra; 13, subdural space; 14, epidural space.

known as the anterior median fissure (*fissura mediana anterior*). In the median line, on the posterior surface of the cord, there is no such deep groove, but only a shallow sulcus called the posterior median sulcus (*sulcus medianus posterior*). These anterior and posterior median sulci indicate the line of subdivision between the two symmetrical halves of the cord—the right and left halves of the spinal cord.

Attached to the surface of the cord are the radicular threads (*fila radicularia*) of the roots (*radices*) of the spinal nerves (*Nn. spinales*). These are arranged in four rows, two ventral or anterior and two dorsal or posterior. These rows of the fila radicularia unite to form roots which are spoken of respectively as the anterior or ventral roots (*radices anteriores seu ventrales*) and the posterior or dorsal roots (*radices posteriores seu dorsales*). Lateralward each ventral root unites with a dorsal root of the same side and level to form a single trunk, the spinal nerve (*N. spinalis*). On each dorsal root, just before its union with a ventral root, is a distinct swelling, the so-called spinal ganglion (*ganglion spinale*). The fila radicularia of the anterior or ventral roots of the spinal nerves leave the spinal cord along a longitudinal area situated a little lateralward from the anterior median fissure; though there is, in reality, very little if any depression of the surface at the points of exit of the anterior or ventral roots, a shallow groove has been described here and designated the anterior lateral sulcus (*sulcus lateralis anterior*). Behind, however, a few millimetres laterad from the sulcus medianus posterior on each side and corresponding to the line of the fila radicularia of the posterior or dorsal roots, there is a distinct groove, called the posterior lateral sulcus (*sulcus lateralis posterior*).

These longitudinal sulci, running the whole length of the cord, subdivide its surface into strands which are known as funiculi (*funiculi medullæ spinalis*). Of these funiculi there are three for each half of the cord. Thus between the fissura mediana anterior and the sulcus lateralis anterior is situated the anterior funiculus (*funiculus anterior*); between the sulcus lateralis anterior and the sulcus lateralis posterior of the same half of the cord is situated the lateral funiculus (*funiculus lateralis*); and, finally, between the sulcus lateralis posterior and the sulcus medianus posterior is situated the posterior funiculus (*funiculus posterior*). In the upper part of the spinal cord the funiculus posterior on each side is further subdivided by an additional sulcus known as the posterior intermediary sulcus (*sulcus intermedius posterior*). The lateral portion of the funiculus posterior included between the sulcus lateralis posterior and the sulcus intermedius posterior is known as the wedge-shaped funiculus (*funiculus cuneatus*). The medial portion, situated between the sulcus intermedius posterior and the sulcus medianus posterior, is known as the delicate funiculus (*funiculus gracilis*).*

Besides the fila radicularia of the anterior and posterior roots of the spinal nerves, there can be made out in the uppermost part of the spinal cord a few fila radicularia coming off from the lateral surface between the anterior and posterior lateral sulci; these unite to form on each side a nerve trunk which passes upward in the vertebral canal to enter the cranial cavity through the foramen magnum. These fila radicularia belong to the so-called accessory nerve (*N. accessorius*) or eleventh cerebral nerve.

Since the time of Sir Charles Bell, it has been customary to speak of the anterior or ventral roots as *motor roots*, of the posterior or dorsal roots as *sensory roots*, and of the spinal nerves resulting from the fusion of anterior and posterior roots as the *mixed nerve trunks*.

The mixed nerve trunk leaves the vertebral canal through the corresponding intervertebral foramen (*foramen intervertebrale*). In some parts of the cord the corresponding intervertebral foramen lies in a horizontal direction from the fila radicularia of the nerve, but in other parts of the cord, owing to greater rapidity of growth at certain periods of development of the bony vertebral canal than of the spinal cord itself, the intervertebral foramina are situated at much lower levels than are the fila radicularia of the corresponding spinal nerves. The result is that certain of the spinal nerves follow a more or less markedly oblique course between the cord and the intervertebral foramina. When this course is very oblique a considerable extent of the spinal nerve may be included within the cavity of the vertebral canal. Particularly striking is the obliquity of course and long intravertebral extent of the lumbar and sacral nerves. Indeed, some of the latter follow almost a vertical course, enveloping the conus medullaris and the filum terminale as a great bundle of nerves known as the horse's tail (*cauda equina*).

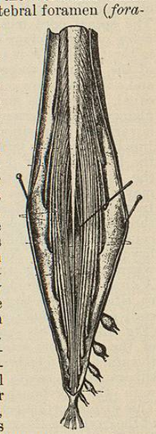

FIG. 4375.—The Lumbar Spinal Cord (pars lumbalis medullæ spinalis) with the terminal cone (conus medullaris), terminal thread (filum terminale), and the horse's tail (cauda equina). Viewed from behind. (After C. Toldt, "Anatomischer Atlas," Wien, 1900.)

There are thirty-one pairs of spinal nerves, connected with the spinal cord. The spinal nerves are named according to their exit from the vertebral canal. The uppermost spinal nerve leaves the vertebral canal between the atlas and the os occipitale. All other spinal nerves come out through the intervertebral foramina between adjacent vertebræ, the lowermost one making its exit through the opening between the first and second por-

*It is customary to find the funiculi of the spinal cord referred to in English text-books as the "columns of white matter" of the cord. It is preferable to retain the term column for the longitudinal strands of *gray* matter, and to use the terms funiculi and fasciculi for the strands of white matter.

tions of the os coccygis. It is customary then to divide the spinal nerves into cervical nerves (*Nn. cervicales*), thoracic nerves (*Nn. thoracales*), lumbar nerves (*Nn. lumbales*), sacral nerves (*Nn. sacrales*), and coccygeal nerve (*N. coccygeus*). There are eight cervical nerves, twelve thoracic nerves, five lumbar nerves, five sacral nerves, and one coccygeal nerve. The portion of the spinal cord connected with the cervical nerves is known as the cervical part (*pars cervicalis*). The portion of the cord connected with the thoracic nerves is known as the thoracic part (*pars thoracalis*). The portion of the cord connected with the lumbar and upper sacral nerves is known as the lumbar part (*pars lumbalis*). That portion of the cord which is below the pars lumbalis is called the conus medullaris. The pars cervicalis includes the intumescentia cervicalis; the pars lumbalis includes the intumescentia lumbalis.

Each spinal nerve belongs to one segment of the body (*metamere*). The motor part of each spinal nerve innervates the muscle derived from the muscular part (*myotome*) of a given metamere. The sensory part innervates all of the derivatives of a given metamere supplied with sensory nerves. One spinal nerve, together with its fibres of distribution, its ramus communicans and corresponding portion of the sympathetic, its roots, and the portion of spinal cord belonging to it, makes up the nervous part (*neurotome*) of a given metamere.

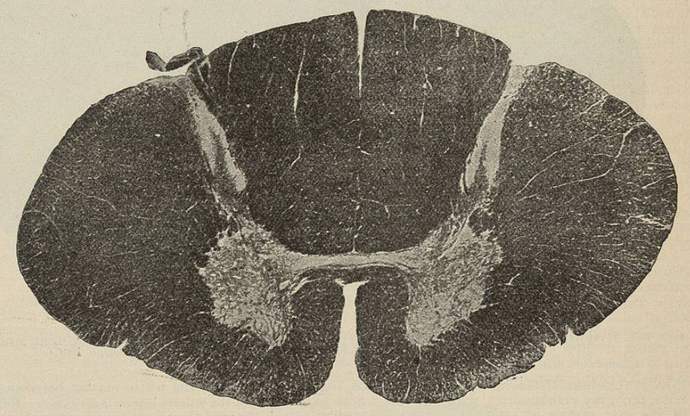

FIG. 4376.—Transverse Section Through the Fourth Cervical Segment of the Human Spinal Cord. (After A. Bruce, "Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

If the spinal cord be cut through at different levels (*sectiones medullæ spinalis*), it will be seen to contain a central canal (*canalis centralis*) and to be made up of gray matter (*substantia grisea*) and white matter (*substantia alba*). In general, the white matter is outside and the gray matter inside, and the latter in a transverse section assumes more or less the shape of the letter **H**; but the relations which exist between the white matter and the gray matter vary somewhat at different levels of the spinal cord. It will be convenient, therefore, to study first the topographical appearances of a transverse section through the *middle of the cervical portion of the spinal cord* (Fig. 4376), and afterward to compare with it the topographical appearances met with at other transverse levels.

On each side of the middle line of the cord the structures are almost identical. The anterior median fissure in front and the posterior median sulcus, together with the septum medianum posterius behind, divide the cord almost completely into two symmetrical halves.

The sulcus medianus anterior is broad and deep; as seen in cross-section it extends through about one-third of the depth of the cord. In it is lodged a fold of the pia mater carrying blood-vessels. The shallow sulcus medianus posterior is situated in the middle line behind. Extending from the floor of this sulcus through the white matter as far as the transverse bar of the **H** of gray matter, the septum medianum posterius can be seen. It consists of a condensed mass of certain supporting structures of the cord (ependyma cells).

While the cord is nearly cut in two by the fissura mediana anterior in front and the septum medianum posterius behind, the two halves are really connected by a transverse bar of nerve substance called the commissure. This commissure consists partly of white matter, partly of gray matter. The anterior third is white matter and is called the white anterior commissure (*commissura anterior alba*). The posterior two-thirds consists of gray matter called the gray commissure (*commissura grisea*). In the middle of the commissure is seen the cross-section of the central canal (*canalis centralis*) of the spinal cord, lined by ependymal epithelium, a canal which is continuous above with the ventricles of the brain. The gray matter surrounding it differs from the rest of the gray matter, being somewhat more transparent and reacting in a different way to staining reagents. This special gray matter is called the central gray substance of the spinal cord (*substantia grisea centralis*). It will be noticed that the central canal divides the commissure into an anterior part (*commissura anterior*) and a posterior part (*commissura posterior*). The anterior commissure consists of white matter in front, the anterior white commissure (*commissura anterior alba*), and gray matter behind, the anterior gray commissure (*commissura anterior grisea*). The posterior commissure (*commissura posterior*) consists chiefly of gray matter, though some white fibres run through it. The posterior median septum abuts upon the commissura posterior. The fissura mediana anterior extends in the depth as far as the commissura anterior alba.

An examination of the distribution of the **H**-shaped mass of gray matter shows that the long lateral limbs of the **H** are directed, generally speaking, from before backward, though they are inclined a little lateralward behind. The gray commissures form the cross bar of the **H**; the lateral limbs of the **H** are not, however, even in thickness, the gray mass being more expanded in its anterior part and more elongated and narrow in its posterior part. On the lateral surface of the gray matter there is a distinct projection of gray matter lateralward into the white matter, to be seen in the cross-section. The expanded anterior part of the gray matter is known as the anterior or ventral horn, and since, when the third dimension is considered, it represents a mass extending the whole length of the cord in its anterior part, it is called the anterior column of gray matter of the cord (*columna anterior*). The posterior narrower portion of