ANATOMY
·OF·THE·
BRAIN AND SPINAL CORD
·BY·
J. Ryland Whitaker

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TO

SIR WILLIAM SCOVELL SAVORY, BART.,

SURGEON EXTRAORDINARY TO H. M. THE QUEEN;

LATE PRESIDENT OF THE ROYAL COLLEGE OF SURGEONS, LONDON;

FELLOW OF THE ROYAL SOCIETY, ETC., ETC.

This little Manual is respectfully Dedicated

IN MEMORY OF MANY KINDNESSES.

THE AUTHOR.

PREFACE.

AS my only apology for publishing the First Edition of this little book, was the repeated requests that I should do so, so my only apology for issuing this Second Edition is the exceedingly favourable reception, in spite of its many errors and defects, accorded to the First Edition. The book has, as far as possible, been brought up to date, and many new Figures and Tables have been added.

Though no one can be more alive than I am to the importance of a developmental aspect of the Brain and Spinal Cord for a proper understanding of its Structure, still, as hitherto, only a short outline has been given in the last Chapter, for it seems to me useless to discuss the development of the several parts, till at least the names and appearances of those parts have been mastered.

I have again to thank Dr SYMINGTON and those who gave me so much help with the First Edition; but especially are my thanks due to Dr EDINGER, of Frankfort, whose splendid work on the Central Nervous System is so well known to all.

CASTLE TERRACE,
EDINBURGH, *August 1892.*

PREFACE TO FIRST EDITION.

My only apology for publishing this little book on the "Anatomy of the Brain and Spinal Cord," when so many excellent Manuals already exist, is that I have been repeatedly requested to do so. The work pretends to no originality, liberal use having been made of the various well-known text-books, such as Quain, Turner, Ecker, Henle, Holden, Gowers, Ferrier, Wilks, and many others. It merely embodies the series of Demonstrations on the Brain and Spinal Cord which it has been my pleasant duty, for several years past, to give to the senior students of the Edinburgh School of Medicine, Minto House. This will, in a great measure, account for the somewhat conversational style adopted. The order followed will be self-evident on inspection of the Table of Contents. In lettering the Plates, if the entire name has not been printed, the initial letters of the name have been used, so that when referring (in the text) to the various figures the letters have not been again employed—the initials of the names indicating the lettering on the Plates. Many of the figures have been taken, by the kind permission of Dr Symington, from the beautiful preparations in the Anatomical Rooms at Minto House; others are from the sources indicated below (see List of Plates). To Dr Symington also I am indebted for many valuable suggestions and much help ; and to my friend and fellow-demonstrator, Mr Kent, and to the several students who, at great inconvenience to themselves, have more than once read over the manuscript and proofs, I cannot sufficiently express my gratitude. Any merit or success which the book may have is in a great measure due to them. Finally, it only remains for me to thank Mr J. T. Murray for the time and trouble he has taken in the reproduction of the Plates, and the publishers, Messrs Livingstone, for their uniform courtesy and excellent execution of the work.

CASTLE TERRACE, EDINBURGH.

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ANATOMY

OF THE

BRAIN AND SPINAL CORD.

THE **Central Nervous System** is made up of the Brain and Spinal Cord. Surrounded by the bony wall of the cranium in the one case, and of the spinal canal in the other, these two parts of the great cerebro-spinal nervous system are continuous with each other through the foramen magnum. They are each enveloped in three distinct membranes, the Meninges, which form additional protective sheaths around them, and help to support them in their respective cavities.

The Brain and Spinal Cord are, moreover, each composed of two kinds of nervous substance, known from their colour as the White and Grey Matter respectively; but with this difference in their arrangement, namely, that in the Brain the grey matter is situated chiefly on the outside, forming the Cortex; whilst in the Spinal Cord the white substance is external, and the grey matter forms the central core or pith.

We shall describe first the Spinal Cord and its Membranes, then the Brain and its Membranes.

Section 1.

THE SPINAL CORD AND ITS MEMBRANES.

DISSECTION.—To see the spinal cord and its membranes it will be necessary to open the vertebral canal. To do this, remove all the muscles from the vertebral grooves, and saw through the laminæ of the vertebræ on each side, close to their union with the pedicles, being careful, especially in the dorsal region, to direct the edge of the saw inwards. Carry the incision downwards as far as the lower end of the sacral canal, and upwards as high in the neck as may be convenient. Break through with the chisel any partially sawn arches, cut through the various ligaments, and remove the pieces of bones thus detached. After having cleared away the connective tissue, veins, and fat covering the outer aspect of the dura mater, snip through the articular processes with the bone forceps, and dissect out one or more of the processes of the dura mater which pass through the inter-vertebral foramina. Examine the outer surface of the dural sheath, and then slit it open by a longitudinal incision in its entire length.

CHAPTER I.

MEMBRANES OF THE SPINAL CORD.

(Plates I., II.)

THESE are identical in many respects with those of the Brain, and are therefore similarly named. They are the Dura Mater, the Pia Mater, and the

Arachnoid. The Dura Mater is the most external, the Pia Mater is in close contact with the cord, and the Arachnoid forms a vertical, tubular partition between the others, dividing the space between them into two —viz., the Subdural and the Subarachnoid. Thus we speak of the subdural space, meaning that between the dura mater and the arachnoid, and of the subarachnoid, or that between the arachnoid and the pia mater. For convenience we shall describe (1) the Dura Mater; (2) the Pia Mater; (3) the Arachnoid.

I.—THE DURA MATER.

(Figs. 1 to 7.)

The Dura Mater, the most external and the strongest covering of the cord, is a firm fibro-serous membrane, continuous at the foramen magnum with the similar membrane which lines the cranial cavity. Enclosed in the spinal canal, it does not, however, form an endosteum to the bones, and in this respect differs from the cranial dura mater. Its outer surface has a shining, pearly-white appearance, and is separated from the walls of the spinal canal by a little fat and loose areolar tissue, and by a plexus of veins. Slender fibrous bands, especially at its lower end, attach it closely to the posterior common ligament of the vertebræ. In extent the dural sheath reaches from the foramen magnum to the second or third piece of the sacrum, and, as you will see on opening it, it encloses a cavity which is much longer and wider than its contents, for the cord ends at the first or second lumbar vertebra. Below the pointed termination of the

Plate I.

Fig. 1.

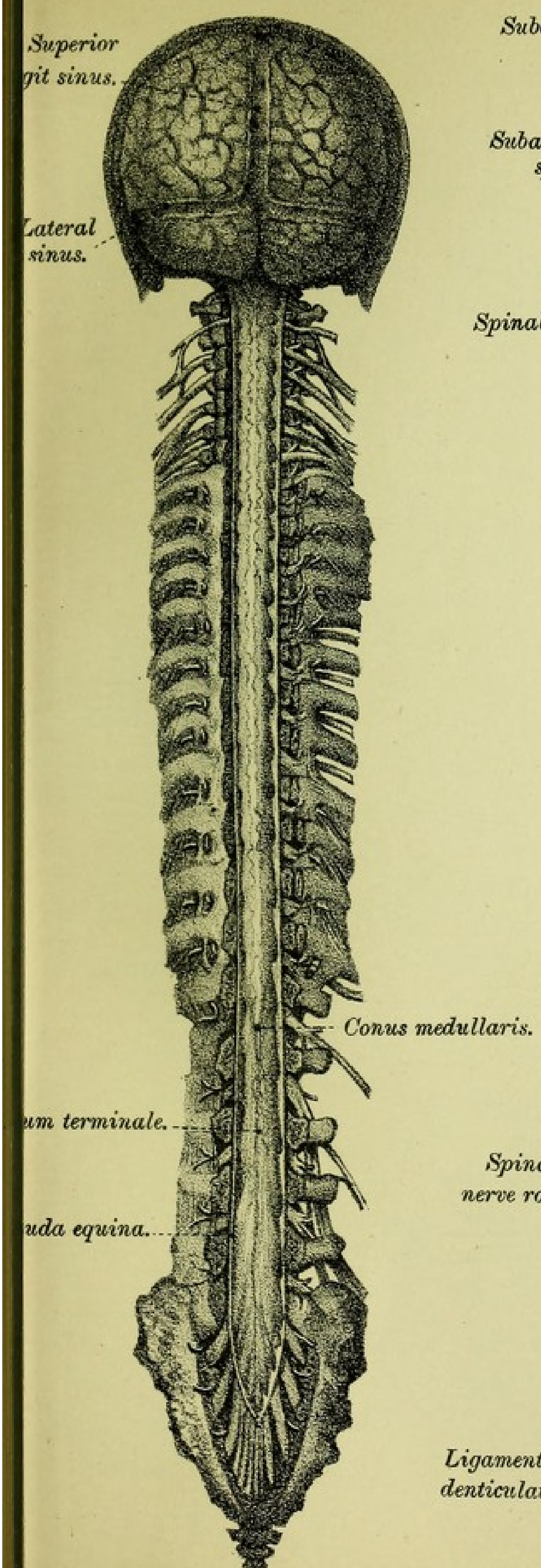


Fig. 2.

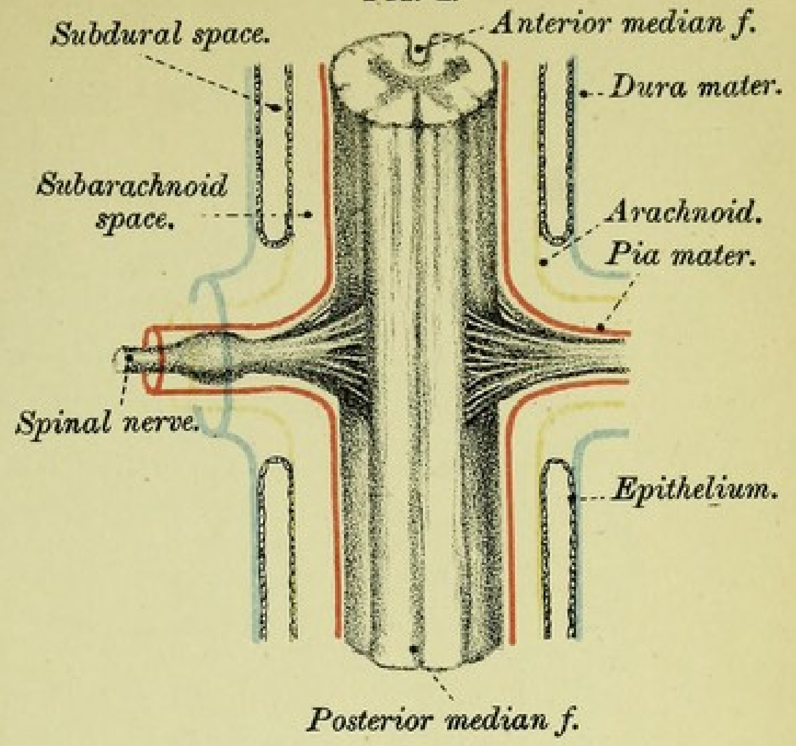
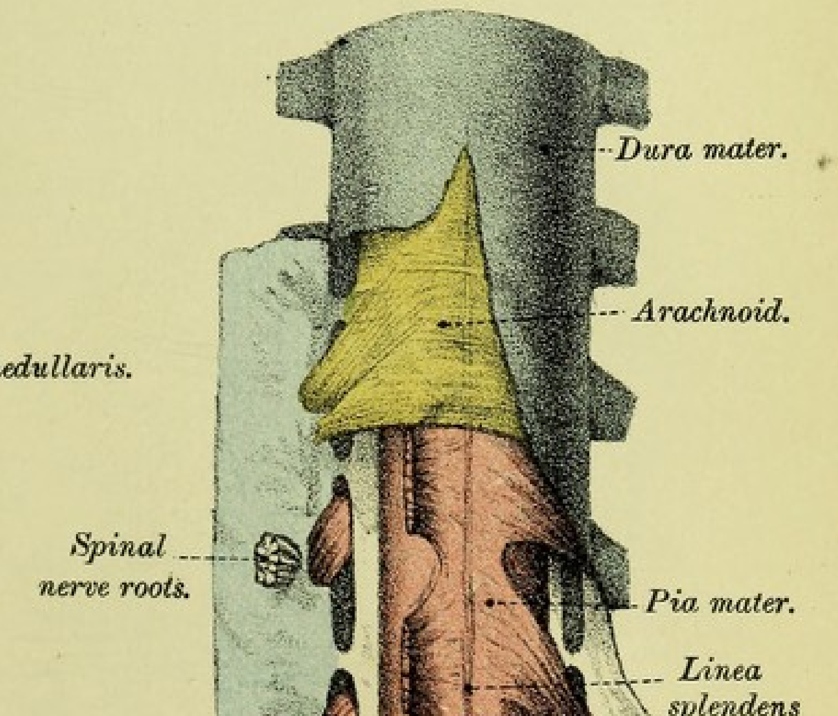


Fig. 3.



spinal marrow—*conus medullaris*—the cavity of the dural sheath is occupied by bundles of nerve roots—*cauda equina* (fig. 1)—in the midst of which you will be able to pick out a slender, silvery-looking thread, the *filum terminale* or central ligament (fig. 1, fil. ter.). Attached to the apex of the conus medullaris this terminal filament runs down the middle line amongst the nerve roots to the lower end of the dural cavity, and there, piercing the dural sheath, receives an investment from it, and passes, to be attached along with this investment, to the back of the sacrum or coccyx. Thus, we see that the dura mater forms a very loose covering to the cord, and we find, moreover, that it has a greater capacity in the neck and back than it has in the loins. Smooth and glistening on its inner aspect, it presents on each side a longitudinal series of rounded openings arranged in pairs, one for each spinal nerve root. These roots, as they pass out to the inter-vertebral foramina, carry with them a tubular prolongation of the dura mater (figs. 2, 4, 6). This prolongation also encloses the spinal ganglion (fig. 4).

It is important to recollect that, although the spinal cord itself ends at the spot indicated—viz., the second lumbar vertebra,—the dura mater, the arachnoid, and the cerebro-spinal fluid extend as far as the second piece of sacrum, so that injuries inflicted upon the spine as low down as this latter point may cause death by inducing inflammation of the meninges.

Minute Structure of the Dura Mater.—Under the microscope the dura mater will be seen to consist of white fibrous and elastic tissues, arranged in longitudinal bands or lamellæ, with flattened, branched, connective tissue corpuscles, clasping the bundles of fibrils. Both its inner and outer surfaces are smooth and covered by endothelial plates. Many lymphatics and blood-vessels, as well as slender nerve filaments, derived from both spinal and sympathetic systems, are furnished to its substance.

II.—THE PIA MATER.

(Figs. 1 to 7.)

DISSECTION.—After slitting open the dura mater, the first membrane you will see is the delicate arachnoid. Pierce it with a sharp-pointed blow-pipe and inflate, as far as you can, the subarachnoid space. Next, to expose the pia mater, remove a small piece of the arachnoid from any part of the cord, leaving it intact elsewhere.

The Pia Mater is a delicate, highly vascular, fibrous membrane, which so closely surrounds the spinal cord that it cannot easily be stripped off. It also furnishes sheaths to the roots of the spinal nerves, and a process or fold passes from it into the anterior median fissure of the cord. Other smaller septa penetrate the spinal marrow at various points, and carry with them blood-vessels and lymphatics for the nutrition of both its white and grey matter. The largest of these septa enters the posterior median fissure (figs. 4, 6). If you compare the pia mater of the cord with that of the brain, you will find that the former is thicker, less vascular, and more adherent to the subjacent nervous tissue. Some anatomists describe two layers in the pia mater of the cord, an inner and an outer layer, differing in the arrangement of their constituent elements. Of these the inner layer only is represented in the pia mater of the brain.

The outer surface of the pia mater is comparatively rough, and has three structures connected with it, thus—

1. Along its anterior aspect it presents a thickened fibrous band, the so-called *linea splendens* (fig. 3). This is sometimes difficult to make out.

2. Another but well-defined structure, the *ligamentum denticulatum* (fig. 3 to 7, lig. dent.), runs longitudinally on each side of the cord in the form of a toothed, white band, having its serrated edge turned outwards. This ligament helps to support the spinal marrow within its dural sheath. Internally, it is attached to the pia mater, about midway between the lines of origin of the anterior and posterior nerve roots, reaching upwards as high as the medulla oblongata, and ending below on the pointed extremity of the cord, the conus medullaris. Externally, its outer margin forms a series of tooth-like processes, about twenty-one in number, which are fixed to the inner surface of the dura mater, in the interval between the points of exit of successive nerve roots. The highest of these denticulations is attached opposite the margin of the foramen magnum, and the lowest opposite the twelfth dorsal or first lumbar vertebra. The ligamentum denticulatum thus partially divides the subarachnoid space into an anterior and a posterior compartment.

3. Further, at the back of the cord is another process or partition—the *septum posticum* (fig. 4, 6, sep. post.)—which also crosses the subarachnoid space and serves to connect the pia mater with the arachnoid.

Below the end of the cord, the pia mater, though at first retaining its tubular form, afterwards becomes suddenly reduced in size, and is finally prolonged as a mere fibrous thread—*filum terminale* or central ligament (fig. 1, f.t.). In its upper half this terminal filament encloses the continuation of the central canal of the spinal cord, surrounded by a little grey matter; but, opposite the first or second sacral vertebra, it pierces the dura mater, and, receiving an investment from it, ends below by blending with the periosteum of the sacrum or coccyx. Its silvery hue will enable you to distinguish it among the surrounding bundles of nerve roots (cauda equina).

Lying between the pia mater on the one hand, and the arachnoid on the other, but connected with both, is a quantity of delicate connective tissue in the form of a spongy network, the subarachnoid trabeculæ (figs. 4, 6, subarach. trab.), the interstices of which are lined by endothelial plates. The lacunæ or areolæ, thus formed, contain the greater part of the cerebro-spinal fluid.

Minute Structure of the Pia Mater (fig. 27).—The pia mater consists of a basis of white fibrous connective tissue, arranged in interlacing bundles. As before mentioned, two layers have been described in the pia mater of the cord, but the difference in their structure is very slight. Both its surfaces are covered by endothelial cells. It possesses a complete network of lymphatics and blood-vessels; and its nervous supply is derived from the sympathetic system.

Plate II.

FIG. 5.

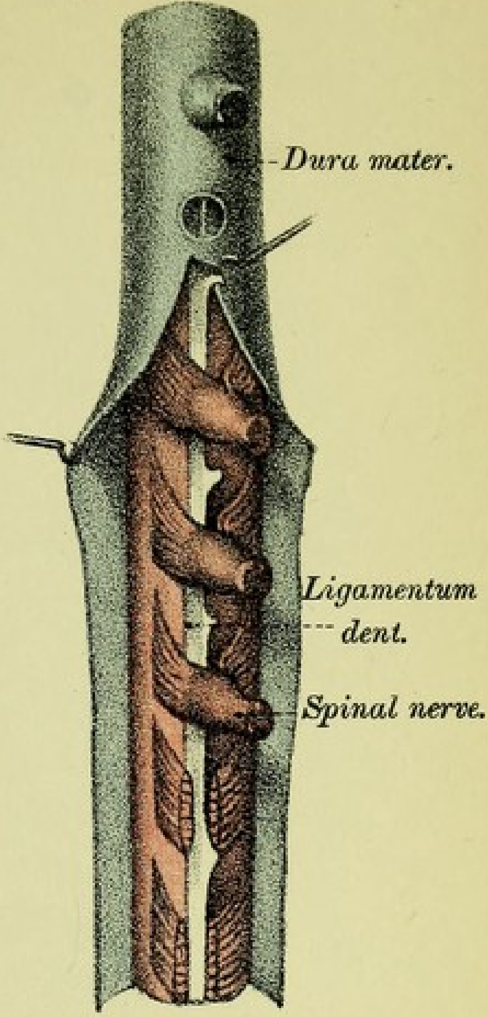


FIG. 4.

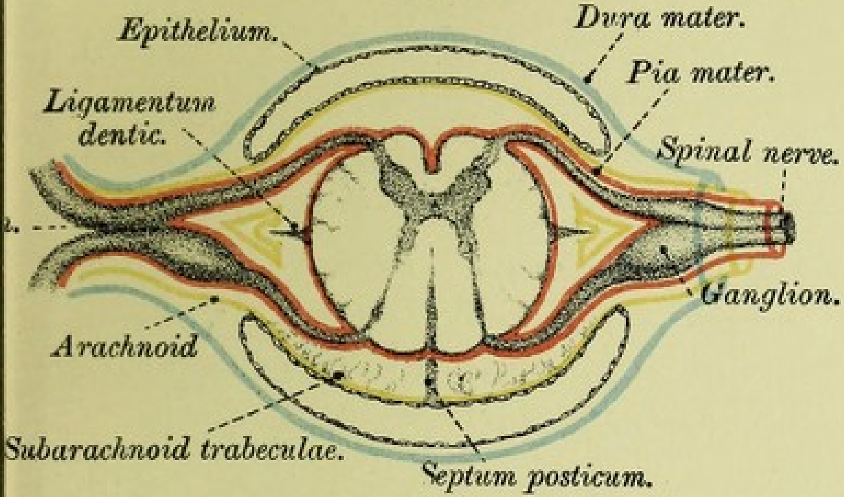


FIG. 6.

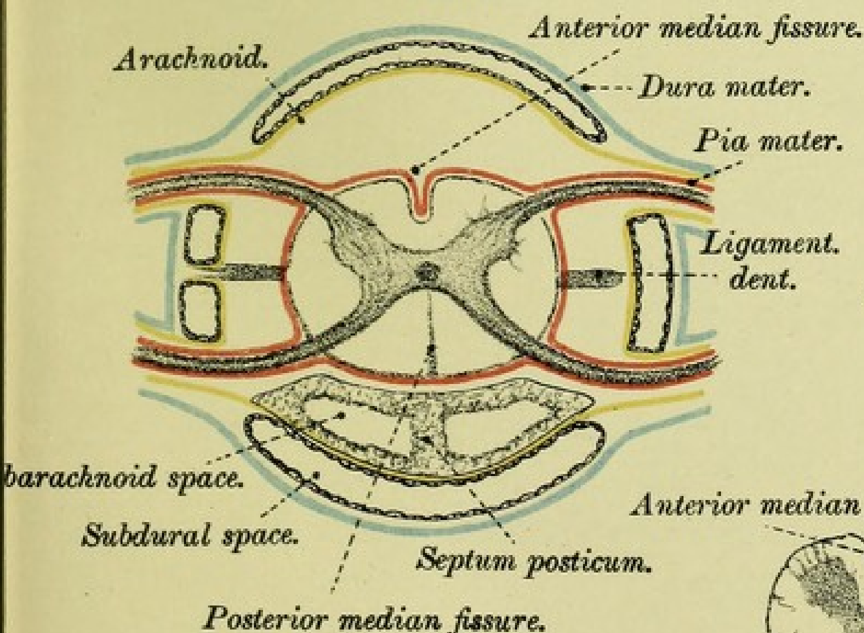
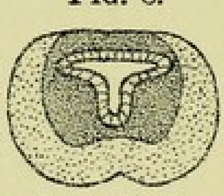
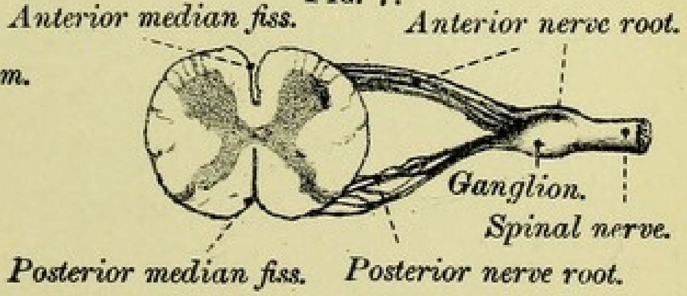


FIG. 8.



Transverse section of lower part of spinal canal.

FIG. 7.



III.—THE ARACHNOID.

(Figs. 2 to 6.)

The Arachnoid is an extremely fine and delicate membrane. It is non-vascular, and thus differs materially from the other two. Its arrangement is by no means easy to understand, the difficulty being increased by the fact that different descriptions of it are given in the various text-books.

Forming a cylindrical partition between the dura mater and the pia mater, the arachnoid divides the space between them into two—the subdural and subarachnoid, previously referred to. The subdural space is very narrow, for the outer surface of the arachnoid is in more or less close contact with the dura mater. The subarachnoid space is much larger; is crossed by the subarachnoid trabeculæ; and contains the chief part of the cerebro-spinal fluid. Moreover, the arachnoid forms tubular prolongations both around the filum terminale and the processes of the ligamentum denticulatum; and similar coverings are furnished to the roots of the spinal nerves. These sheaths enclose the nerves as they pass outwards to the dura mater, but, when the nerve roots pierce that membrane, the epithelium of the outer surface of the arachnoid becomes continuous with the epithelium lining the inner surface of the dura mater, whilst the rest of the arachnoidal sheath blends with the perineurium of the nerves (figs. 2, 4, 6, epith.). Thus we see that each spinal nerve root receives a covering from all three membranes of the cord (figs. 2, 4, 6, n.). It is stated, too, that the subdural and subarachnoid spaces, though they do not directly communicate with one another, are still both continuous with the lymphatic plexuses which surround the spinal nerves. It may perhaps be well to mention that the subdural space was formerly spoken of as "the cavity of the arachnoid"—the arachnoid membrane itself being then looked upon as a serous membrane, enclosing a serous cavity, and the epithelial lining of the dura mater as one of its layers.

MINUTE STRUCTURE OF THE ARACHNOID.—The arachnoid consists of bundles of white fibrous tissue, interlacing with one another, and arranged for the most part longitudinally. Both its surfaces are covered by endothelial cells. The source from which it derives its nerves is still very doubtful; most probably they are of sympathetic origin.

Cerebro-spinal Fluid.—The cerebro-spinal fluid, about two fluid ounces in quantity, is a clear-looking, alkaline, albuminous liquid, which chiefly occupies the interstices of the sub-arachnoid trabeculæ. By its means, probably, an equality of pressure is maintained upon the brain and cord; hence we find that any sudden disturbance of the fluid, such as would be caused by pressure on a spina bifida, at once gives rise to serious cerebral symptoms—such as convulsions and loss of consciousness.

CHAPTER II.

THE SPINAL CORD.

THE **Spinal Cord** is the elongated cylindrical mass of nervous substance contained in the vertebral canal. Invested by three membranes—the meninges, it gives origin to thirty-one pairs of spinal nerves; is partially divided by anterior and posterior median fissures into two lateral segments, united by a band called a commissure; and is composed of two kinds of nervous substance—an outer cortical part, consisting principally of white or medullated nerve fibres, and an inner grey core or pith, consisting chiefly of nerve cells and nerve cell processes. You have already seen that the spinal marrow is much smaller than the capacity of its bony case, so much so, that, in the adult, it occupies only about two-thirds of the length of the spinal canal. About eighteen inches long, the spinal cord reaches from the foramen magnum to the lower border of the first or second lumbar vertebra. Above, it is continuous with the medulla oblongata; below, it ends in a pointed extremity, the conus medullaris, from the apex of which the filum terminale is prolonged downwards. According to the regions of the spine in which they are situated, different portions of the cord have received special names; thus we speak of the *cervical, dorsal,* and *lumbar* portions. The spinal cord, moreover, presents two swellings or enlargements — an upper one, the *cervical enlargement,* extending from about the third cervical to the first dorsal vertebra, and a lower or *lumbar enlargement,* which, beginning at the tenth dorsal vertebra, is largest opposite the twelfth, and then gradually tapers away to the pointed extremity of the cord. The connection between the increase of nervous substance in these two parts of the cord and the origin of the large nerve bundles given off to the upper and lower limbs respectively is sufficiently obvious.

I.—FISSURES OF THE CORD.

On both the anterior and posterior aspects of the spinal cord there is seen a median longitudinal cleft or depression, which penetrates some distance into the nervous substance, and partially divides it into two lateral halves. These clefts are called the *anterior* and the *posterior median fissures* (figs. 4, 6, 7, 12).

1. The ANTERIOR MEDIAN FISSURE is the wider of the two, though in depth it extends through only one-third of the thickness of the cord. It contains a distinct fold of the pia mater, which conveys blood-vessels into the interior of the spinal marrow (fig. 6, 15). At the bottom of this fissure lies a transverse band of nerve fibres, the *anterior* or *white* part of the commissural band (Plate III., fig. 9), which unites together the two lateral halves of the cord.

2. The POSTERIOR MEDIAN FISSURE, narrower but deeper than the anterior, is rather a septum than an actual fissure, for it does not contain a fold of the pia mater, but is filled up by connective tissue and blood-vessels derived from the deeper layer of that membrane. The *posterior* or *grey* part of the commissural or connecting band lies at the bottom of this septum (Plate III., fig. 9).

Plate III.

Fig. 9.—Cervical Region—

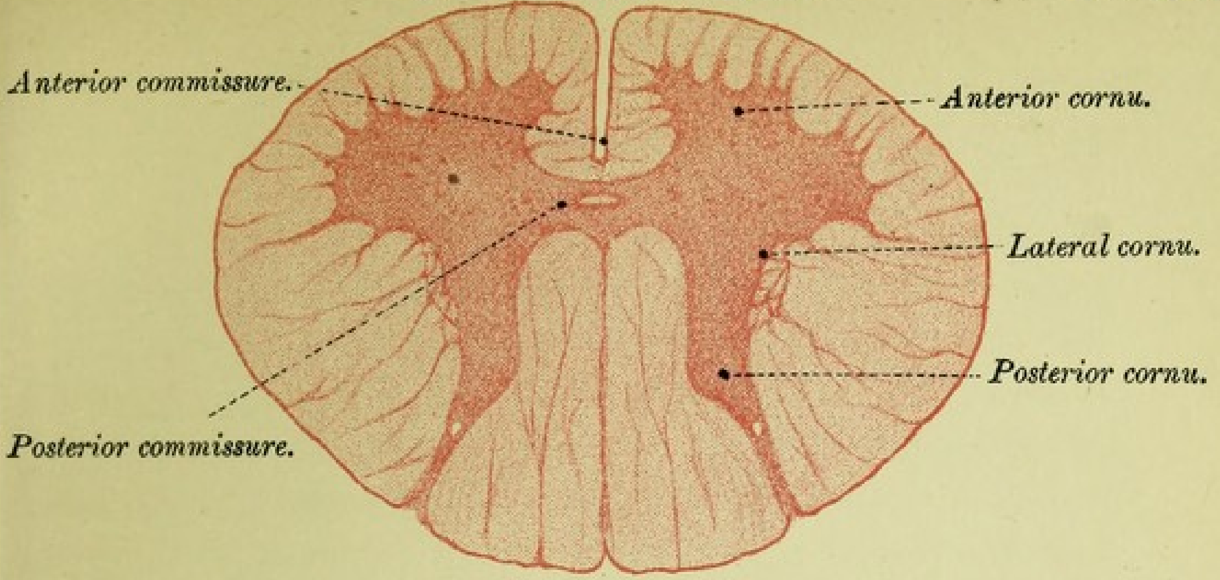


Fig. 10.—Dorsal Region—

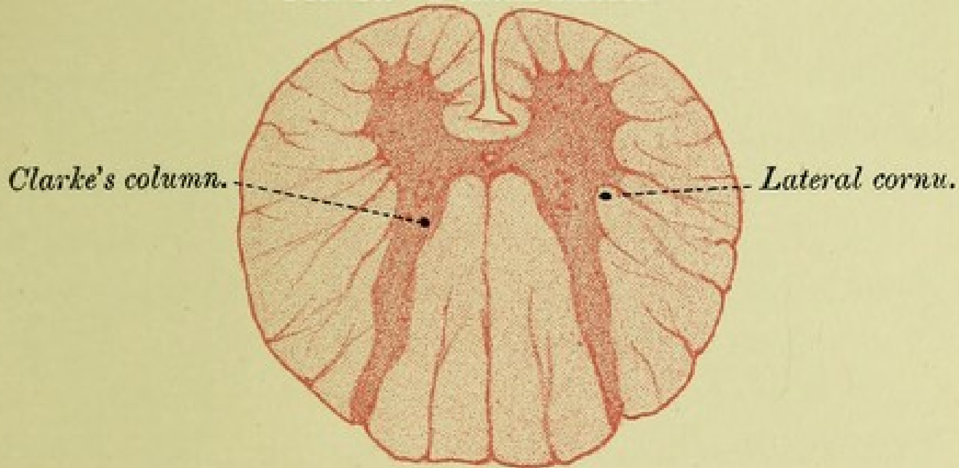


Fig. 11.—Lumbar Region

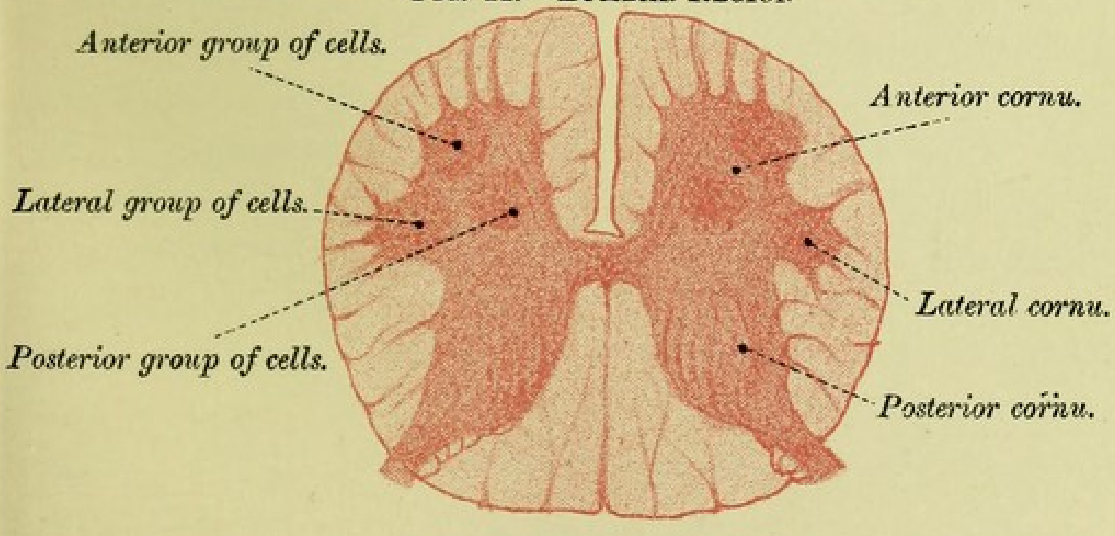
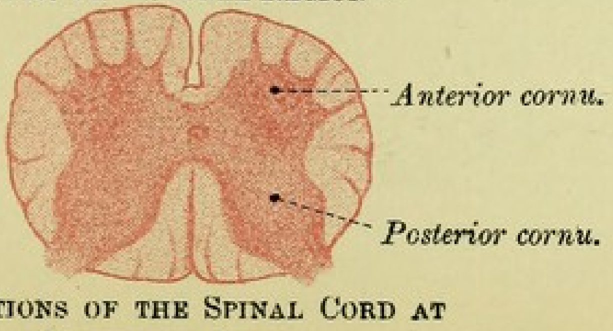


Fig. 12.—Sacral Region—



Sections of the Spinal Cord at Different Levels.

In addition to these median fissures, we have yet to describe, on each side, two lateral longitudinal depressions, the positions of which are indicated by the lines of origin of the anterior and posterior nerve roots (figs. 3, 7). They are called the ANTERO-LATERAL and POSTERO-LATERAL grooves, though the antero-lateral is scarcely a distinct groove. They mark off the surface of each half of the cord into three columns—an anterior, a lateral, and a posterior. The *anterior* column lies between the anterior median fissure and the anterior nerve roots; the *lateral* column between the nerve roots; and the *posterior* column between the posterior nerve roots and the posterior median fissure.

In the cervical region, close to the posterior median fissure, two additional slightly marked clefts can be made out, one on each side, which, with the other minor septa, break up the cord into many tracts or columns, to be described hereafter.

Some authors divide the cord thus:—1. Posterior segment — between the posterior median fissure and the posterior nerve roots. 2. Antero-lateral segment—between the anterior median fissure and the posterior nerve roots. The antero-lateral segment is again divided, by the line along which the anterior nerve roots take origin, into (*a*) an anterior part, between the anterior median fissure and the anterior nerve roots; and (*b*) a lateral part, between the anterior and posterior nerve roots.

II.—SPINAL NERVES.

(Figs. 3, 4, 5, 6, 11, 13.)

Along the sides of the spinal cord arise the thirty-one pairs of spinal nerves—eight cervical, twelve dorsal, five lumbar, five sacral, and one coccygeal—each nerve taking origin by two roots — anterior and posterior—springing from the antero-lateral and postero-lateral grooves respectively. They are each enclosed in sheaths similar to those of the cord itself, and pierce the dura mater by two separate openings, one for each root (figs. 3, 6). Often, however, each root, especially the posterior one, consists of two bundles, which pierce the dura mater by two separate openings. The posterior roots, except in the case of the first nerve, are the larger, and their fasciculi are more numerous and thicker than those of the anterior roots. They moreover, pass through a ganglion, or collection of nerve cells, before they join the anterior roots to form a spinal nerve. The anterior roots are motor, the posterior sensory in function, whereas the spinal nerves themselves are mixed nerves, carrying both motor and sensory impulses. These nerve roots, with the exception of the first or highest, are not attached to the cord opposite the vertebra below which they leave the vertebral canal, but at a higher level. This difference between the points of origin and exit (a matter of considerable clinical importance), though slight in the cervical region, increases as we descend the cord, until at its lower end the nerve roots form an almost vertical bundle, known as the *cauda equina* (fig. 1).

III.—SPINAL VESSELS.

(Plate IV., fig. 15.)

1. **Arteries.**—The arteries on the surface of the spinal cord are the Anterior and Posterior Spinal.

The ANTERIOR SPINAL ARTERY, formed above by the union of two branches, arising one from each vertebral artery, runs along the front of the cord underneath the linea splendens, and is reinforced, as it passes downwards, by a series of anastomotic branches from arteries in the neck and back. It gives off branches to the roots of the spinal nerves, to the anterior median fissure, to the pia mater, and ends below upon the filum terminale.

The POSTERIOR SPINAL ARTERIES two in number, run downwards, one on each side, behind the line of origin of the posterior nerve roots. They are derived from the same source as the anterior, and are joined by small branches which enter the inter-vertebral foramina along the roots of the spinal nerves. They anastomose freely and send offsets into the posterior median fissure.

2. **Veins.**—The spinal veins lie within the dura mater and form a fine and complicated plexus over both aspects of the cord. They pass out with the spinal nerves through the inter-vertebral foramina and open into either the vertebral, intercostal, or lumbar veins, according to the regions in which they occur.

IV.—WHITE AND GREY MATTER OF THE SPINAL CORD.

A transverse section of the spinal cord, such as that represented in the figures, Plate IV., will show you distinctly its subdivision into two lateral halves, and will demonstrate clearly the existence of the white cortex, of the central grey core, and of the twofold commissural band of white matter anteriorly and grey matter posteriorly, connecting together its lateral segments.

THE WHITE MATTER.

Taking up the spinal cord, and examining it with the naked eye, you will see that the white matter forms the outer or cortical part of the cord, and surrounds the grey centre. This white matter is arranged in a series of columns, and gradually increases in amount from below upwards, being specially augmented in the cervical and lumbar enlargements. Compared with the grey matter, it is more abundant in the neck and back, but less so in the loins.

1. White Columns of the Cord, and their Subdivisions.—Your attention, you will remember, has already been called to the fact that the exit and entrance of the nerve roots subdivide each lateral half of the cord into three longitudinal white segments or columns—namely, an ANTERIOR, a LATERAL, and a POSTERIOR; each of which, however, can be again subdivided into smaller tracts or strands, which have received special names (fig. 13, page 18).

To determine by actual dissection the course of the various tracts or strands of fibres which pass along these columns would be impossible. The task, however, has been much simplified by experimental physiology and histology, and by the study of development and of pathology; for "we may learn as much of the course of the fibres by studying them in their birth as in their death—in their development as in their decay." The former teaches us that different tracts or bundles of fibres acquire their white substance — medullary sheath—at different periods of their development (see page 21), so that, in specially prepared specimens, we are enabled to pick out and trace these tracts or systems through successive sections of the cord. On the other hand, the selective action exercised by disease (so analogous to that exercised by certain poisons) affords equally valuable information. For to pathology we are indebted for the knowledge that, when a nerve fibre degenerates in consequence of injury or disease, the proper nerve substance is replaced by connective tissue, which, when treated with certain staining re-agents, behaves differently from the surrounding undegenerated nerves. Moreover, by the special histological methods introduced by Golgi, much light has lately been thrown, not only on the constitution of these columns, but also on their relations to the grey matter; and a new departure in experimental physiology has recently been initiated by Horsley, which not only promises to accomplish, but has already accomplished, most brilliant results.*

* See Horsley's "Method of Testing the Course, etc., of Nerve Fibres by means of Negative Variation."—*Philosophical Transactions of Royal Society of London,*" Vol. CLXXXII. (1891) B, pp. 267-526.

By the above means we can define with more or less certainty nine different tracts or systems in the several white columns of the spinal cord (page 21).

(*a*) **Anterior Column.**—In this column have been mapped out a median and a lateral division. The median division, ANTERO-INTERNAL TRACT—*the direct pyramidal tract, fasciculus of Türck,* is a well-marked bundle of fibres, situated close to the anterior median fissure (fig. 13, page 18). It is, as we shall see hereafter, a continuation of that part of the anterior pyramid of the medulla oblongata which does not decussate in the medulla; hence its name, *direct* pyramidal tract. It extends downwards to the mid-dorsal region, and decreases from above downwards. Its fibres finally cross over at lower levels to the opposite side of the cord, and thence through the grey matter become connected with the opposite anterior nerve roots.

The lateral part of the anterior column, ANTERO-EXTERNAL TRACT, forming by far the larger part of the column, has also been called the *anterior root zone,* or *basis bundle.*

(*b*) **Lateral Column.** — This well-defined tract, marked off on the surface of the cord by the antero-lateral and postero-lateral grooves, and limited internally by the two grey cornua, is composed of four distinct strands of fibres. Thus occupying the posterior part of the column, at a little distance from the surface of the cord, is a bundle of fibres, known as the CROSSED PYRAMIDAL TRACT (fig. 13, crossed pyram.), which, as we shall afterwards see, is continued upwards into the anterior pyramid of the *opposite* side of the medulla oblongata; hence the name, *crossed* pyramidal tract. This tract exists in all regions of the cord. It is a

Fig. 13.

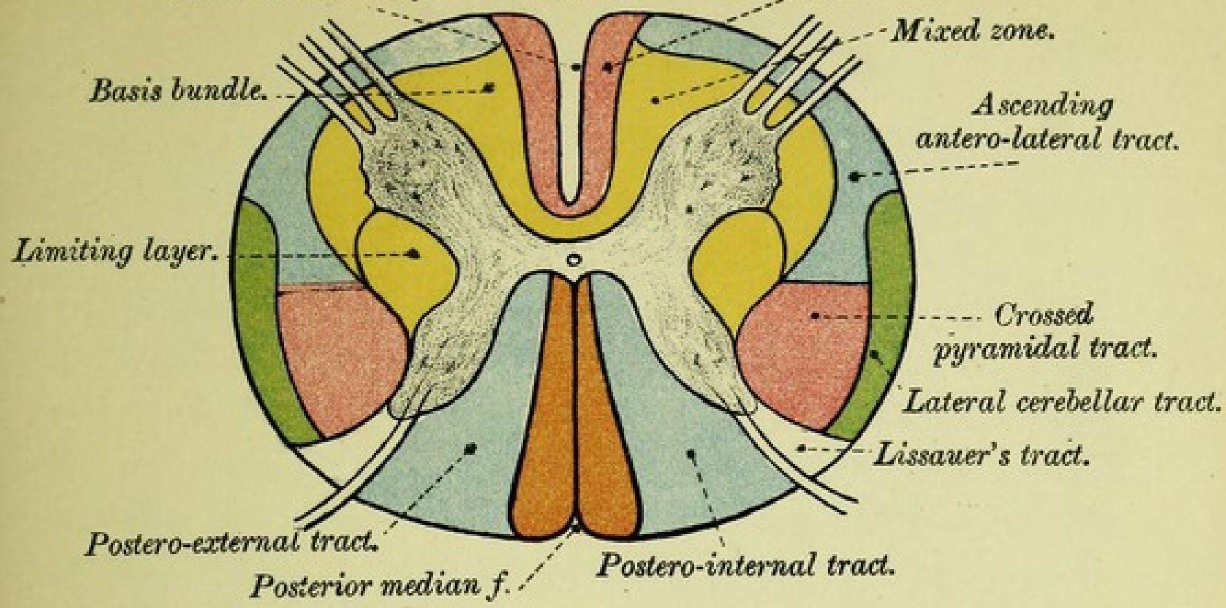


Fig. 14.

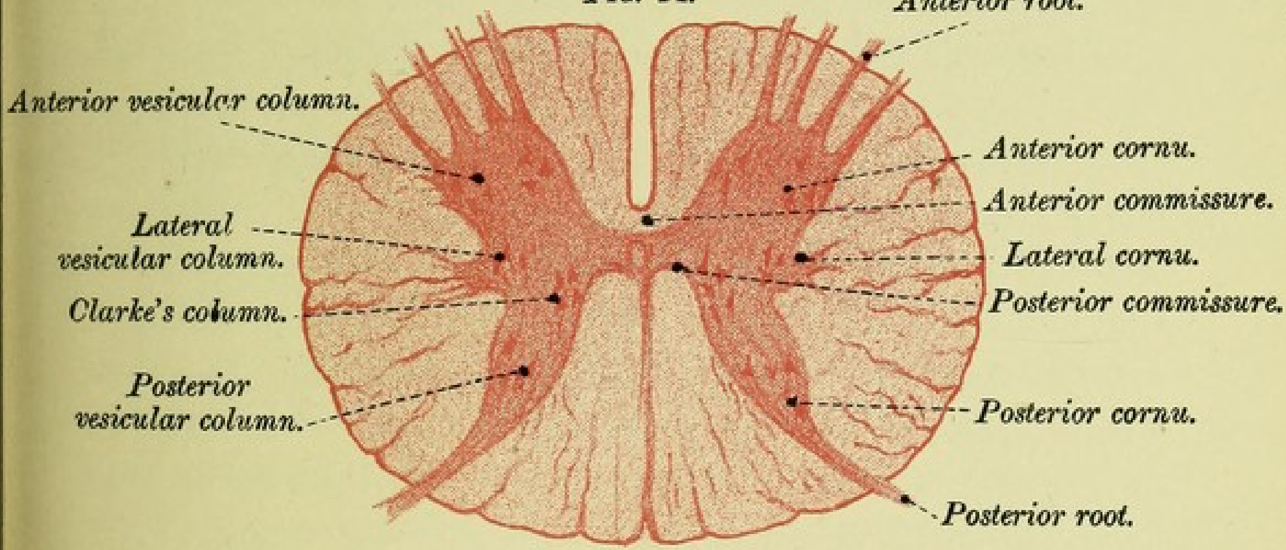


Fig. 15.

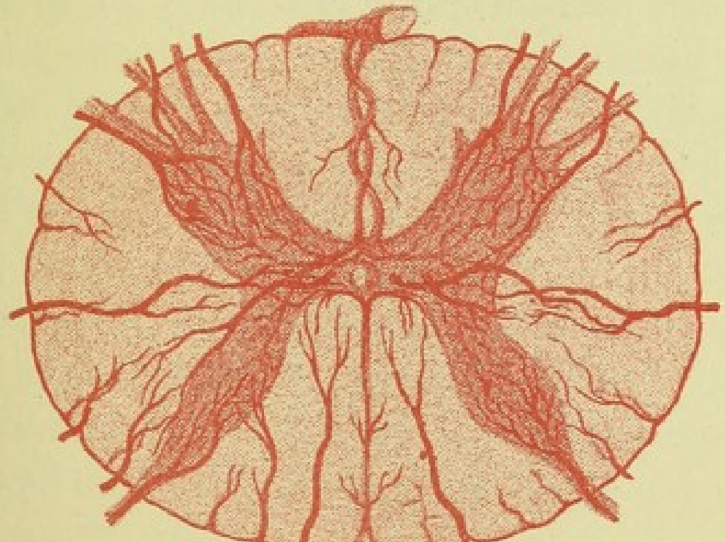


Diagram of thc vessels of the cord.

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motor tract, and decreases in area as we descend the cord; for, it constantly gives off fibres to the grey matter (figs. 23, etc., Plate VI., page 28).

The thin lamina of white matter, which separates this tract (crossed pyramidal) from the surface of the cord, constitutes the DIRECT LATERAL CEREBELLAR TRACT (fig. 13, and Plate VI., figs. 23, etc., direct lat. cereb.), so-called from its connection with the cerebellum on the same side. It is an ascending tract, and extends from the level of the second lumbar nerve upwards to the restiform body. The fibres are probably connected, through the cells of Clarke's column, with the posterior nerve roots.

Then again Hadden and Gowers have been able to define two symmetrical areas, situated one in the anterior part of each lateral column in front of the crossed pyramidal tract (fig. 13). They lie on the surface of the cord and extend into the anterior column nearly as far as the anterior median fissure. They are called by Gowers the *antero-lateral ascending tracts*, or comma tracts—not to be confounded with the ill-defined descending comma tracts sometimes described in the posterior columns. These bundles most likely exist in all regions of the cord, but their lowest limit has not yet been defined. Their fibres come from the opposite posterior roots and, after decussating in the posterior commissure, end above in the lateral nucleus. They are probably a sensory route from the spinal cord to the brain (Gowers).

The rest of the lateral column is called the MIXED ZONE (fig. 13), though it is often divided into two parts, anterior and posterior mixed strands—the latter being also called the "limiting layer" (fig. 13).

(*c*) **Posterior Column.**—The arrangement of the strands in this column somewhat resembles that in the anterior (fig. 13). Thus, especially in the cervical region, we find close to the posterior median fissure a narrow band called the POSTERO-INTERNAL TRACT—*posterior median column, fasciculus of Goll;* and an external division named the POSTERO-EXTERNAL TRACT, *cuneate fasciculus, posterior root zone, fasciculus of Burdach.*

The POSTERO-INTERNAL TRACT, *Goll's tract,* increases from below upwards. It is best seen in the dorsal region. It gets its fibres from the posterior roots of the spinal nerves.

The POSTERO - EXTERNAL STRAND, *fasciculus of Burdach,* also increases as it ascends. Its fibres, like those of the last bundle, are derived from the posterior roots. We shall presently trace them to their ultimate destination.

The distinction between these two parts of the posterior column of the spinal cord is of considerable importance in the pathology of locomotor ataxy;* for in these tracts travel fibres which are closely connected with the muscular sense and with the mechanism of co-ordination of movement.

Another small zone—the *posterior marginal zone*—lies in this column round the tip of the posterior horn. It is called Lissauer's tract (fig. 13), and receives its fibres from the posterior roots. They run for a short distance upwards and downwards in this tract, and then enter the grey matter. (See below "Posterior Roots.")

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* Bristowe, page 1050. Edition, 1890.

Several other minor strands have been described in the different columns of the cord, but are not of sufficient importance to detain us here.

TABLE OF WHITE TRACTS OF THE SPINAL CORD.

(Plate IV., fig. 13, page 18.)

Anterior column	1. *Antero-internal.*—Fasciculus of Türck. Direct pyramidal tract. Uncrossed pyramidal tract. 2. *Antero-external.*—Basis bundle. Anterior root zone. Anterior ground fibres.
Lateral column	1. *Crossed pyramidal tract.* 2. *Direct lateral cerebellar tract.* 3. *Sensory zone*—antero-lateral ascending tract or comma tract (Gowers). 4. *Mixed zone*—anterior mixed; posterior mixed or limiting layer.
Posterior column	1. *Postero-internal.*—Fasciculus of Goll. 2. *Postero-external.*—Fasciculus of Burdach. Posterior root zone. Fasciculus cuneatus. Posterior ground fibres. 3. *Marginal zone*—Lissauer's tract.

TABLE OF THE ORDER IN WHICH THE SEVERAL TRACTS OF WHITE MATTER RECEIVE THEIR MEDULLARY SHEATHS.

1. Anterior and posterior root fibres.
2. Ground fibres of the antero-external column.
3. Ground fibres of the postero-external column.
4. Lateral mixed zone.
5. Limiting layer and antero-lateral ascending tract.
6. Postero-median column.
7. Direct lateral cerebellar tract.
8. Crossed and direct pyramidal tracts. In man these tracts get their medullary sheath for the first time, at birth.

2. **White Commissure.**—The two anterior white columns of opposite sides of the cord are united across the middle line by a band of white fibres, the anterior or white part of the spinal commissure, seen at the bottom of the anterior median fissure (fig. 9, page 12, ant. com.). Its constitution is too complex for an elementary work of this kind. Sufficient to say that it consists (1) of decussating fibres—axis cylinder processes and protoplasmic process of the nerve cells of the anterior horn (see grey matter); (2) of what are known as *collaterals* (decussating collaterals) from different sources; and (3) of *neuroglia* cells and their prolongations (see "Neuroglia").

MINUTE STRUCTURE OF THE WHITE MATTER.—Besides blood-vessels and lymphatics, the white matter of these various columns of the spinal cord consists—(1) Of *medullated* or *white nerve fibres* running for the most part longitudinally, and (2) of a supporting framework of connective tissue called *neuroglia*, which will be fully described under the grey matter. The white nerve fibres themselves are the axis cylinder processes of nerve cells, and have the same structure as peripheral nerves, consisting of a central core or axis cylinder, which in transverse section appears as a dark spot, surrounded by a laminated white (medullary) sheath (fig. 28). Usually, however, neither neurilemma nor nodes of Ranvier can be detected, though some hold that they are both present.

Collaterals.—By Golgi's method, before mentioned, it has been shown—(1) That not only are the white nerve fibres of these various columns of the spinal cord the axis-cylinder processes of nerve cells of the brain,

Plate V.

Fig. 16.

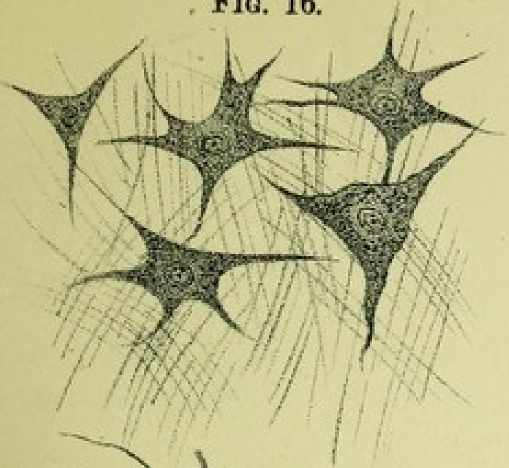
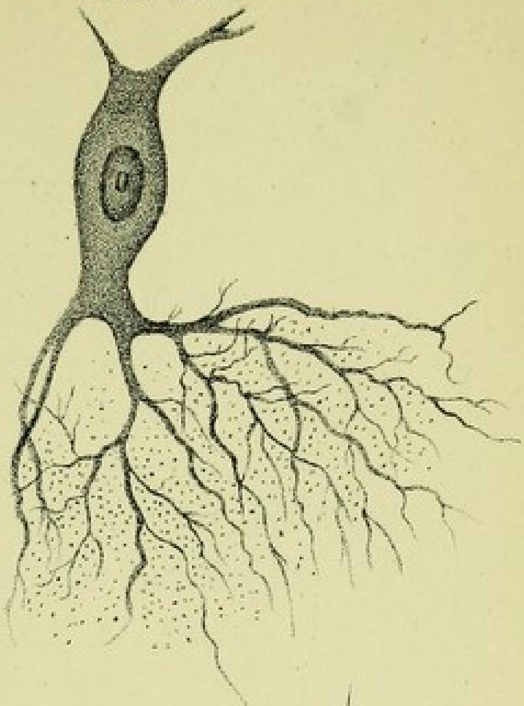


Fig. 17.



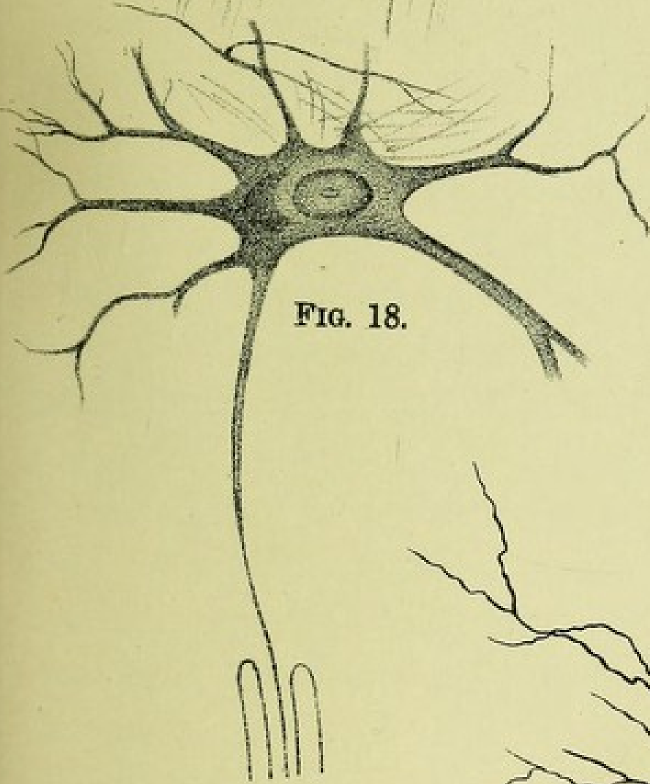
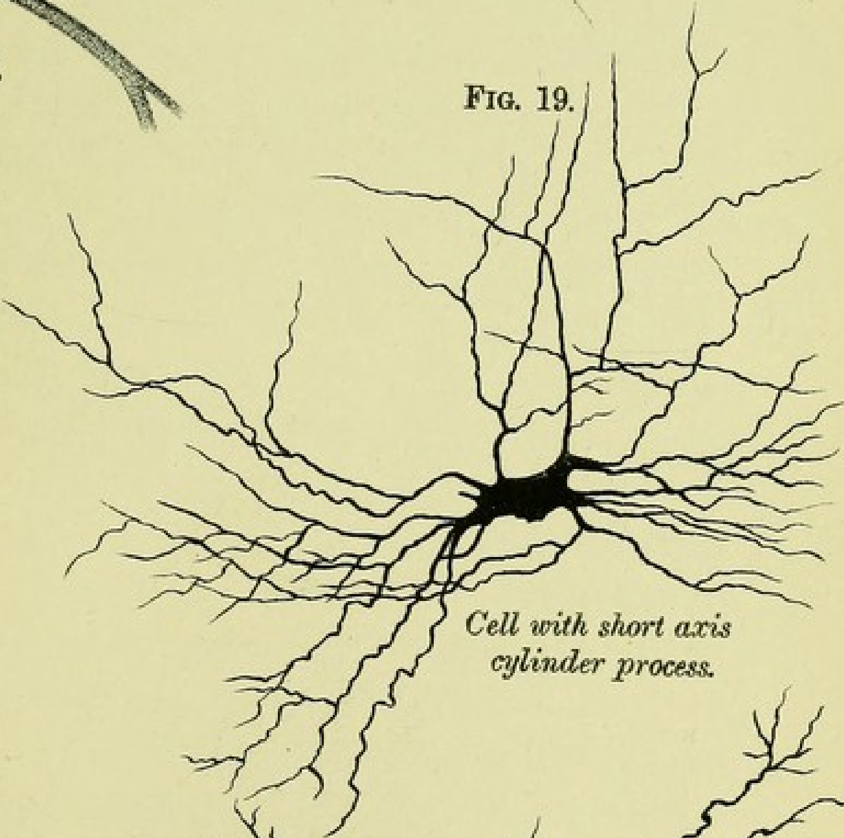


Fig. 18.

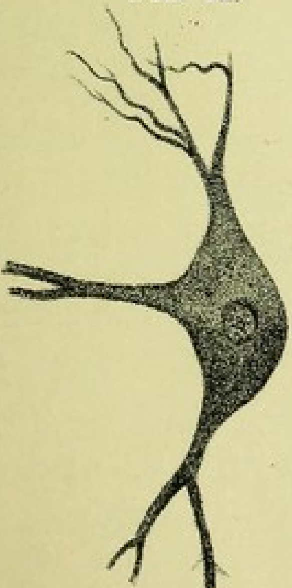
Fig. 19.



Cell with short axis cylinder process.

Fig. 20.

Fig. 21.



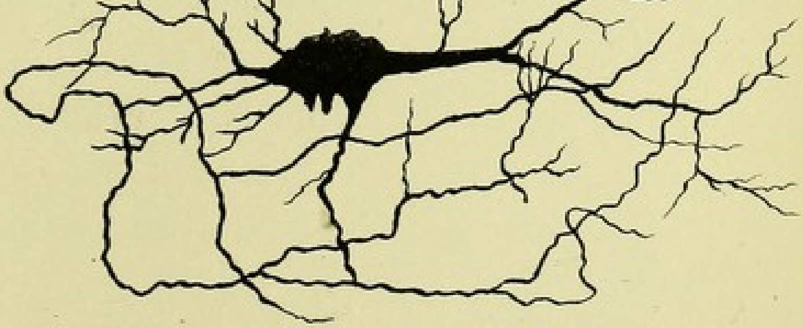


Fig. 22.—*Cell with long axis cylinder process.*

Different Kinds of Nerve Cells.

or of the spinal cord, but also that, in their course along the spinal cord, the fibres turn in at right angles to their direction, and entering the grey matter, there break up into branches which end free. (2) Moreover, by the same method, the important fact has been demonstrated that most of the longitudinal fibres of these columns—anterior, lateral, and posterior—give off at more or less right angles to their course a series of side branches called *collaterals*,* which can be traced to different parts of the grey matter in which they end in *tufts*, or *brushlets*, composed of fine varicose fibrillæ. These brushlets ultimately end in little knots, and do not anastomose with each other, nor with the neighbouring fibrillæ, nor with the processes of nerve cells, but merely form a beautiful plexus around the body of the cells. At the point where the collaterals are given off, the fibres usually have a small triangular-shaped enlargement (fig. 31, page 32). Thus, for example, the fibres of the posterior nerve roots, after entering the posterior columns, or Lissauer's tract, break up into an ascending and a descending branch (fig. 31), which sooner or later enters the grey matter and ends in tufts of small branches. Either before or after they divide, the fibres give off collaterals which end as above described. The same is true of the fibres of the antero-lateral columns, some of which are the axis-cylinder processes of nerve cells of the brain—pyramidal tracts; others, the axis-cylinder processes of the nerve cells of the spinal cord itself.

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* For full account of Collaterals see the able translation and interesting summary of Köllikers' and other papers, by William Aldren Turner, M.B. Edin., M.R.C.P. Lond.—*Journal of Anatomy and Physiology*, Vol. XXV.

THE GREY MATTER.

The grey matter occupies the centre of the cord, and is completely surrounded by the white substance. It forms a double column, extending through the entire length of the cord, and is united across the middle line by a vertical grey band—the posterior or grey part of the spinal commissure. In transverse section, therefore, it presents more or less the appearance of the capital letter **H**, for it is arranged in two irregularly crescent-shaped masses—one in each lateral half of the section (Plate III., page 12). These two grey crescents are united across the middle line by a transverse band of grey matter—the cross-bar of the **H**—which represents the grey or posterior commissure previously mentioned. Each grey crescent is semi-lunar in shape, having its horns or cornua pointing, the one forwards and outwards, the other backwards and outwards; hence they are known as the *anterior* and the *posterior cornua.* The convexity of each grey mass looks inwards towards the middle line, whereas the corresponding concavity is directed outwards.

1. **Cornua.**—The ANTERIOR HORN of each crescent, irregular in outline, is, for the most part, shorter and thicker than the posterior, and arches outwards towards the place of superficial origin of the anterior nerve roots. It does not, however, quite reach the surface of the cord, some white matter being interposed. It can be divided into an enlarged anterior part or head—a narrow part or neck, and a hinder part or base.

The POSTERIOR HORN, on the other hand, is longer, more slender and pointed than the anterior, and almost reaches the surface of the cord at the fissure along which the posterior nerve roots take their superficial origin. Here it tapers to a point, called the *apex* cornu posterioris, which contains a stratum of rather clear-looking connective tissue, known from its gelatinous aspect as the *substantia gelatinosa* of Rolando. Near its base the posterior horn, like the anterior, is somewhat constricted, forming the *cervix* or neck, while the slightly enlarged part between the apex and neck forms the *caput* cornu posterioris.

Now, examine the outer concave side of each crescent slightly behind its centre, and you will find that the grey matter at this part assumes the form of a network, projecting out into the white substance. This network, called the "processus recticularis," is best seen in the cervical region. Immediately in front of this process, and about midway between the anterior and posterior cornua, lies a pointed collection of grey matter—the INTERMEDIO-LATERAL TRACT—lateral vesicular column—which may be regarded as a lateral horn (fig. 14, page 18). Look for it especially in the dorsal region.

If, now, you take a series of transverse sections from the different regions of the cord, and compare them together, you will find that the grey matter is relatively most abundant in the lumbar region, and least so in the cervical. Again, if you notice the relative sizes of the anterior and posterior horns of each grey crescent, you will see that they differ in different regions; for in the cervical region the anterior horn is broad, the posterior narrow; whilst both are narrow in the dorsal, and both broad in the lumbar.

2. **The Grey Commissure** (Plate IV.)—We have already seen that the convex sides of the two crescents are united across the middle line by a band of grey nerve substance, forming the POSTERIOR or GREY part of the COMMISSURE, which connects together the lateral segments of the cord. This band is placed nearer to the anterior than to the posterior ends of the crescents, and consists of cells and transverse nerve fibres—viz., decussating collaterals, decussating axis-cylinder processes, and decussating protoplasmic processes (see below). About its centre may be seen a small opening — the central canal or ventricle of the spinal cord. This canal is the remains of the primitive medullary canal of the embryo, and extends throughout the entire length of the spinal marrow. Above, it expands into the fourth ventricle of the brain, whilst below it enlarges, becomes T-shaped in section (fig. 8), and is said by some to open on the posterior surface of the conus medullaris. It is lined by a layer of columnar cells, which are ciliated in the child, though it is doubtful whether such is the case in the adult.

MINUTE STRUCTURE OF THE GREY MATTER.—To examine the minute structure of the grey matter you will require specially prepared microscopic sections. Such specimens will show you that there are two chief constituents of the grey matter, namely—(1) A ground substance or stroma, called NEUROGLIA (nerve glue); (2) NERVOUS ELEMENTS, nerve cells and nerve fibres—processes of the nerve cells—embedded in this stroma.

1. **Neuroglia** is a delicate and peculiar kind of connective tissue, which pervades both the grey and white substance of the cord. It is epiblastic and not,

like other connective tissues, mesoblastic in origin, and is of especial interest clinically, as being the probable seat of most of the inflammatory processes which affect the central nervous system. It is a fibro-granular material, containing nuclei and is made up of the following distinct elements—(*a*) A homogeneous jelly-like matrix, which in sections, hardened in spirit, becomes somewhat granular; (*b*) a network of fine fibrillæ, called by Klein "neuroglia fibrils," and said by him to be "in some respects similar to, but not identical with, elastic fibres;" (*c*) small branched nucleated cells, known as neuroglia cells; (*d*) certain larger cells which look stellate in section though in reality they are merely applied to the neuroglia fibrils which cross and recross them in every direction. They occupy the intervals between the nerve fibres, and are called the cells of Deiters (Plate VIII.).

The neuroglia is pretty evenly distributed throughout the grey substance, but around the central canal will be found a considerable collection of it, which has been called the central grey nucleus. The substantia gelatinosa of Rolando, previously referred to, was formerly regarded as a similar accumulation of neuroglia, but is now known to contain many nerve cells.

In addition to these accumulations of neuroglia, there is upon the surface of the cord, immediately beneath the pia mater, a layer of this same substance, which sends processes into the various clefts on the surface of the cord.

2. **The Nervous Constituents** of the grey matter are of two kinds—(*a*) Multipolar nerve cells (fig. 16, etc., page 22) of large size, occurring either singly or collected into groups called *vesicular columns*.

(*b*) Non-medullated and medullated nerve fibres, which are either strands of fibres from various sources, or branched and unbranched processes of nerve cells, which traverse the grey matter in all directions.

Vesicular Columns (fig. 14, page 18). The various groups of nerve cells seen in transverse sections of the spinal cord are, you will readily understand, sections of columns of cells, which extend either through the whole length of the grey matter, or only through certain regions of it; hence they are known as vesicular or ganglionic columns. These groups of cells are best marked in the cervical and lumbar regions.

The largest of these groups is that situated in the fore part of the anterior cornu. It can be traced throughout the entire length of the cord, and is known as the ANTERIOR VESICULAR COLUMN—*motor ganglionic column*—though it can be subdivided into two groups—the one anterior or inner, the other lateral (fig. 14, page 18). In the lumbar region an additional posterior group, which lies behind the anterior, makes its appearance.

Since it is to these groups of cells of the anterior cornu that the anterior or motor nerve roots can be traced, the entire collection has been termed the "motor vesicular column." More recently, however, it has been stated that the cells exercise a trophic influence on motor nerves and on the muscles. This conclusion receives support from the fact that, in any injury to the cells of certain regions of the brain cortex, called the *first trophic realm*,* the degeneration of the

* These well-chosen terms we owe to Dr Wyllie, Lecturer on Medicine, School of Medicine, Edinburgh.

FIG. 23.

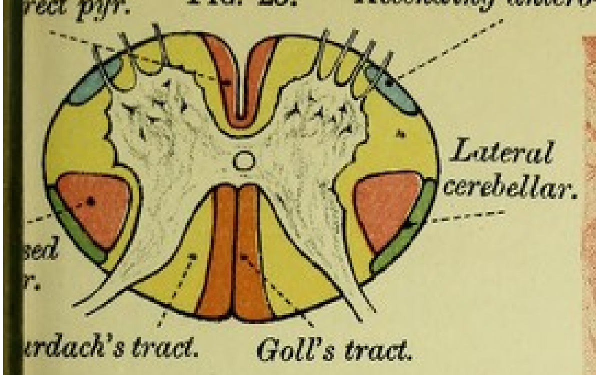
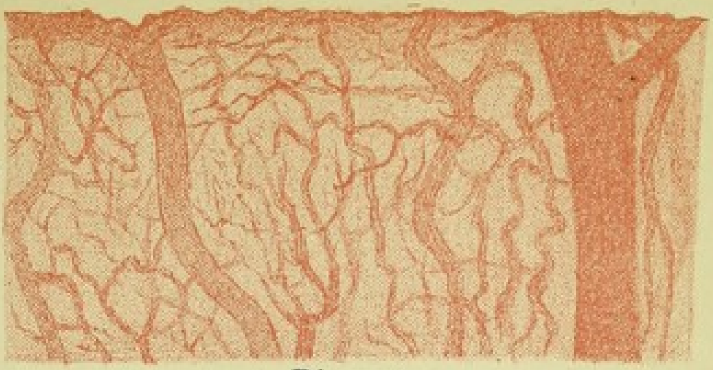


FIG. 27.



Pia mater.

FIG. 24.

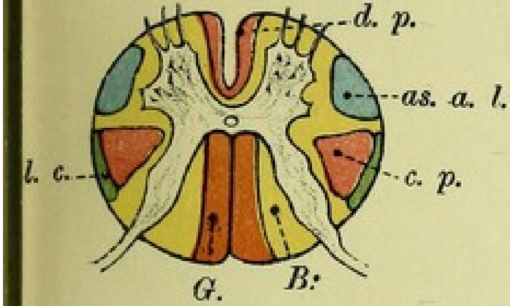
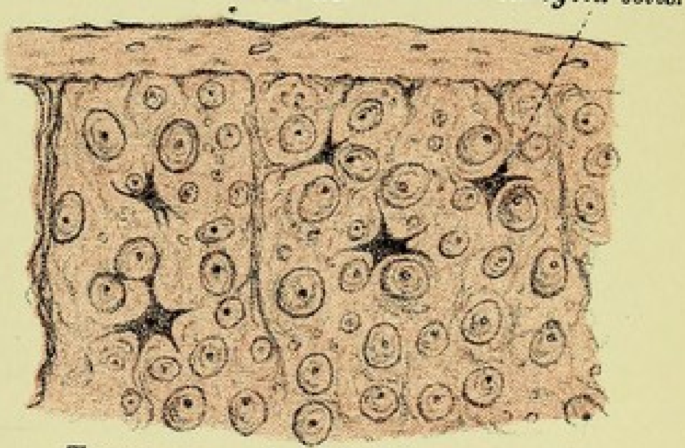


FIG. 28.



Transverse section of white matter of spinal cord.

FIG. 25.

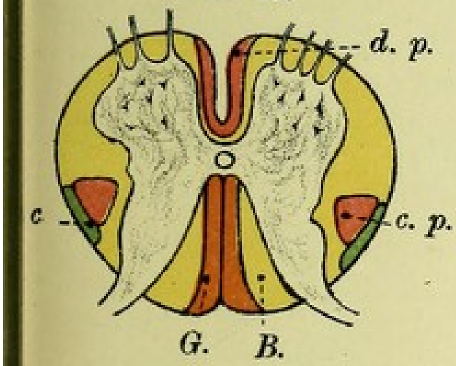
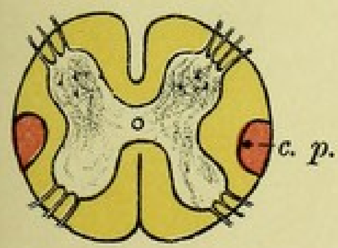


FIG. 29.

Anterior cornu of spinal cord.

FIG. 26.



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muscles which follows is by no means rapid; whereas, if the cells of the anterior vesicular column, *second trophic realm,* be injured, besides paralysis of the nerves, rapid degeneration of the muscles is the result.

The second well-marked group of cells is placed at the base of the posterior horn, near its inner angle. Though it is found only along the middle region of the cord, from the level of the seventh cervical to that of the third lumbar nerve, it probably has representations in all regions of the cord, even as far as the bulb. It is variously known as POSTERIOR VESICULAR COLUMN, *Clarke's column*, *Dorsal nucleus* (fig. 14), and has an intimate connection with the posterior or sensory nerve roots.

A third group of nerve cells—the NUCLEUS OF THE INTERMEDIO-LATERAL TRACT, or *lateral vesicular column*, often called *the lateral horn* (fig. 14), —lies at the root of the posterior cornu on its outer side, within the column of grey matter of the same name, and, like it, can be distinguished in the dorsal region only.

TABLE OF VESICULAR COLUMNS.

(See fig. 14, Plate IV., page 18.)

1. Anterior vesicular column.	Antero-internal group. Antero-external group. Posterior group—found in the lumbar region.
2. Lateral vesicular column.	Lateral horn—found in thoracic and lumbar regions.
3. Posterior vesicular column.	Clarke's column; dorsal nucleus —found in all regions of the cord.

STRUCTURE OF THE NERVE CELLS.—The nerve cells of the grey matter of the spinal cord vary considerably, both in size and in shape. Most of them are stellate or multipolar in transverse section, and give off two sets of processes—

1. *Protoplasmic or grey processes.*—These are a series of delicate ramifying branches which cross and recross each other in all directions.

2. *Axis-cylinder processes* are branched or unbranched processes, which, in many cases, soon acquire a medullary sheath, and become the axis-cylinders of nerve fibres.

The cells themselves have no distinct nucleated sheath, and in this respect differ from those found in the various ganglia throughout the body—*e.g.*, the spinal and sympathetic ganglia which have a fibrous capsule lined by epithelial cells. Each cell, however, has a large, round or oval nucleus, enclosed in a membrane, and contains a network of fibrillæ and one or more nucleoli (Plate V.). The largest cells will be found in the anterior vesicular column, especially in its outer group; and similar ones occur in Clarke's column. The cells of Clarke's column are, moreover, spherical in transverse, but fusiform in longitudinal section; they are said to be bipolar, but are in reality multipolar.

CLASSIFICATION OF THE NERVE CELLS.—The nerve cells of the grey matter may be arranged under two groups—

1. *Cells with short axis-cylinder processes,* in which case the axis-cylinder process soon breaks up into branches which do not become encased in a medullary

sheath, but form a fine plexus of fibrillæ. These are the *sensory type* of cell, and are almost entirely confined in their distribution to the posterior horns (fig. 30.)

2. *Cells with long and distinct axis-cylinder processes,* which do not branch or branch but slightly, and which ultimately becomes clothed with a medullary sheath, and form the axis-cylinder processes of nerve fibres. They are regarded as the *motor type* of cell, and may be subdivided into two groups—

(*a*) *Root Cells,* which occur in the anterior horn. Their axis-cylinder process is continued into the anterior nerve roots; and their protoplasmic processes pass in various directions through the grey matter (fig. 30).

(*b*) *Column Cells* are met with in all parts of the grey matter. They are so-called because their axis-cylinder processes pass into the antero-lateral white columns of the same side, or into those of the opposite side (commissural cells) of the cord. On reaching these columns their axis-cylinder processes either by branching, or by turning at right angles to their course, or by T-shaped junctions, become longitudinal and form part of the constituent fibres of these columns. All these fibres whether ascending or descending give off *collaterals,* as already described, which end free in the grey matter.

Thus we see that our ideas in regard to the constitution of the spinal cord must undergo at least this modification that, whereas formerly the spinal cord was regarded as made up of two distinct elements—nerve fibres and nerve cells,—we must now consider that there is only one nerve element—*the nerve cell*—automatic and independent, with its protoplasmic and axis-cylinder prolongations and other branches. These facts have important bearings on the physiology of the spinal cord.

V.—DEEP ORIGINS OF SPINAL NERVES.

It is exceedingly difficult to arrive at anything like a satisfactory conclusion in regard to the deep origins of the spinal nerves: what follows, therefore, is partially provisional.

The several spinal nerves are, as you already know, mixed nerves—*i.e.*, they contain both motor and sensory fibres. On reaching the spinal cord these two groups of fibres—motor and sensory—separate from each other; the former entering the spinal cord by the anterior roots, the latter passing along the posterior roots.

1. The ANTERIOR NERVE ROOTS—motor roots—taking their superficial origin from the antero-lateral grooves, can be traced inwards through the peripheral white substance to the anterior cornu, which they enter in several bundles. Their fibres may be traced to the groups of nerve cells of the anterior horn (anterior and lateral groups), where each fibre becomes connected with a nerve cell—root cell—and forms its axis-cylinder process.

2. The POSTERIOR NERVE ROOTS—sensory roots—before reaching the spinal cord, pass through the ganglion of the posterior roots in which there are unipolar nerve cells. At a little distance from these cells the pole, or axis-cylinder process of the cell, bifurcates in a T-shaped manner, one limb of the T giving origin to the distal, the other to the central end of a nerve fibre of the posterior root. On entering the spinal cord the fibres at once divide in the marginal zone (Lissauer's tract) into ascending and descending branches, which become constituent fibres of the posterior columns. As they ascend and descend in

FIG. 30.

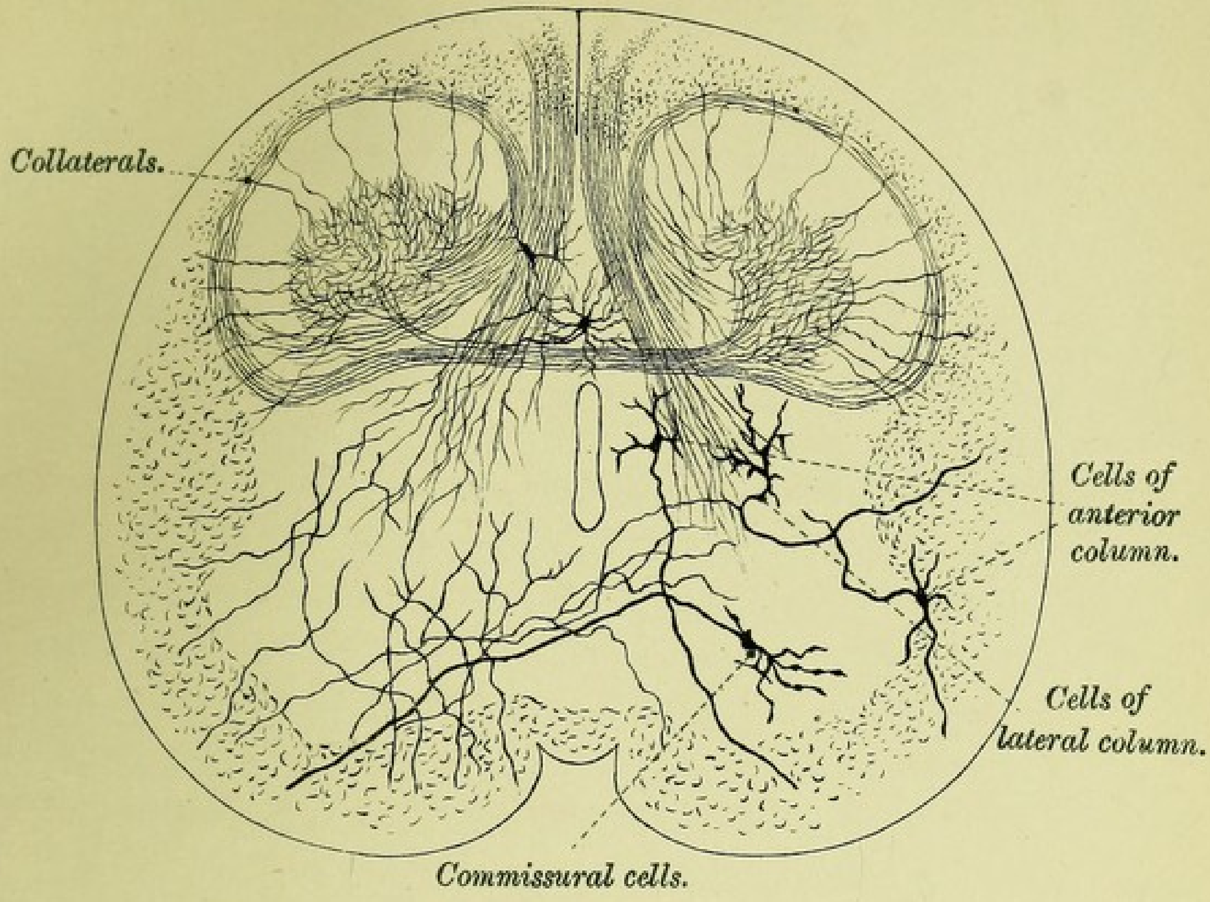


FIG. 31.

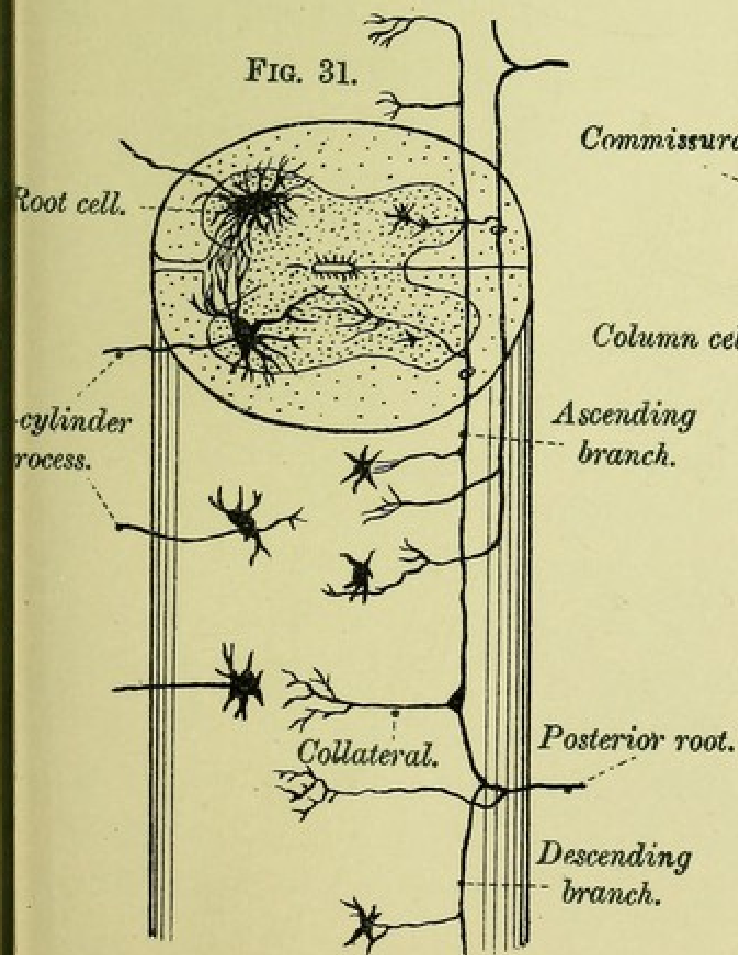
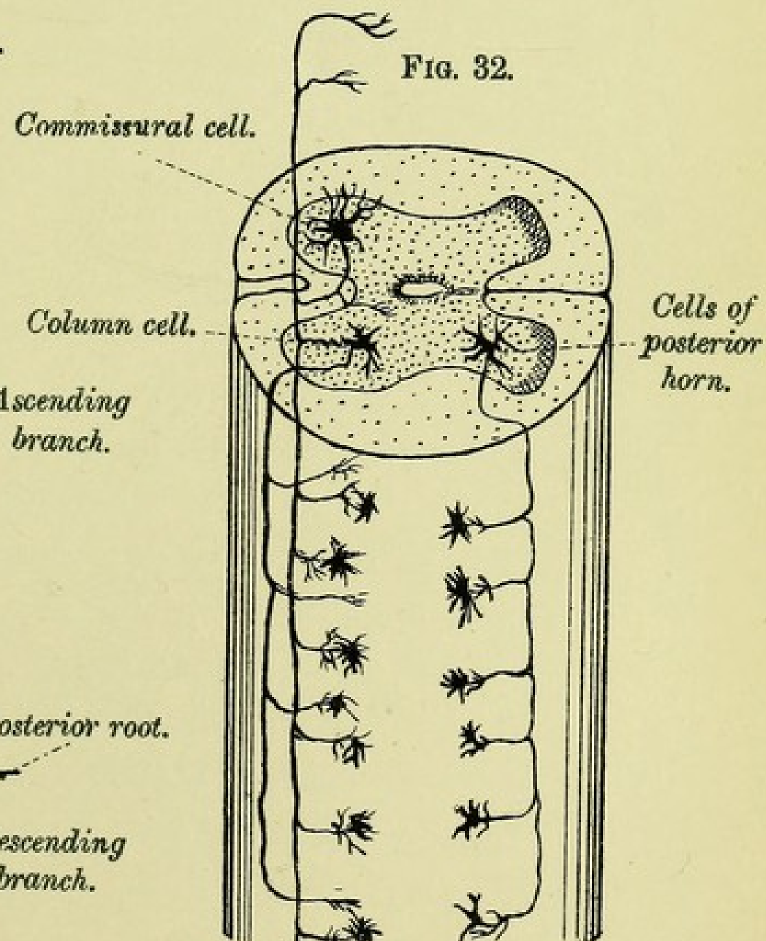


FIG. 32.



these columns the branches give off collaterals (connecting collaterals of Ramón y Cajal), which, as we have already seen, end free in different parts of the grey matter. Of the ascending and descending branches the latter after a variable course turn at right angles into the grey matter and end free in little tufts of branches. The ascending fibres, on the other hand, mostly run a long course, travelling upwards in the posterior columns (Goll and Burdach), to nuclei (nucleus gracilis and nucleus cuneatus) in the medulla; where, as we shall presently see, they cross over to the opposite side in what is known as the *superior pyramidal or sensory decussation.* Some of the ascending fibres probably enter the grey matter of the cord.

But besides these fibres of the posterior roots which are thus connected with the nerve cells of the ganglion, there are others, a few no doubt, which have no such connection, but which merely pass through the ganglion on their way to nerve cells in the spinal cord. On entering the cord these fibres do not, like the last group, divide into ascending and descending branches, but pass at once into the grey matter, and can be followed in various directions, even as far as the anterior horn. The exact mode of connection, however, of the posterior roots with the cells of the posterior horn has not as yet been decided.

Thus we see that the posterior roots take two paths in the spinal cord. The one, a direct path, chiefly in the columns of Goll, thence to nuclei in the medulla. They do not decussate in the cord, but in the medulla. The other is an indirect path through the cells of the posterior horn, thence by some unknown route to the opposite side of the cord.

VI.—FUNCTIONS OF SPINAL CORD.

The chief functions of the spinal cord may be considered under two headings—

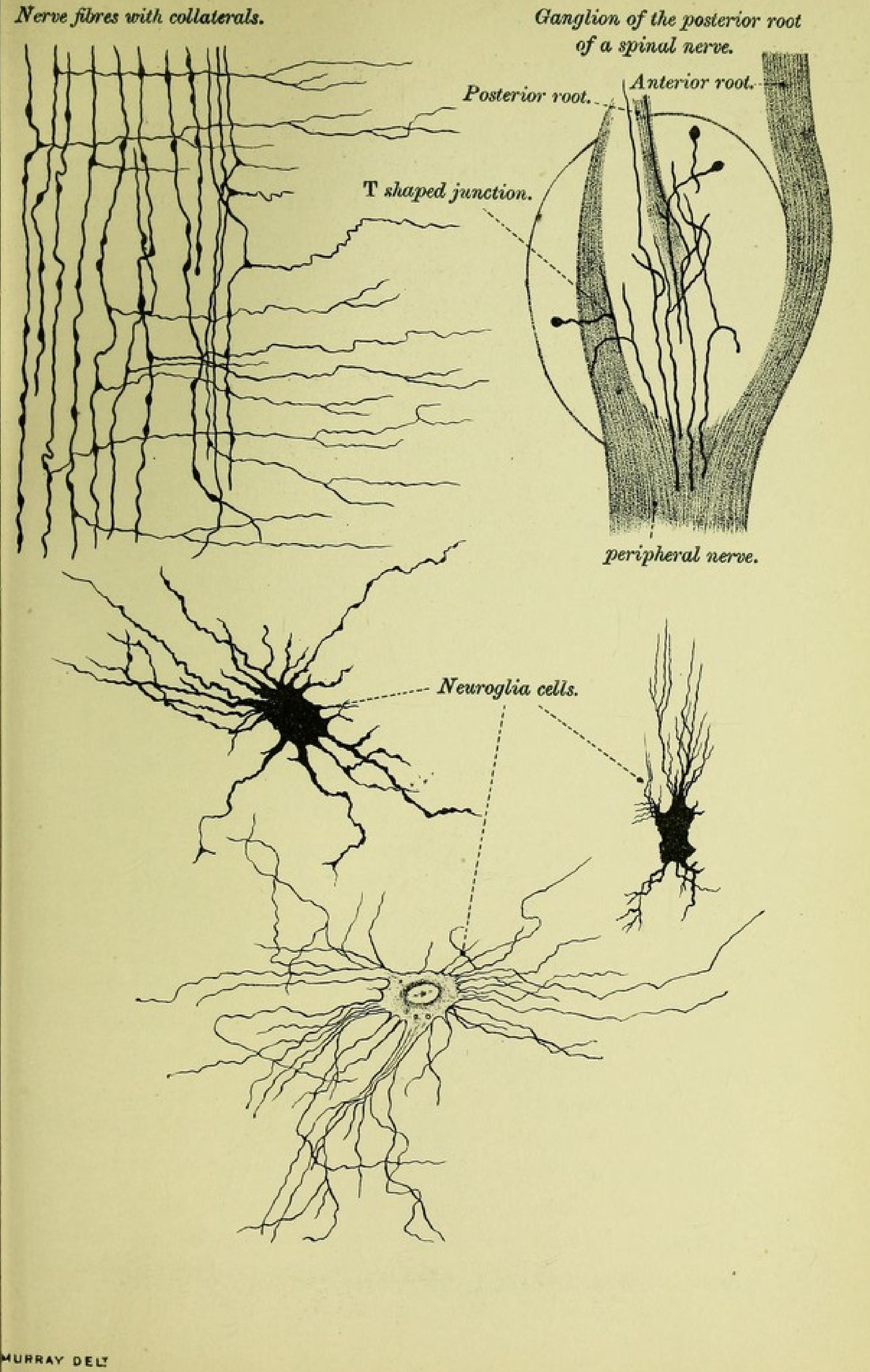
1. Those connected with its nerve fibres—the spinal cord as a conductor.
2. Those connected with its nerve cells—the spinal cord as an independent centre.

It must, however, be remembered that these two sets of functions constantly overlap one another, for although the various kinds of nerve conduction are probably connected with the several white columns of the cord, still the grey matter can transmit impulses in all directions.

I. The Spinal Cord as a Conductor.—Two chief kinds of impulses travel along the white matter—(1) Efferent or Motor, and (2) Afferent or Sensory.

1. Motor Impulses.—These impulses start from the motor areas in the brain and pass down through the pyramidal tracts to the medulla where the greater part of the motor fibres cross over, by the *crossed pyramidal tract,* to the lateral column of the opposite side of the cord. Thence the impulses travel through the cells of the anterior horn, and through the anterior or motor nerve roots to the muscles.

The pyramidal fibres which travel along the anterior column of the same side—*direct pyramidal tract*—also cross over, as you already know, at lower levels of the cord, before becoming associated with the same nerve roots. Hence, in cases where we find total or partial paralysis of the muscles, with increased


Nerve fibres with collaterals.
Ganglion of the posterior root of a spinal nerve.
Anterior root.
Posterior root.
T shaped junction.
peripheral nerve.
Neuroglia cells.
MURRAY DELᵀ

excitability to mechanical stimuli and a tendency to contracture, we can justly conclude that the pyramidal tracts are affected (Edinger).

2. SENSORY IMPULSES.—These include the sense of touch, pain, and temperature, and the sensation known as muscular sense.

(*a*) *Sensations of touch* are conducted along the postero-external strand—fasciculus of Burdach,—and along the postero-internal strand—fasciculus of Goll—of the opposite side.

(*b*) *Sensations of pain*, as well as vaso-motor impulses, most likely travel along the lateral columns—lateral limiting layer—of the opposite side to that at which they enter the cord, though their exact course has not yet been worked out. Some hold that sensations of pain pass through the grey matter.

(*c*) The paths taken by the *sensations of temperature*—heat and cold—are as yet unknown.

Motor impulses, therefore, travel along the same side of the cord; sensory impulses along the opposite side to that at which they enter. For unilateral lesions of the spinal cord cause, in a great measure, loss of sensation of all kinds—touch, pain, and temperature—on the opposite side of the body; but loss of motion, rise of temperature, and increased sensibility, on the same side.

In the present state of our knowledge, however, these statements must be taken as only partially true, for Horsley has recently shown that the tracts of sensation are probably through—(1) the posterior columns of the same side; (2) the posterior columns of the opposite side; (3) the lateral columns of the same side; (4) the lateral columns of the opposite side.

(*d*) *Muscular Sense.*—The sense of effort is closely connected with the postero-internal and postero-external strands, and probably also with the antero-lateral ascending column; for in the disease known as locomotor ataxy, the columns of Goll and Burdach are the ones chiefly affected. In this disease the muscular sense always suffers, though the cutaneous sensibility often escapes and motor power is not lost. Hence the disorders of locomotion — loss of co-ordination and equilibrium,—the lancinating and lightning pains, so characteristic of this disease, are probably connected with affections of the muscular sense not with those of cutaneous sensibility.

Again, a further proof that the columns of Goll and Burdach conduct sensory impulses from the muscles, is furnished by the fact that in whales, where the extremities are not developed, these columns—Goll and Burdach—are rudimentary in comparison to what they are in animals with well-developed limbs.

Functions of the Various Tracts.

1. *Direct and pyramidal tracts* are motor tracts.

2. *Antero-lateral ascending tracts* are crossed tracts of sensation. Their precise relations are not yet understood, many holding that they are outlying parts of the lateral cerebellar tracts.

3. *Lateral cerebellar tracts.*—The exact functions of these tracts are as yet unknown, though they are usually said to be associated with equilibrium. They are, however, sensory tracts, and are probably connected, through Clarke's column, and through the posterior nerve roots, with visceral sensations and sensations from tendons and other parts (see page 40).

4. *Goll's tract.*—The fibres of this tract are, as we have before stated, direct tracts between the muscles and the brain. They do not deccusate in the cord, and probably do not join its grey matter but pass directly to the grey nuclei in the medulla—their first primary station (trophic centres). Their fibres, however, cross over to the opposite side in the medulla, in what we have come to know as the crossed sensory or *superior pyramidal decussation.*

5. The *basis bundle* of the anterior column, the *mixed strands* of the lateral columns, and some of the *fibres of Burdach's strand* are short commissural or internuncial fibres between the different segments of the cord.

Injuries to the posterior nerve roots cause loss of sensation of all kinds, and also of those reflexes which are set in motion by the sensory tracts, as well as the so-called "tendon reflexes" which do not depend upon sensation.

The following Table will show you the various tracts which undergo what is known as *ascending and descending degenerations*—those undergoing ascending degeneration being regarded as strands which probably conduct impulses towards the brain; those undergoing descending degeneration as carrying impulses from the brain. We must, however, remember that because a tract degenerates in a particular direction it does not of necessity follow that it must conduct in that direction only, for as we have seen the fibres of the posterior roots, on entering the spinal cord, break up into ascending and descending branches and must therefore be able to conduct impulses in both directions.

TABLE OF ASCENDING AND DESCENDING DEGENERATIONS.

I.—LONG TRACTS OF CONDUCTION TO AND FROM THE BRAIN.

Tracts which undergo Ascending Degeneration	1. Lateral cerebellar tract, from visceral tract. 2. Postero-internal strand, Goll's tract, from posterior roots. 3. Antero-lateral ascending tract of Gower's, from crossed sensory roots.
Tracts which undergo Descending Degeneration	1. Crossed pyramidal tract, the chief motor tract, contains 90 per cent. of the motor fibres. It is often called the lateral pyramidal tract. 2. Direct pyramidal tract, fasciculus of Türck, usually contains only about 10 per cent. of the motor fibres.

II.—SHORT COMMISSURAL TRACTS.

These neither undergo ascending nor descending degeneration, or at least for no great distance, and are therefore considered to be commissural fibres between different segments of the cord.

1. The postero-external strand—fasciculus of Burdach.
2. Antero-external column—anterior root zone.
3. Part of the lateral column—lateral limiting layer.
4. Lissauer's tract—marginal zone.

II. Spinal Cord as an Independent Centre.—The various centres in the spinal cord are closely connected with the grey matter, and are as follows:—

1. Cilio-spinal centre, in the lower cervical and upper dorsal region.

2. Automatic and reflex centres (see Table, page 42), such as centres presiding over—

(1) The tone of muscles.

(2) Walls of blood-vessels—vaso-motor.

(3) Production of heat.

(4) Nutrition of tissues—trophic centres to muscles, nerves, bones, joints (Charcot's disease).

(5) Secretion of skin—sweat centres.

3. Centre for the co-ordination of muscular movements.

4. Inhibitory centres; for just as the higher centres in the brain can inhibit the centres in the spinal cord, so the higher centres in the cord can influence the lower segments.

5. Centres connected with—
    (1) Micturition.
    (2) Erection of the penis.
    (3) Parturition.
    (4) Defæcation.

In man these centres probably reside in the lumbar enlargement.

Functions of the Various Groups of Nerve Cells.

1. *Cells of the Anterior Horn.*—These are both motor and trophic. The trophic influence of the cells of the anterior horn is well seen in cases of infantile paralysis, in which, owing to damage to these cells, there is rapid wasting of the muscles as well as loss of motion. In lesions above these cells, *i.e.*, between the brain and the anterior horn—though we get paralysis, there is at first no wasting of the muscles.*

2. *Cells of the Posterior Horn.*—The functions of the grey matter of the posterior horn are not sufficiently known. Damage to them causes sensory and trophic disturbances of the skin. It is quite evident, however, that near the base of the anterior and posterior horns there are centres connected with the blood-vessels and with the innervation of the skin.

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* Wyllie's "First and Second Trophic Realms," page 28.

3. *The Cells of Clarke's Column* are probably connected through the lateral cerebellar tract with the cerebellum, and through the posterior roots carry visceral sensation.

Gaskell has suggested that each spinal segment has two sets of nerve roots:—

1. A SOMATIC SET.—The motor and sensory nerves usually described—(*a*) the former, the MOTOR, being *aganlionic* and connected with the cells of the anterior horn; and (*b*) the latter the SENSORY, being *ganglionic* and connected with the cells of the posterior horn.

2. The other set of nerve roots—the SPLANCHNIC SET or visceral set—are distributed to blood-vessels, to the heart, and to other hollow viscera. They, too, consist of two groups—

(*a*) A *ganglionic set,* connected with the cells of Clarke's column—their ganglia being the lateral ganglia of the sympathetic trunk; and

(*b*) An *aganglionic* set, connected with the cells of the lateral horn.

These visceral set of nerves are, moreover, according to Gaskell, divisible into two groups with different functions—

(1) The *motor group* pass to the lateral ganglia of the sympathetic, thence to the walls of blood-vessels and viscera. When stimulated, they cause contraction of blood-vessels and viscera, and give rise to increased activity and increased waste.

(2) The *inhibitory group,* on the other hand, do not pass to the ganglia of the sympathetic but run on as medullated nerve fibres to ganglia situated in the tissues themselves. Stimulation of this set causes dilation of the vessels and various inhibitory phenomena—such as cardio-inhibition. They diminish activity and tend to promote repair.

Processes of Nerve Cells.—Of the processes of nerve cells, only the axis-cylinder process is in direct relation to a nerve fibre. This axis-cylinder process is connected to the nerve fibres either directly, as seen in the motor type of cell, or indirectly, through a plexus of nerve fibrillæ, as seen in the sensory type. The other processes—*i.e.*, protoplasmic processes—probably subserve the nutrition of nerve elements through their relations to the neurolgia cells and to the blood-vessels. These processes are neither continuous with nor do they anastomose with nerve fibres or with other nerve cells, but are in contact only with the nerve elements. Hence, it follows that contact, and not actual continuity, of nerve cells, nerve fibres, and nerve processes is sufficient for the conduction of motor, sensory, and reflex impulses along the spinal cord.

SUMMARY.

To sum up, then, we have the cord presented to us as an elongated mass of nervous substance, consisting of white and grey matter; invested by three membranes; having two distinct enlargements; giving origin to thirty-one pairs of spinal nerves; nourished by spinal vessels, and divided by anterior and posterior fissures into two lateral segments, each with three subdivisions which can be mapped out into numerous tracts, or systems of varying significance.

The following Tables will be found useful for reference.

STARR'S TABLE.

LOCALISATION OF FUNCTION IN THE DIFFERENT SEGMENTS OF THE SPINAL CORD.

Segment.	Muscles.	Reflexes.	Sensation.
Cervical—2nd and 3rd.	Sterno mastoid. Trapezius. Scaleni and neck. Diaphragm.	Hypochondrium (?). Sudden inspiration produced by sudden pressure beneath lower border of ribs.	Back of head to vertex. Neck.
4th.	Diaphragm. Deltoid. Biceps. Coraco-brachialis. Supinator longus. Rhomboid. Supra-spinatus and infra-spinatus.	*Pupil.* 4th to 7th cervical. Dilatation of the pupil produced by irritation of neck.	Neck. Upper shoulder. Outer arm.
5th.	Deltoid. Biceps. Coraco-brachialis. Brachialis anticus. Supinator longus. Supinator brevis. Deep muscles of the shoulder-blade. Rhomboid. Teres minor. Pectoralis (clav. part). Serratus magnus.	*Scapular.* 5th cervical to 1st dorsal. Irritation of skin over the scapular produces contraction of the scapular muscles Supinator longus. Tapping its tendon in the wrist produces flexion of forearm.	Back of shoulder and arm. Outer side of arm and forearm. Anterior upper two-thirds of arm.
6th.	Biceps. Brachialis anticus. Pectoralis (clav. part). Serratus magnus. Triceps. Extensors of wrist and fingers. Pronators.	Triceps. 5th to 6th cervical. Tapping elbow-tendon produces extension of forearm. Posterior wrist. 6th to 8th cervical. Tapping tendons causes extension of hand.	Outer side of arm and forearm. Inside and front of forearm.
7th.	Triceps (long head) Extensors of wrist and fingers. Pronators of wrist. Flexors of wrist. Subscapular. Pectoralis (costal part). Latissimus dorsi. Teres major.	Anterior wrist. 7th to 8th cervical. Tapping anterior tendon causes flexion of wrist. Palmar. 7th cervical to 1st dorsal. Stroking palm causes closure of fingers.	Inner and back of arm and forearm. Radial distribution in the hand.
8th.	Flexors of wrist and fingers. Intrinsic muscles of hand.		Forearm and hand; median and ulnar areas.

SEGMENT.	MUSCLES.	REFLEXES.	SENSATION.
Dorsal—1st.	Extensors of thumb. Intrinsic hand-muscles. Thenar and hypothenar eminences.		Ulnar distribution to hand.
2nd and 12th.	Muscles of back and abdomen. Erectores spinæ.	*Epigastric.* 4th to 7th dorsal. Tickling mammary region causes retraction of the epigastrium. *Abdominal.* 7th to 11th dorsal. Stroking side of abdomen causes retraction of belly.	Skin of chest and abdomen, in bands running around and downward corresponding to spinal nerves. Upper gluteal region.
Lumbar—1st.	Ilio-psoas. Sartorius.	*Cremasteric.* 1st to 3rd lumbar. Stroking inner thigh causes retraction of scrotum.	Skin over groin and front of scrotum.
2nd.	Ilio-psoas. Sartorius. Flexors of knee (Remak). Quadriceps femoris.	*Patella tendon.** Striking tendon causes extension of leg.	Outer side of thigh.
3rd.	Quadriceps femoris. Inner rotators of thigh. Adductors of thigh.	*Bladder centre.* 2nd to 4th lumbar.	Front of thigh.
4th.	Abductors of thigh. Abductors of thigh. Flexors of knee (Ferrier). Tibialis anticus. Peroneus longus.	*Rectal centre.* 4th lumbar to 2nd sacral. Gluteal. 4th to 5th lumbar. Stroking the buttock causes dimpling in fold of buttock.	Inner side of thigh and leg to ankle. Inner side of foot.
5th.	Outward rotators of thigh. Flexors of knee (Ferrier) Flexors of ankle. Peronei. Extensors of toes.	*Achillis tendon.* Over-extension causes rapid flexion of ankle, called *ankle-clonus.*	Lower gluteal region back of thigh. Leg and foot, outer part.
Sacral—1st and 2nd.	Flexors of ankle. Long flexor of toes. Intrinsic muscles of foot.	*Plantar.* Tickling sole of foot causes flexion of toes and retraction of leg.	Leg and foot except inner side. Perineum and back of scrotum. Anus.

* Depends upon the branches to the vastus internus and sub-crureus (Sherington).

GOWERS' TABLE

SHOWING THE APPROXIMATE RELATION TO THE SPINAL NERVES OF THE VARIOUS MOTOR, SENSORY, AND REFLEX FUNCTIONS OF THE SPINAL CORD.

MOTOR.	(Nerves.	MOTOR.		SENSORY.		REFLEX.
	C 1	Small rotators of head	1	Scalp	1	
St.-mastoid, Upper neck muscles, Upper part of Trapezius	2	Depressors of hyoid	2		2	
	3	Lev. ang. scapulæ	3	Neck and upper part of chest	3	
	4	Diaphragm (Shoulder muscles)	4	Shoulder	4	
	5	Serratus; Flex. of elbow; Supinators (Shoulder muscles)	5		5	Scapular
Lower neck muscles, Middle part of Trapezius	6	Ext. wrist and fingers	6	Arm, outer side; Radial side, fore-arm and hand; thumb	6	
	7	Ext. elbow; Flex. wrist and fingers; Pronators	7		7	
	8	Muscles of hand	8	Arm, inner side ulnar side of forearm and hand; tips of fingers	8	
	D 1		1		1	
Lower part of Trapezius and dorsal muscles	2	Intercostals	2	Front of thorax	2	
	3		3		3	
	4		4		4	Epigastric
	5		5		5	
	6		6	Ensiform area	6	
	7	Abdominal muscles	7		7	
	8		8	Abdomen (Umbilicus 10th)	8	Abdominal
	9		9		9	
	10		10		10	
	11		11	Buttock, upper part	11	
	12		12		12	
	L 1		1	Groin and Scrotum (front)	1	Cremasteric
	2	Cremaster; Flexors of hip	2	Thigh: outer side, front, inner side	2	
Lumbar muscles	3	Extensors of knee; Adductors of hip	3		3	*Knee-jerk*
Peroneus, l. Flex. of ankle, Ext. of ankle	4	Ext. and abduct. of hip	4		4	Gluteal
	5	Flexors of knee	5	Leg, inner side	5	
	S 1	Intrinsic muscles of foot	1	Buttock, lower part; Back of thigh; Leg & foot except inner part	1	*Foot-clonus*
	2		2		2	Plantar
	3	Perineal and anal muscles	3	Perinæum and anus	3	
	4		4		4	
	5		5	Skin from coccyx to anus.	5	
	Co.		co		co	

Section 2.

THE BRAIN AND ITS MEMBRANES.

UNDER the term BRAIN or ENCEPHALON is included all that part of the great central nervous system which is enclosed within the cavity of the cranium. Invested by three membranes or meninges it presents, as you will afterwards see, three distinct subdivisions:—(1) The CEREBRUM, a large convoluted mass, or big brain; (2) the CEREBELLUM or little brain, with the PONS VAROLII, a white transverse band uniting the two halves of the little brain; and (3) the MEDULLA OBLONGATA, the enlarged upper end of the spinal cord.

From a developmental point of view, the brain is divided into six parts, the fore-brain, tween-brain, mid-brain, hind-brain, and after-brain. (For the description and subdivisions of these, see "Development.")

We shall describe—(1) The membranes of the brain, and (2) the parts of the brain; but before doing so, we shall give seriatim the following Dissections:—

DISSECTION.—1. *To Expose the Membranes of the Brain*—Make an incision along the middle line through the entire thickness of the scalp, from the root of the nose in front to the external occipital protuberance behind. Turn back the pericranium to the level of the ears, and then saw through the outer table of the skull-cap along a line passing round the skull, about half-an-inch above the external occipital protuberance behind, and about the same distance above the supra-orbital arch in front. Break through the inner table with the chisel and forcibly raise the detached skull-cap, which you will find more or less adherent to the subjacent membrane, especially along the lines of the cranial sutures. Branches of the meningeal arteries will be seen ramifying on the outer surface of the exposed membrane, between it and the bone.

2. *To Remove the Brain*—With a sharp pair of scissors cut through the dura mater at the same level at which you have sawn the bones, and reflect it upwards towards the top of the head. Examine as far as you can the strong process, *falx major*, passing down mesially between the halves of the cerebral hemispheres. Divide this process in front where it is attached to the crista galli of the ethmoid, and cut through the veins which enter the sinus contained within its upper border. Raising the falx out of the longitudinal fissure, turn it back, but do not cut it behind. Now pass the fingers of the left hand beneath the fore-part of the brain, and gently raise it from the anterior cranial fossæ, taking care to detach the small white rounded bands, OLFACTORY LOBES, 1st pair of nerves, from the cribriform plate of the ethmoid. The OPTIC NERVES, 2nd pair, and the two INTERNAL CAROTIDS will now be seen close to the anterior clinoid processes, and should be divided. Piercing the dura mater, external to the carotid, are the round 3rd NERVES; and in the free margin of the tentorium cerebelli, now exposed, are seen the slender 4th NERVES. Cut through these, and through the INFUNDIBULUM which passes down towards the sella turcica of the sphenoid. Then with the point of the knife make an incision through the margin of the tentorium on each side, just behind and parallel to the upper margin of the petrous part of the temporal bone, carrying the incision as far back

FIG. 33. **Plate IX.**

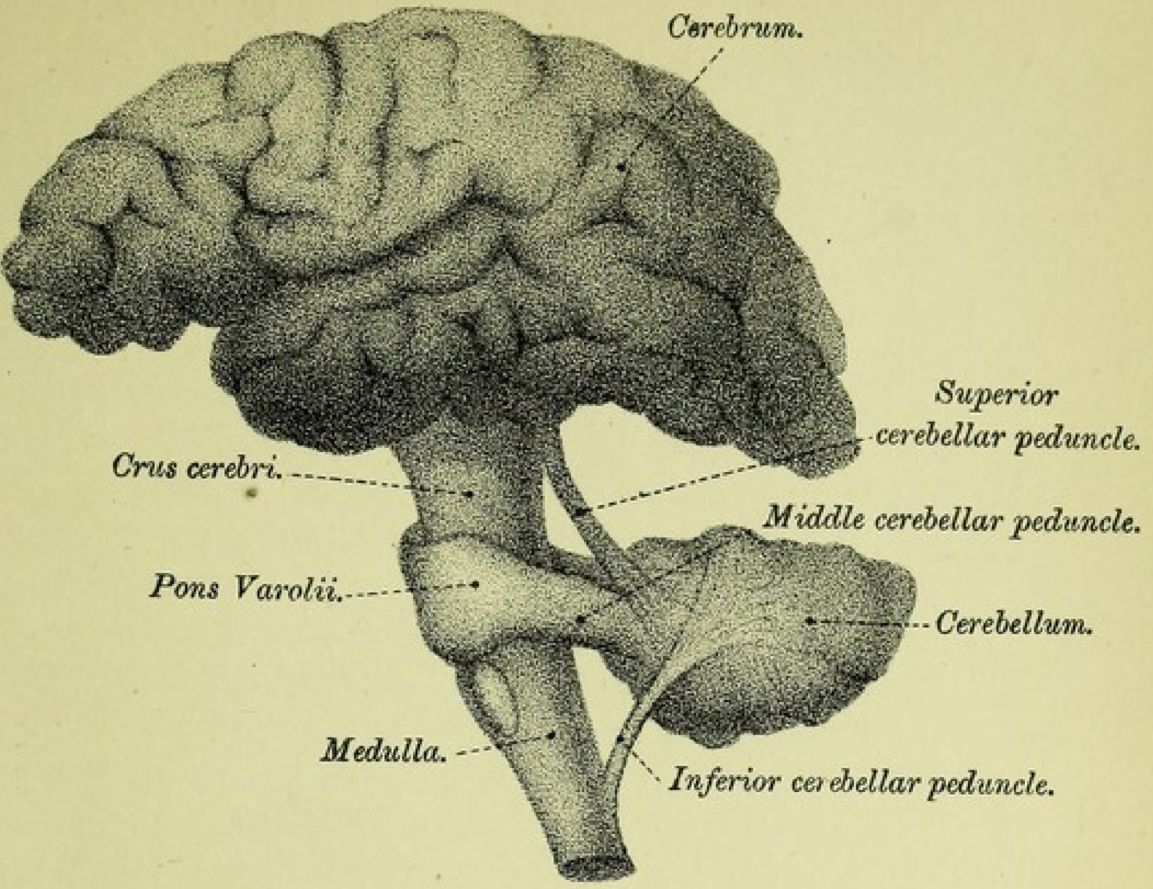
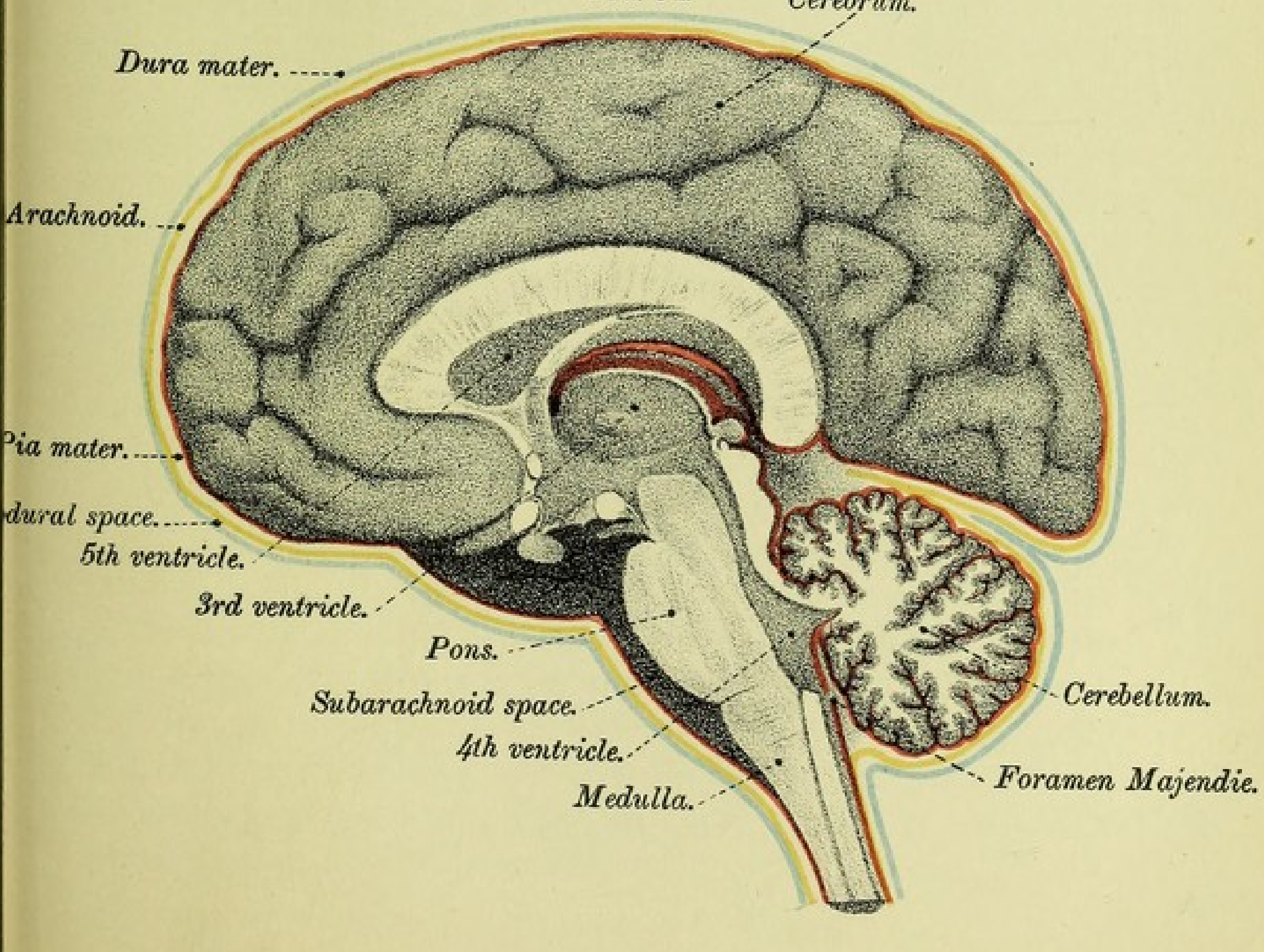


FIG. 34.



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as necessary, but being careful not to injure the parts beneath. You will now see the following nerves, which will require to be divided one after another. Just below the anterior end of the tentorium will be found the large 5th NERVES; nearer the middle line, the slender 6th NERVES; below and external to the 5th, the FACIAL and AUDITORY parts of the 7th nerve, and the auditory artery; immediately below the 7th, the THREE DIVISIONS of the 8th NERVE. Cut the *glosso-pharyngeal* and the *vagus*, but leave intact the spinal part of the *spinal accessory* nerve; lower down near the middle line is the 9th or HYPO-GLOSSAL NERVE, consisting of two bundles which pierce the dura mater by two separate openings. Next pass the knife as far down the spinal canal as possible, and divide the spinal cord, the nerve roots attached to its sides, and the vertebral arteries as they wind round from the back. Tear through the veins of Galen, and the entire brain can now be easily removed from its bed, and should be at once placed in spirit. Leave it there for a few days; then examine it, and carefully remove the pia mater, except at the back between the cerebrum and cerebellum, in order not to disturb the velum interpositum, which we shall afterwards see is a process of pia mater, which passes into the ventricles of the brain at this point.

CHAPTER I.

MEMBRANES OF THE BRAIN.

To examine the cranial dura mater, replace, as far as you can, the falx major and the tentorium cerebelli, and fasten them in their places by a few stitches. It will, however, be far more satisfactory for you if you can obtain a specimen specially prepared to show the arrangement of the dura mater.

I.—THE DURA MATER.

THE **Cranial Dura Mater** is a dense white fibro-serous membrane, rough externally, but smooth and polished within. It is lined by a layer of endothelial cells similar to that which lines the spinal dura mater. Composed of two layers—an inner, which sends processes between the parts of the brain, and an outer, which forms the endosteum of the inner table of the cranium—it adheres to the bones of the skull, especially along the lines of the cranial sutures and at the base of the cranium. This latter fact accounts for the rare occurrence of accumulations of pus or blood at the base of the brain. The dura mater, moreover, sends a process along the several cranial nerves as they leave the skull through their various foramina; part of this process forms a sheath to the nerve, part of it becomes attached to the pericranium. It also passes into the orbital cavities, and there blends with the periosteum. At the lower margin of the foramen magnum it is closely attached to the bones, and becomes continuous with the spinal dura mater. Along certain lines, the two layers of which the cranial dura mater is composed, separate from each other, leaving variously shaped channels called VENOUS SINUSES, for the passage of the blood from the brain into the venous system.

Of the partitions given off from its inner layer, two —the FALX CEREBRI and the FALX CEREBELLI,—are vertical; the third, the TENTORIUM CEREBELLI, is usually said to be horizontal, though it is far more vertical than horizontal, for it slopes downwards and backwards.

1. **The Falx Cerebri**—so called from its sickle-shaped form (fig. 37, page 56)—is the vertical process of dura mater which is lodged in the great longitudinal fissure, and which separates the inner surfaces of the cerebral hemispheres from each other. In front it is pointed, and is attached to the apex and to the posterior margin of the crista galli. Behind it widens out and is fixed along the middle line to the upper surface of the tentorium cerebelli. Its upper convex margin contains the superior longitudinal sinus, and adheres to the inner surface of the skull along the ridges seen on each side of the median depression, on the inner aspect of the vault of the skull. The lower margin, concave and free, is almost in contact with the upper surface of the corpus callosum, and contains the inferior longitudinal sinus.

2. **The Falx Cerebelli** (fig. 37) is the small median vertical triangular partition, attached behind to the internal occipital crest, and above, at its widest part, to the under surface of the tentorium cerebelli. Its free concave margin projects forwards and fits into the notch between the halves of the cerebellum. Its posterior attached margin contains the occipital sinus, which is single above, but bifid below.

3. **The Tentorium Cerebelli** (fig. 37), supporting the posterior part of the cerebrum, passes forwards and upwards, somewhat horizontally, as an arched tent-like partition between the big brain and the little brain. Its posterior convex margin is attached behind to the transverse ridges on the occipital, parietal, and temporal bones, and further forwards to the upper margin of the petrous part of the temporal bones. It ends in front at the posterior clinoid processes. This margin contains

the lateral sinuses behind, and the superior petrosal sinuses in front. The anterior concave margin, free in the greater part of its extent, is attached on each side by a narrow slip to the anterior clinoid processes. Between this margin and the dorsum sellæ of the sphenoid is an oval opening for the passage of the crura cerebri, the superior peduncles of the cerebellum, and the posterior cerebral arteries. Along the middle line of the upper surface of the tentorium runs the straight sinus, which receives the veins of Galen from the interior of the brain (fig. 37).

The Minute Structure of the dura mater of the brain is similar to that of the spinal cord.

Table—Agreements and Differences in the Arrangement of the Cranial and Spinal Dura Mater.

Agreements—	1. Both are fibro-serous membranes. 2. Both invest their respective organs. 3. Both form the boundaries of the subdural space.
Differences—	1. The cranial dura mater forms the periosteum of the bones, the spinal does not, though some authors hold that there are two layers in the spinal dura mater, the outer forming the periosteum of the bones. 2. The cranial dura mater sends off processes between the parts of the brain : not so the spinal dura mater, it gives off no processes. 3. The cranial dura mater, by the separation of its constituent layers, encloses the various venous sinuses : the spinal dura mater forms no such sinuses.

Plate X.

Fig. 35.

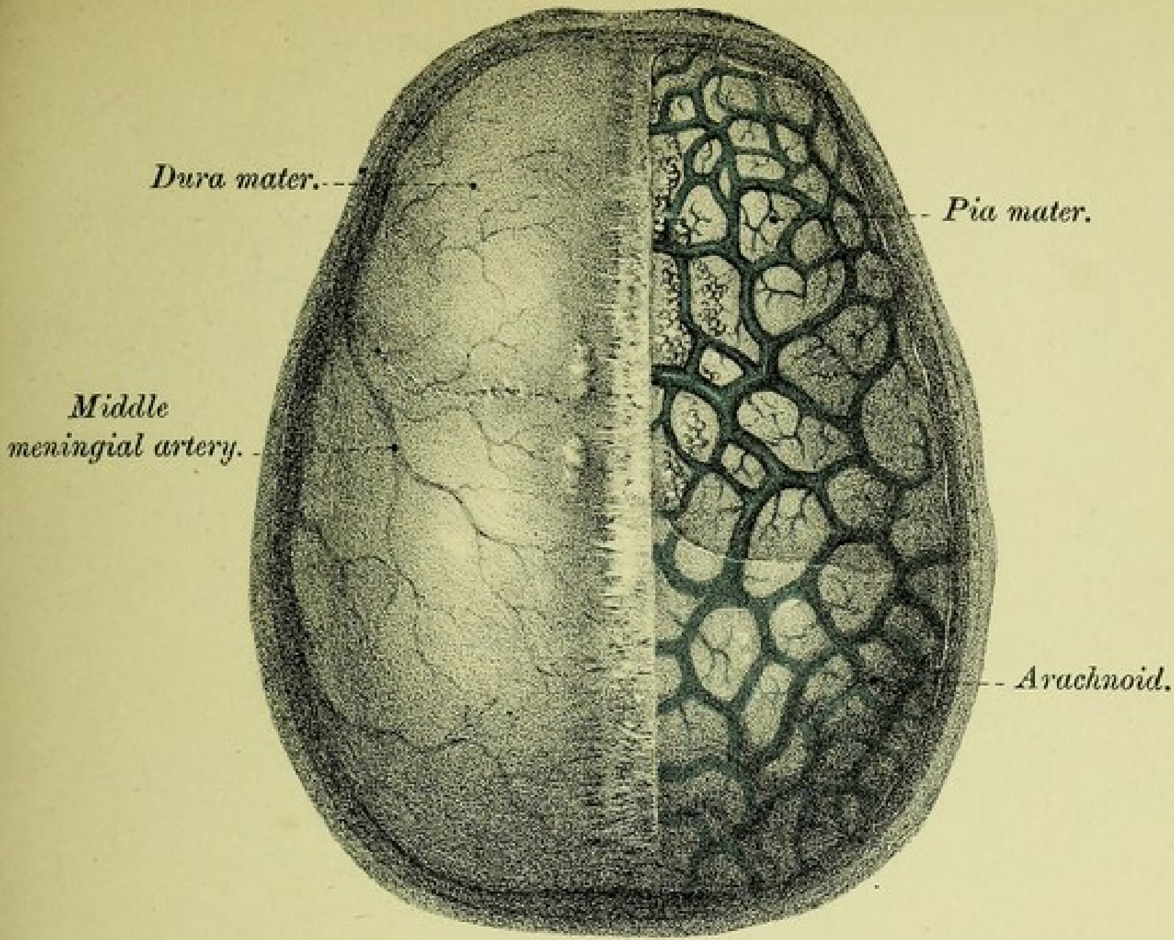
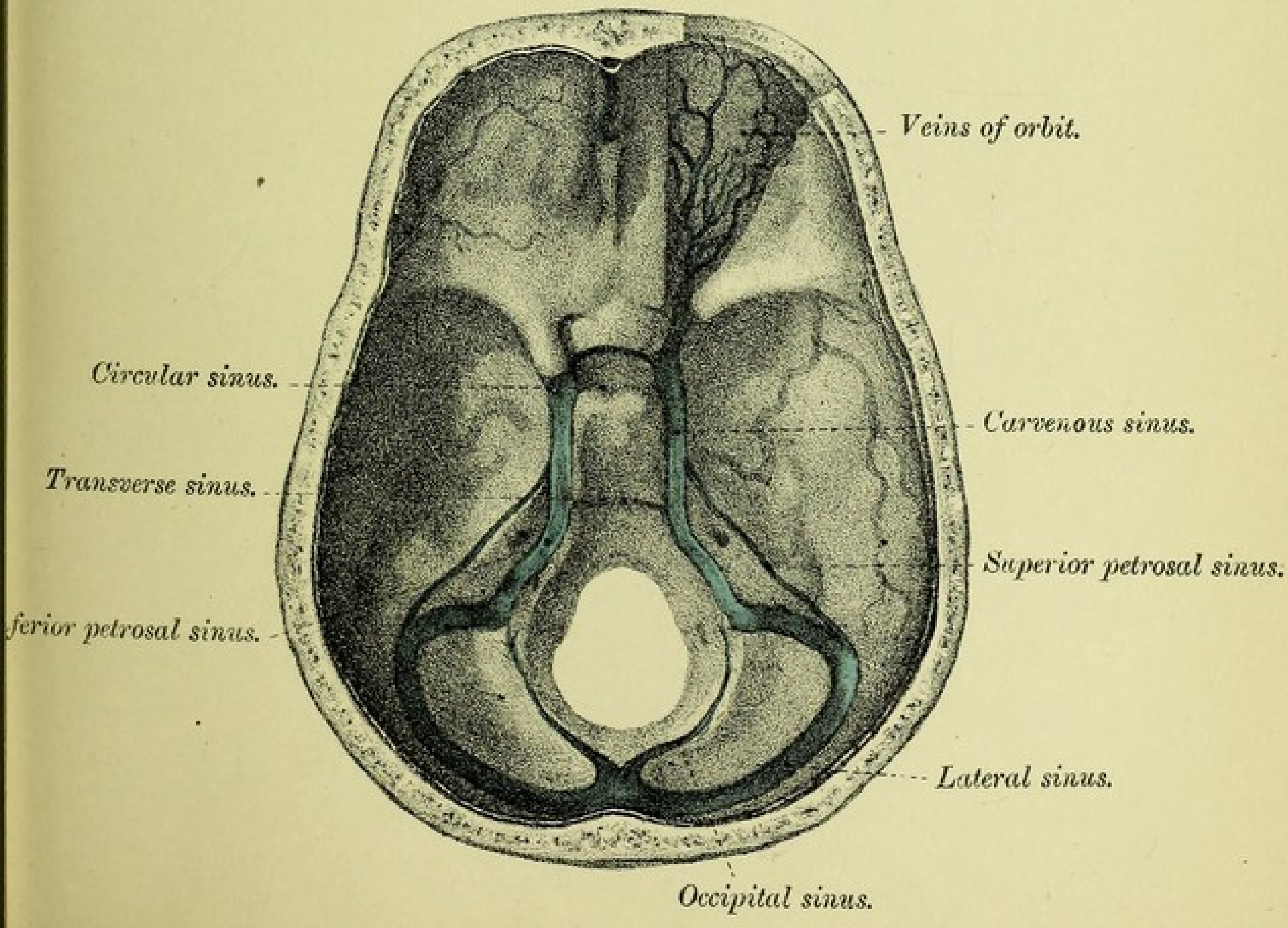


Fig. 36.



The cranial dura mater receives its nerve supply from the 4th, 5th, and the sympathetic.

Pacchionian Bodies (or Glands) are small white elevations, which indent the inner surface of the skull, along each side of the middle line. They are overgrowths of the villi which normally exist in the arachnoid. Their use is unknown.

II.—THE PIA MATER.

The Pia Mater of the brain, like that of the spinal cord, is an extremely fine vascular membrane, composed of a plexus of capillary blood-vessels held together by delicate connective tissue (fig. 35). Covering the surface of the brain, it dips into the various fissures between the convolutions; and, from its inner surface, pass numberless blood-vessels for the nourishment of the substance of the brain. Besides the septa between the convolutions, the pia mater also sends into the lateral ventricles, through a large fissure, called the *great transverse fissure,* a special prolongation, the *velum interpositum,* the margins of which are wrinkled and folded, forming a vascular fringe, the *choroid plexus;* and a similar vascular process of pia mater, known as the *tela choroidea inferior* or choroid plexus of the 4th ventricle, lies on the roof of that cavity (see "Ventricles," page 97).

In STRUCTURE the pia mater of the brain corresponds to the inner of the two layers of the pia mater of the cord. Its receives its nerve supply from the 3rd, 5th, 6th, facial, and 8th nerves, as well as from the sympathetic.

III.—THE ARACHNOID.

The Arachnoid is a smooth, glistening, transparent, colourless membrane, situated between the dura mater and the pia mater (fig. 35). Formed of a single layer, which envelops the brain but does not pass into its fissures, it is connected to the pia mater beneath by the subarachnoid trabeculæ, which are far more numerous than those in the spinal cord. At certain spots, especially at the base of the brain, the pia mater and the arachnoid are widely separated from each other, forming the SUBARACHNOID SPACE, which contains most of the cerebro-spinal fluid.

There is no difference in STRUCTURE between the cranial and spinal arachnoid. The nerve supply to the former is probably the 5th, the facial, and the spinal accessory nerves.

Subarachnoid and Subdural Spaces (fig. 34).—The space between the dura mater and the arachnoid is called the subdural space, and is lined by endothelial cells. The space between the arachnoid and pia mater is the subarachnoid space, and is crossed by the subarachnoid trabeculæ. It contains cerebro-spinal fluid. Both its inner and outer walls are lined by endothelial cells, which also cover the surfaces of the trabeculæ. The subarachnoid space is most distinct (1) at the great longitudinal fissure; (2) at the base of the brain, in the triangular interval, between the anterior border of the pons Varolii and the middle and anterior lobes of the cerebrum; and (3) posteriorly, between the cerebellum and the medulla oblongata.

Cerebro-Spinal Fluid.—The principal part of this fluid is contained in the meshes of the subarachnoid trabeculæ, though a little is found in the subdural space. It communicates with the fluid in the central canal of the spinal cord, and in the ventricles of the brain, through an opening—the *foramen of Majendie*—in the roof of the 4th ventricle (fig. 34, page 46), and through two similar openings in the ventricular roof between the medulla and cerebellum, beneath the flocculus and behind the upper roots of the glosso-pharyngeal nerves. Corresponding communications also exist at the inferior horns of the lateral ventricles. The cerebro-spinal fluid is not merely intended to fill the subarachnoid space, but helps to protect the nerve centres from sudden shocks; acting in fact as a water-bed (Hilton) on which the brain rests. According to Foster it is probable that the cerebro-spinal fluid, being of the nature of lymph, subserves the nutrition of the brain.

IV.—VENOUS SINUSES.

(Figs. 36, 37, Plates X., XI.)

The sinuses of the brain, formed by the separation of the two layers of the dura mater, are lined by endothelial cells continuous with those in the interior of the veins. These sinuses are fifteen in number, five paired and five single. The single sinuses are the superior and the inferior longitudinal, the straight sinus, the circular, and the transverse. The paired set includes the two lateral, the two superior, and the two inferior petrosals; the two cavernous and the two occipital sinuses.

1. **The Superior Longitudinal Sinus** (figs. 37, 38, page 56) begins in front at the foramen cæcum as a small vein, which often communicates with the veins of the nose, and thence arches upwards and backwards in the convex margin of the falx cerebri to reach the internal occipital protuberance, where it is joined by several other sinuses at the triangular dilation, called the Torcular Herophili, or the meeting of the sinuses. Cut open the sinus in its entire length and you will see that it is wider above than below, being triangular in section, and that it increases in size as it passes backwards, its cavity being crossed by many slender bands—chordæ Willisii. Numerous veins, from the substance of the brain, pour their blood into this sinus. They run mostly from behind forwards, that is in the reverse direction to the blood current in the sinus, and they pierce the wall of the sinus by slit-like openings, which act as valves and thus prevent regurgitation of the blood. Before entering the sinus they pass through small spaces, called the parasinoidal spaces, which lie on each side of the superior longitudinal sinus (fig. 38). Other smaller veins enter this sinus from the diploë of the surrounding bones, and it receives an emissary vein through the parietal foramen.

2 **The Inferior Longitudinal Sinus** (fig. 37) is really a small vein contained in the free concave border of the falx major. It commences in front by minute venous radicles within the substance of the falx and ends behind in the straight sinus.

3. **The Lateral Sinuses** (fig. 36).—These are two in number, right and left, the right being usually the larger of the two. Through them most of the venous blood from the brain reaches the internal jugular

veins. They commence at the internal occipital protuberance, and running outwards and downwards in the attached margin of the tentorium cerebelli, in the grooves on the inner surface of the occipital, parietal, and temporal bones, finally turn forwards to end in the bulb of the internal jugular vein. Blood enters these sinuses from the superior and inferior petrosal sinuses, from the inferior cerebral and cerebellar veins, from the diploë of the bones, and from the scalp by emissary veins.

4. **The Straight Sinus** (fig. 37) lies in the middle line of the upper surface of the tentorium cerebelli, where the falx major is attached. Behind, it ends at the meeting of the sinuses; while, in front it receives the inferior longitudinal sinus and the two veins of Galen, the latter bringing blood from the third and from the lateral ventricles of the brain. Cerebral and cerebellar veins also open into this sinus.

5. **The Cavernous Sinuses** (fig. 36), so called from the spongy appearance of their interior, are placed in the grooves on each side of the body of the sphenoid. They are oval in section, and contain in their thickened outer wall the 3rd, the 4th, and the ophthalmic division of the 5th nerve; while internally, and separated from the blood of the sinus by a thin lining membrane, is the internal carotid artery, with the 6th nerve on its outer side. These sinuses communicate with the circular sinus, with the superior and inferior petrosal sinuses, and receive small cerebral veins and the veins from the orbit (fig. 36).

6. **The Circular Sinus** (fig. 36) surrounds the pituitary body in the sella turcica. At each side it communicates with the cavernous sinuses.

7. **The Petrosal Sinuses** (fig. 36) are two on each side—the superior and the inferior. The *Superior Petrosal sinus* lies along the upper border of the petrous part of the temporal bone, and connects the cavernous sinus with the lateral sinus. The *Inferior Petrosal sinus* runs in the groove between the occipital bone and the petrous part of the temporal bone. It unites the cavernous sinus to the lateral sinus before the latter enters the jugular vein. Cerebral, cerebellar, tympanic, and auditory veins pour their blood into one or other of these sinuses.

(In a case examined in our dissecting-rooms, the inferior petrosal sinus of the left side, passed as a small vein through the jugular foramen, and joined the internal jugular vein two inches below the jugular foramen. The spinal accessory nerve passed between the two veins.)

8. **The Transverse or Basilar Sinus** (fig. 36), sometimes double, is placed across the basilar process of the occipital bone, connecting together the inferior petrosal sinuses. It communicates below with the anterior spiral veins.

9. **The Occipital Sinuses** (fig. 36) commence below, near the foramen magnum, as two small channels which run upwards in the attached margin of the falx cerebelli, and then join above to form a single sinus which opens into the Torcular Herophili.

Emissary Veins are small vessels which pass through foramina in the skull, and unite the veins of the scalp with the cranial sinuses. If it were not for these veins injuries to the scalp would lose half their significance (Treves).

FIG. 37.

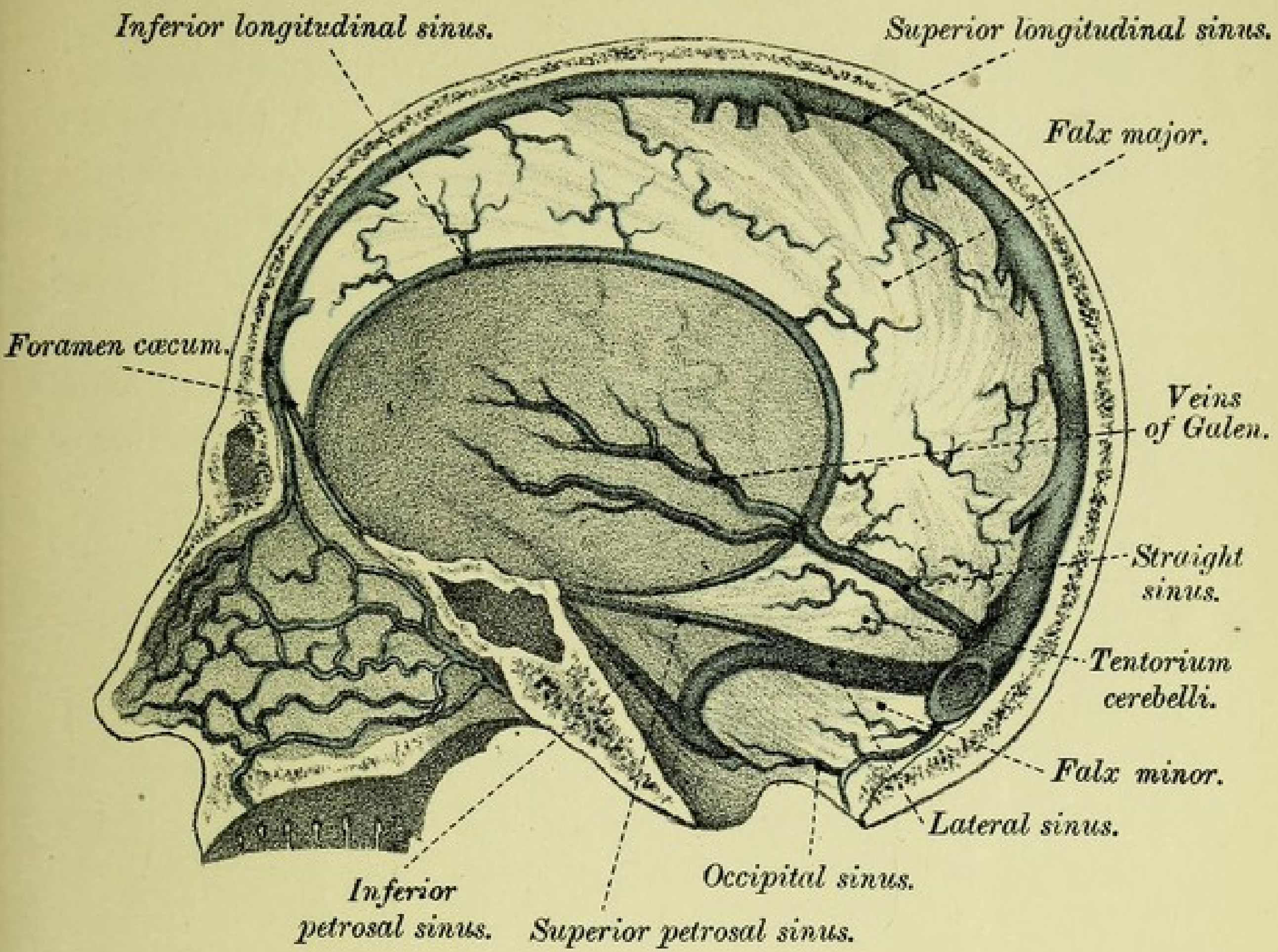
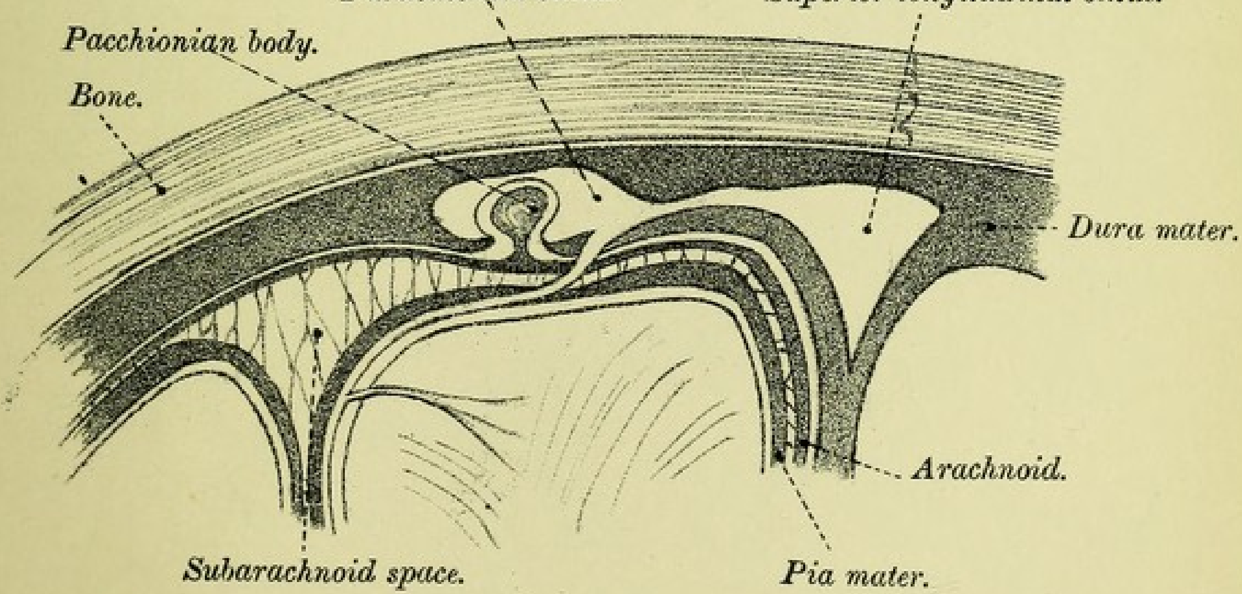

Inferior longitudinal sinus.
Superior longitudinal sinus.
Falx major.
Foramen cæcum.
Veins of Galen.
Straight sinus.
Tentorium cerebelli.
Falx minor.
Lateral sinus.
Occipital sinus.
Inferior petrosal sinus.
Superior petrosal sinus.

FIG. 38.


Parasinoidal sinus.
Superior longitudinal sinus.
Pacchionian body.
Bone.
Dura mater.
Arachnoid.
Subarachnoid space.
Pia mater.

The Meningeal Arteries, which supply the dura mater with blood, ramify in branching grooves on the inner surface of the cranium, between it and the outer surface of the dura mater (fig. 35, page 50). From the fossæ in which they ramify they are called the anterior, the middle, and the posterior meningeal arteries, and arise from the ethmoidal, ascending pharyngeal, internal maxillary, occipital, and vertebral arteries respectively.

CHAPTER II.

VESSELS OF THE BRAIN.

(Plate XII., figs. 39, 40.)

I.—ARTERIES.

THE arteries of the brain are derived from the *two internal carotids* and from *two vertebrals.*

I. **The Internal Carotid Arteries**, when they reach the anterior clinoid processes, give off the ophthalmic branches, and then divide into anterior, and middle cerebral, and posterior communicating.

1. The Anterior Cerebral Arteries run forwards to the fore part of the great longitudinal fissure, and, curving round the anterior end of the corpus callosum, pass backwards on its upper surface under the name of the arteries of the corpus callosum. At their commencement they are joined by a short transverse branch—the *anterior communicating;* while behind they anastomose by small branches with the posterior cerebral arteries. They supply blood to the frontal and olfactory lobes, to the optic nerves, to the corpus callosum, and to the anterior perforated spots (figs. 39, 40).

2. The Middle Cerebral or Sylvian Arteries are the largest branches of the internal carotid, and pass upwards and outwards in the fissure of Sylvius till they reach the surface of the island of Reil, where they ramify in the pia mater, forming part of the cortical system of arteries. They anastomose freely with the

Fig. 39.

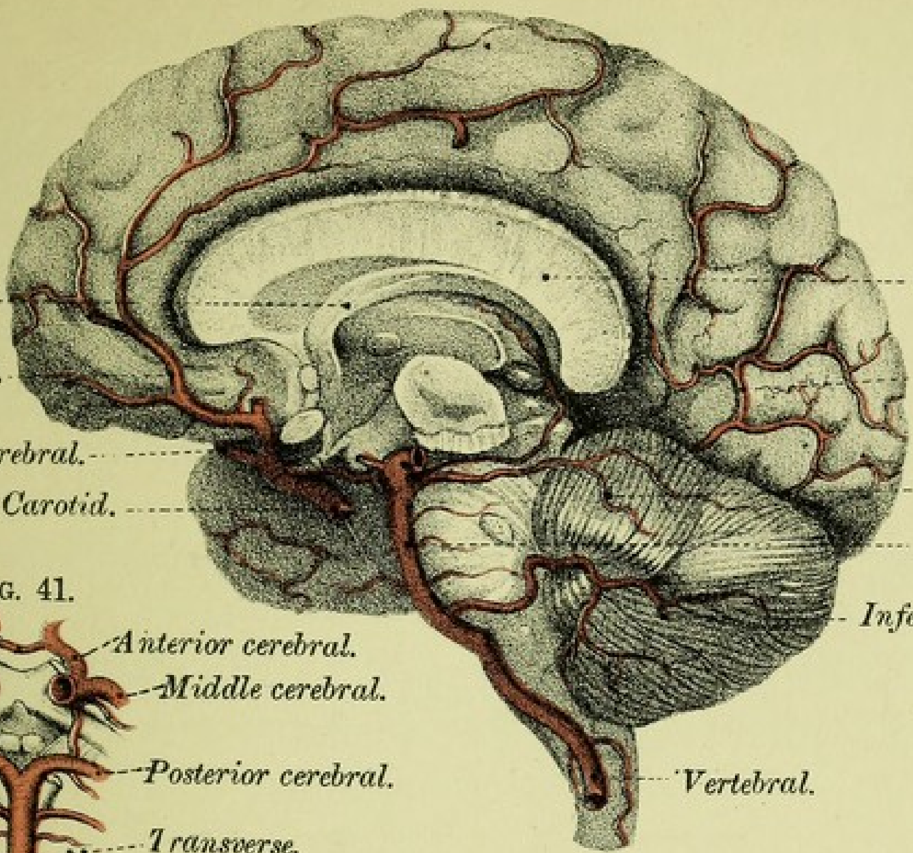


Fig. 41.

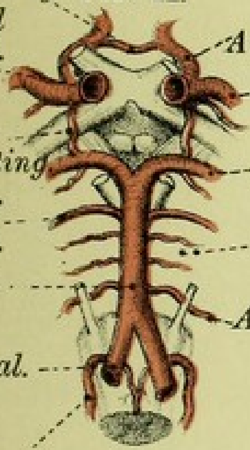
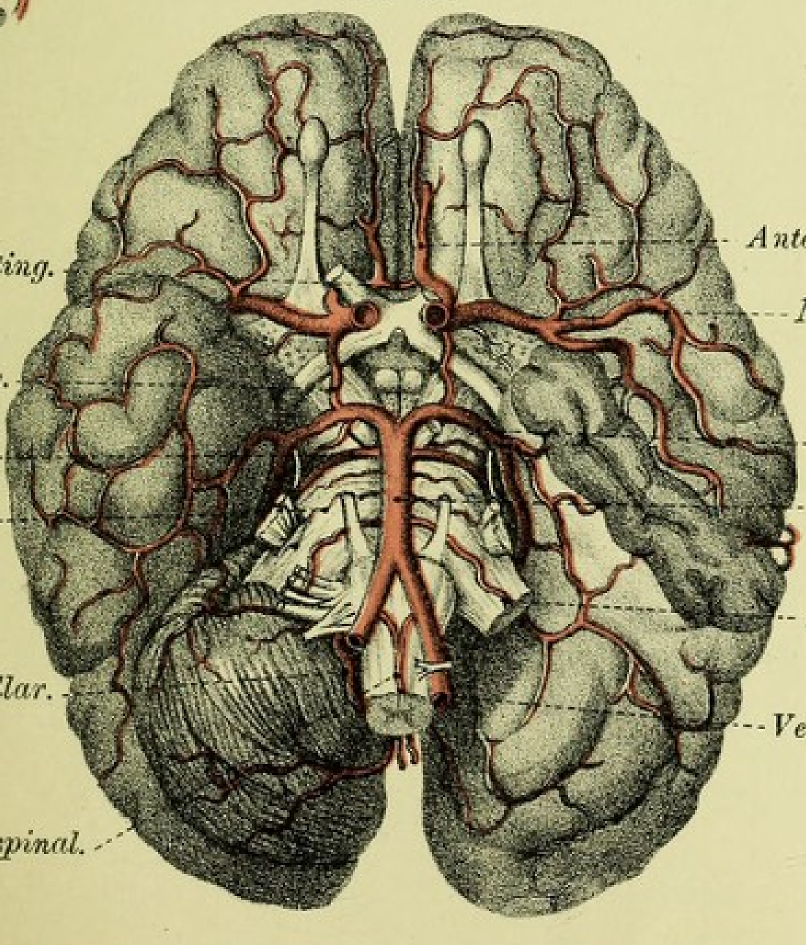


Fig. 40.



Arteries of the Brain.

anterior and posterior cerebral arteries, and are distributed by four branches to part of the frontal, parietal, and tempero-sphenoidal lobes (figs. 42, 43). Other branches of the Sylvian artery are furnished through the anterior perforated spot to the corpus striatum, and are all terminal arteries, belonging to the "ganglionic system" of branches. They are the lenticular, the lenticulo-striate, the lenticulo-optic; and will be again referred to in describing the nuclei of the ventricles of the hemispheres. The middle cerebral artery is the one chiefly concerned in cerebral hæmorrhage.

3. The Anterior Choroidal Arteries, one or two in number, are either branches of the internal carotids or of the middle cerebrals. Entering the fissure between the temporo-sphenoidal lobe and the crus cerebri (fig. 40), they reach the descending cornu of the lateral ventricle and there form the vascular fringe—the choroid plexus.

4. The Posterior Communicating Arteries run backwards and join the posterior cerebral arteries (branches of the basilar artery), and thus is established a free anastomosis between the carotids and the vertebrals.

II. The Vertebral Arteries—branches of the subclavian—enter the foramen magnum by perforating the dura mater, and then curve round to the anterior surface of the medulla. At the lower border of the Pons they unite to form a single trunk—the Basilar Artery—which may be seen running in the groove on the front of the Pons, till it reaches its upper margin, when it divides into two branches—the posterior cerebral arteries (fig. 40).

1. Branches of the Vertebral Arteries.—Only one branch, *the posterior inferior cerebellar*, which may, however, sometimes be a branch of the basilar, is given off by the vertebral artery to the brain. It supplies the under surface of the cerebellum.

2. Branches of the Basilar (fig. 40).—

(*a*) *Transverse branches*, three or four in number, run transversely outwards on the Pons. One of them, the internal auditory branch, passes into the internal auditory meatus.

(1) *The anterior inferior cerebellar arteries* are distributed to the anterior part of the lower surface of the cerebellum, and anastomose with the other cerebellar arteries.

(2) *The superior cerebellar arteries*, given off near the termination of the basilar, supply the upper surface of cerebellum, and send branches to the valve of Vieussens, to the pineal gland, and to the velum interpositum.

(3) *The posterior cerebral arteries*—the terminal branches of the basilar—curve outwards and backwards, round the crura cerebri, to the under surface of the posterior cerebral lobes, supplying them and anastomosing with the anterior and the middle cerebral arteries. They send branches to the posterior perforated spot and to the velum interpositum (posterior choroidal), and give three chief cortical branches (fig. 40).

Circle of Willis (fig. 40, 41, page 58).—This important arterial inosculation takes place at the base of the brain between the internal carotids and the vertebrals. In front the circle is formed by the anterior communicating artery which joins together the two anterior

Plate XIII.

Fig. 42.

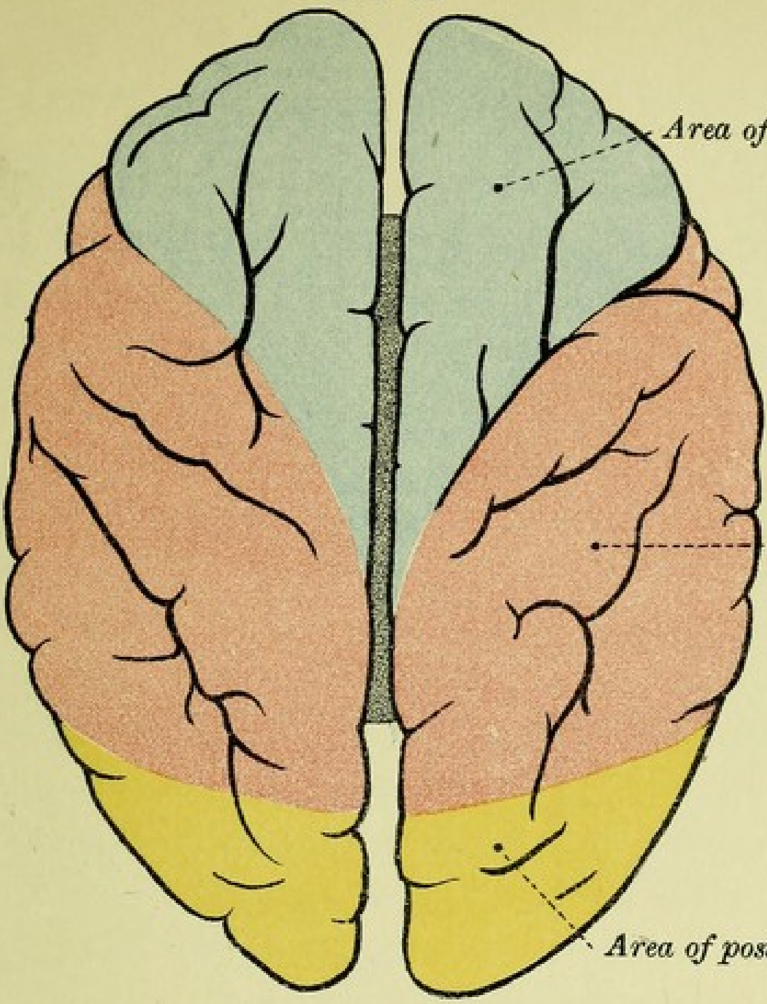


Fig. 43.

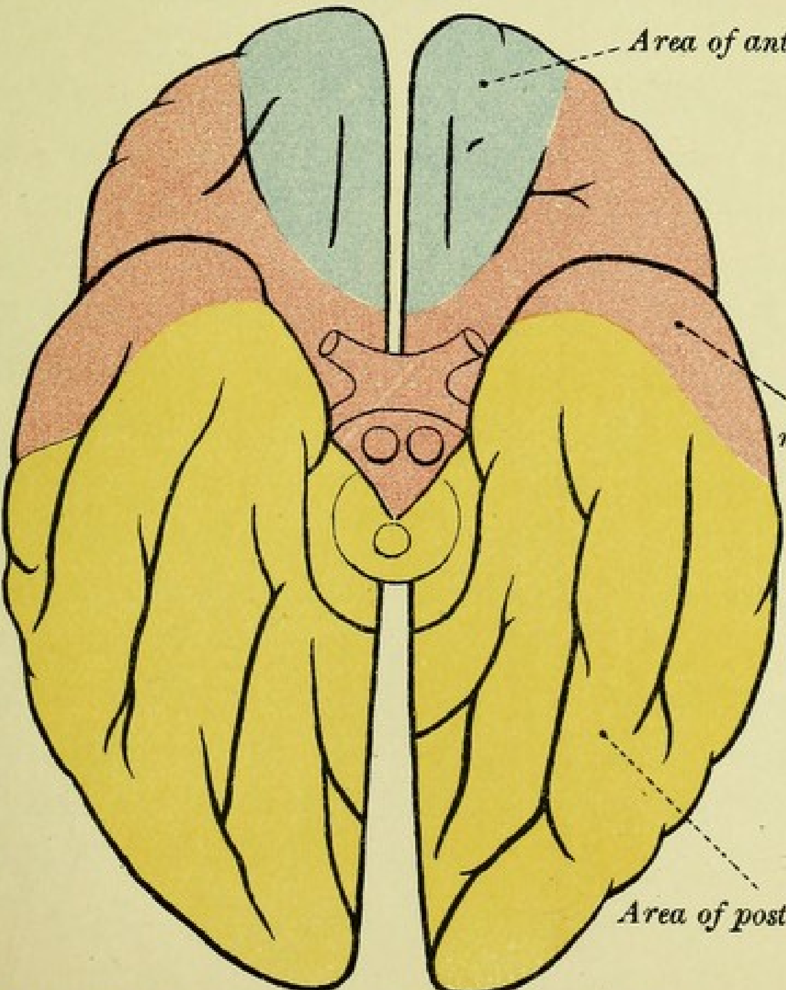


Diagram of Distribution of Arteries of Brain.

cerebral arteries; behind by the two posterior cerebral arteries, branches of the basilar; and on each side by the internal carotids, the anterior cerebrals, and the posterior communicating.

In front,
ANTERIOR COMMUNICATING,
On each side

Left.	*Right.*
ANTERIOR CEREBRAL.	ANTERIOR CEREBRAL.
INTERNAL CAROTID.	INTERNAL CAROTID.
POSTERIOR COMMUNICATING.	POSTERIOR COMMUNICATING.

Behind,
THE TWO POSTERIOR CEREBRALS,
Branches of the
BASILAR.

II.—VEINS.

Cerebral Veins.—The veins of the brain do not accompany the arteries, but open into the various sinuses in the dura mater. In the cerebrum we have two sets of veins—the one superficial, on the surface of the brain, the other deep. Of the superficial set those above open into the superior longitudinal sinus; those on the lateral and under aspect of the brain open into the lateral and cavernous sinuses chiefly. The deep set of veins, gathering the blood from the interior of the brain, enters the veins of Galen, and thus pours its blood into the straight sinus.

Cerebellar Veins.—Those on the upper surface of the cerebellum enter the veins of Galen and the straight sinus; those on the under surface end in the occipital, and in the lateral sinuses.

Special Characters of the Cerebral Circulation are—

1. The free anastomosis at the circle of Willis, which provides a ready supply of blood from other vessels in case of the sudden blocking of any of the more direct channels.

2. The tortuous course through bony canals of the arteries as they enter the skull, thus mitigating the force of the heart's beat.

3. Their ramifications in the pia mater before entering the substance of the brain.

4. The thinness of the arterial walls, and the smallness of the capillaries.

5. Except at the circle of Willis, there is little communication between the branches of the cerebral arteries, except by capillary vessels, so that if any artery be obstructed, the nutrition of the area to which it is supplied becomes impaired.

6. The existence of venus sinuses which are without valves, and which do not run with the arteries—the larger arteries, in fact, having no companion veins.

Plates XIII. and XIV. will give you an idea of the distribution of the chief arterial branches to the cerebral cortex.

FIG. 44.

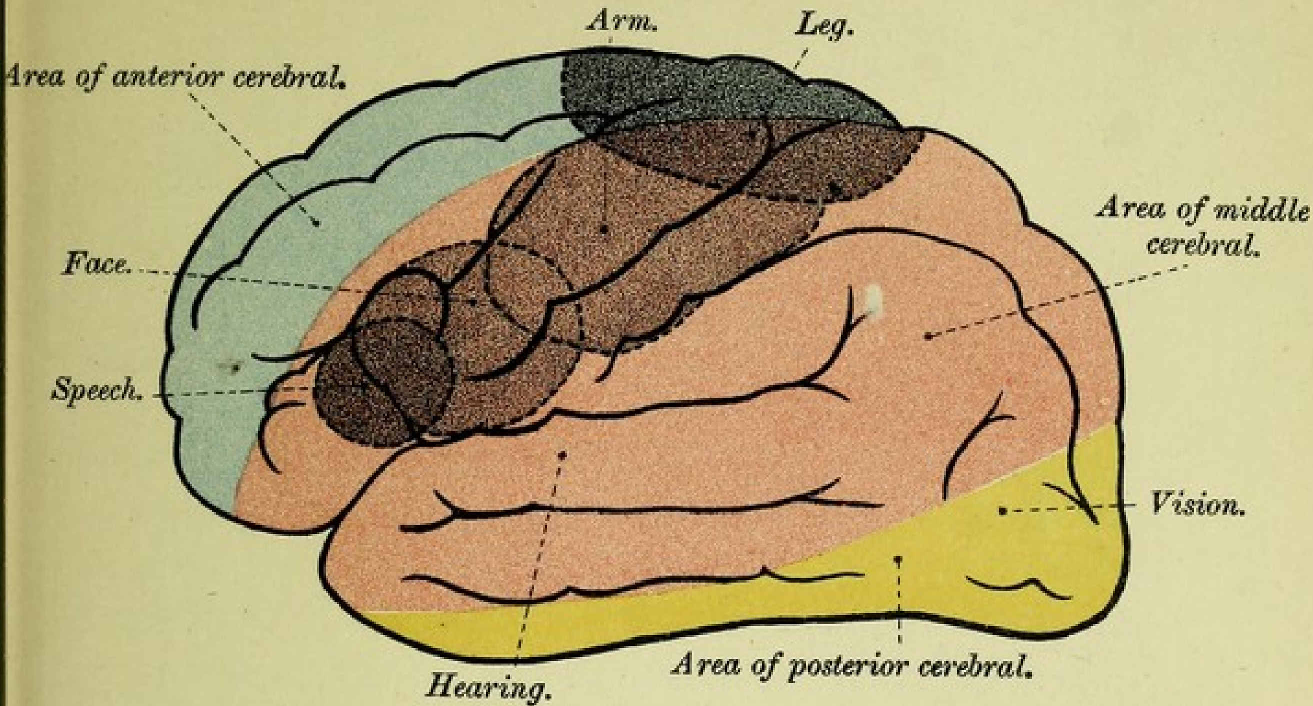


FIG. 45.

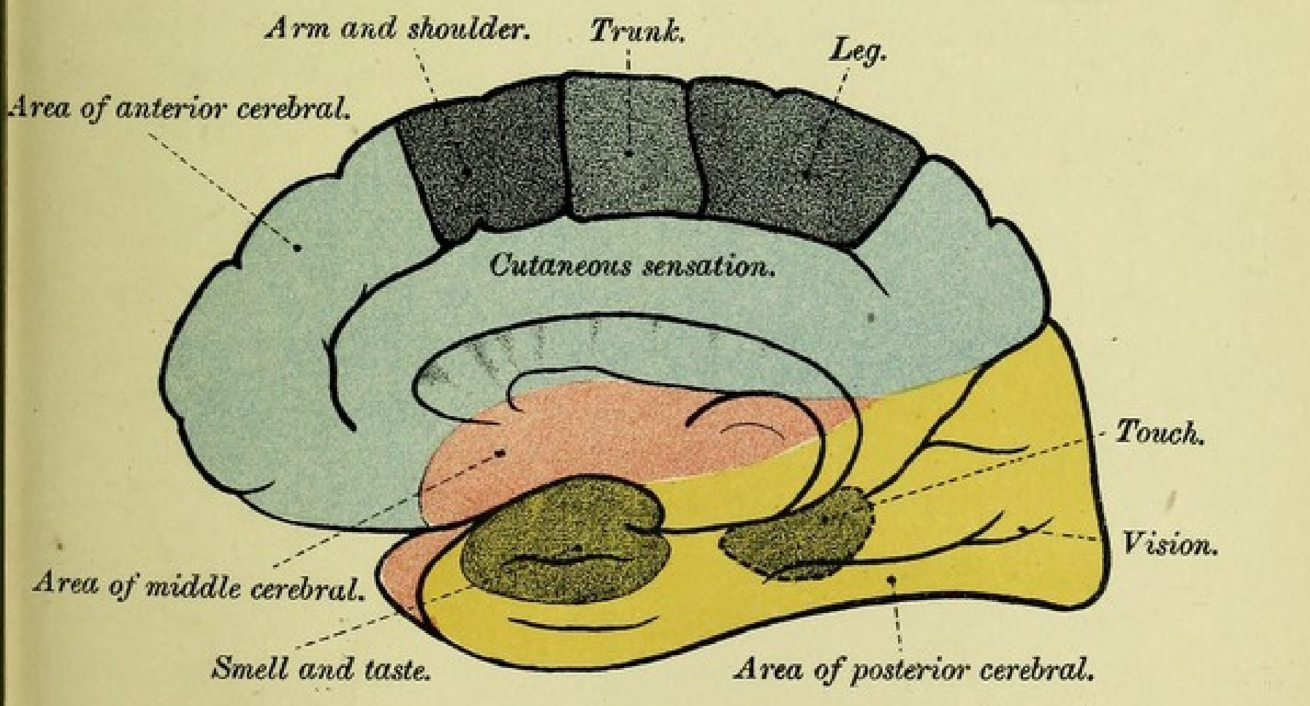


DIAGRAM OF ARTERIES AND CHIEF CENTRES IN BRAIN.

CHAPTER III.

SUBDIVISIONS OF THE BRAIN.

(Figs. 33, 34, page 46.)

General Outline of the Brain.—Placing the brain before you, you will see that it is an oval-shaped mass of nervous substance, that has not inaptly been likened to the kernel of a walnut. Its upper and outer surface is arched and convex, and presents many tortuous folds or convolutions of nerve substance with intervening fissures or furrows, the whole giving to the exterior of the brain a most characteristic appearance. Along the middle line of this aspect of the brain runs a deep longitudinal fissure, which lodges the falx cerebri, and which divides the mass into two similar halves. These symmetrical halves are the CEREBRAL HEMISPHERES, and they together form the first great division of the encephalon—the CEREBRUM,—which is united to the rest of the brain and to the spinal cord by two masses of nerve substance known as the crura cerebri. On separating the walls of this median fissure you will find that, in front and behind, the cleft extends right through to the base of the brain; but that, in the middle of its extent, it is interrupted below by a transverse band of nerve fibres, the CORPUS CALLOSUM, or great commissure of the brain.

The under surface of the brain, convoluted similarly to the upper surface, is very irregular, for it fits into the corresponding fossæ at the base of the skull. On this aspect you will recognise the other subdivisions of the brain—viz., (1) the CEREBELLUM (fig. 34) or little brain, lying behind and below the posterior part of the cerebral hemispheres; (2) the PONS VAROLII (fig. 34), a broad white band, crossing transversely between the two halves of the cerebellum, above the upper part of the front of the medulla; (3) the MEDULLA OBLONGATA (fig. 34) or bulb, placed between the cerebrum above, the pons in front, and the cerebellum behind, and serving to connect these several parts of the brain with the spinal marrow.

We shall describe (1) the MEDULLA, (2) the PONS, (3) the CEREBELLUM, and (4) the CEREBRUM.

I.—MEDULLA OBLONGATA.

(Figs. 45 to 48, Plate XV.)

The Medulla Oblongata, the most complicated portion of the central nervous system, is, as you already know, the expanded upper end of the spinal cord, and, like it, is composed of grey and white matter. It has an anterior, a posterior, and a lateral aspect. By its anterior surface it rests upon the basilar process of the occipital bone, and its posterior surface is hidden by the cerebellum. In general outline, it is more or less conical, with its long axis nearly vertical, its base being directed upwards and forwards towards the pons Varolii; its apex downwards and backwards, and continuous with the spinal marrow at the lower border of the foramen magnum. In length it measures about one and a quarter inches; in breadth, at its widest part, about one inch; in thickness about half-an-inch. On its anterior aspect it is convex, and is limited above, by the transverse fibres of the pons; below, by what is known as the decussation of the pyramids—several bands of fibres passing from one side of the medulla

Plate XV.

Fig. 46.

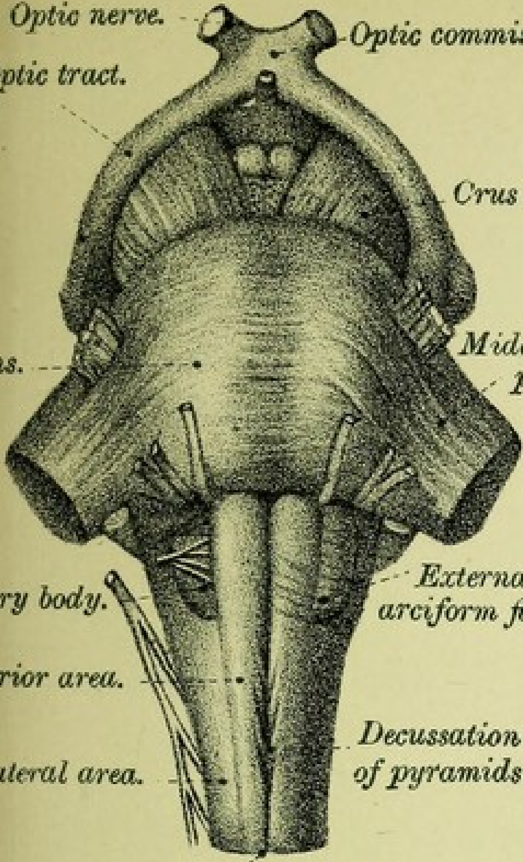


Fig. 47.

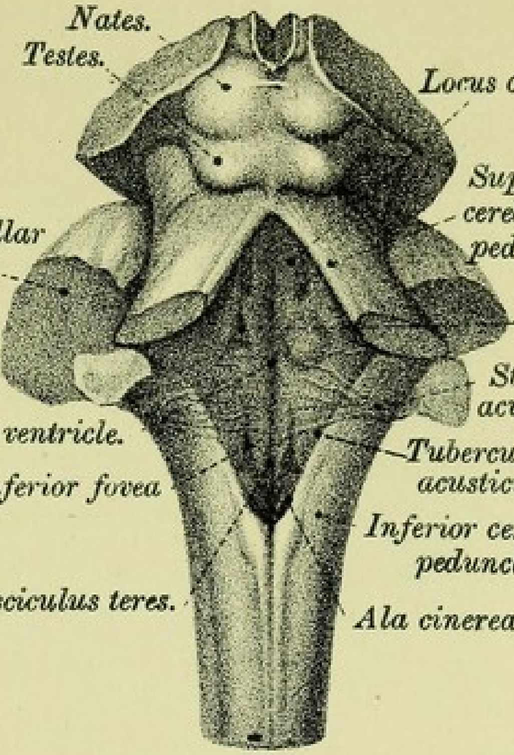


Fig. 48.

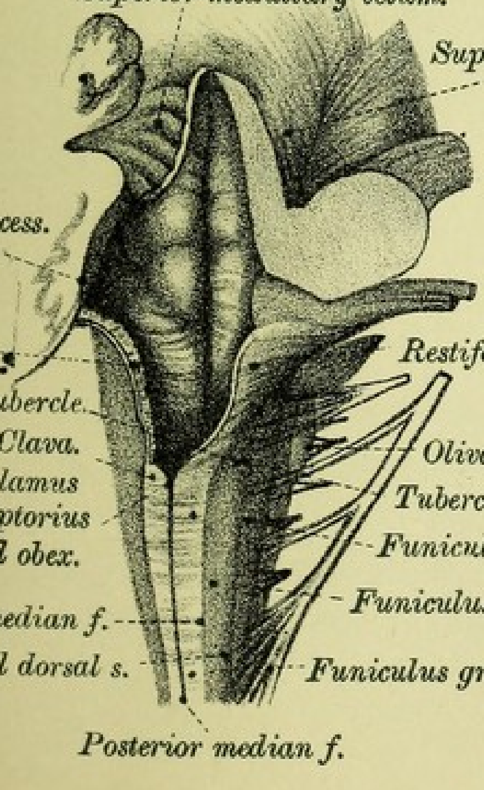
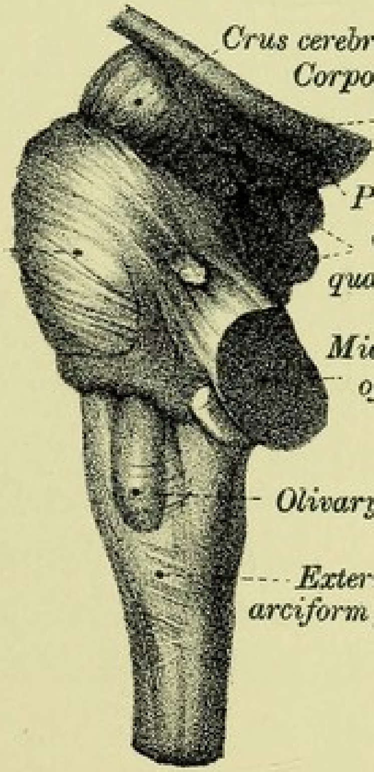


Fig. 49.



to the other. Behind, on the other hand, it is convex in its lower half, but in its upper half, it expands and becomes flattened to form part of the rhomboidal depression called the floor of the 4th ventricle. On this aspect, its upper boundary is marked by several transverse lines—the *striæ acusticæ*—running across the widest part of the ventricular floor (fig. 47); the lower boundary is purely artificial, corresponding with the lower margin of the foramen magnum. The lateral aspect of the medulla supports an oval eminence, the olivary body, crossing the lower part, and below which you may be able to make out several transverse lines, the external arciform fibres (figs. 46, 49), the significance of which you will understand hereafter.

(1) FISSURES OF THE MEDULLA.

(Figs. 46 and 48.)

Like the spinal cord the medulla is a symmetrical organ, being divided by superficial median clefts, anterior and posterior, into two similar lateral segments, which are again subdivided into anterior, posterior, and lateral areas by the continuation upwards, though not in a direct line, of the place of origin of the anterior and posterior spinal nerve roots.

1. The ANTERIOR MEDIAN FISSURE of the medulla, a direct continuation upwards of the anterior median fissure of the spinal cord, ends above, at the lower margin of the pons, in a slight recess needlessly named the foramen cœcum; while below, at the lower limit of the medulla, it is interrupted by the decussation of the pyramids.

2. The POSTERIOR MEDIAN FISSURE, continuous with the posterior median fissure of the spinal cord, expands above into the floor of the 4th ventricle, along the centre of which runs a mesial groove, in a line with the median fissure of the cord. External to this fissure are two minor sulci—the paramedian and lateral dorsal sulci (figs. 47, 48).

3. The LATERAL FISSURES, following up the lateral fissures of the cord, give origin to the roots of the 8th and 9th pairs of cranial nerves; the 8th pair springing from the continuation of the postero-lateral groove, and the 9th pair from that of the antero-lateral groove.

By means of these several fissures the surface of each half of the medulla is marked out into three areas, for the most part artificial—viz., an *anterior area,* between the anterior median fissure and the line of origin of the 9th nerve; a *lateral area,* between the 9th nerve in front and the 8th nerve behind; and a *posterior area,* between the posterior median fissure and the 8th pair of nerve roots.

(2) WHITE MATTER OF THE MEDULLA.

(Areas of the Medulla.)

(Figs. 46 to 49).

It will be convenient to begin with the description of the posterior area.

1. **Posterior Area.**—This area, lying between the posterior median fissure and the line of origin of the 8th pair of nerve roots, may be divided into an upper or anterior part, and a lower or posterior part. The *upper* portion of this area enters into the formation

of the floor of the 4th ventricle. This cavity should naturally be described at this stage, but since many of its parts are connected with the pons and cerebellum, we are forced to defer its account until we have treated of that division of the brain (page 97).

The *lower portion* of the posterior area is, for the most part formed by the upward prolongation of the various white tracts of the posterior column of the cord—the several strands there defined changing, when they reach the medulla, their arrangement, their position, and their names.

In dealing with the white substance of that column, you will doubtless remember that we called your attention to the existence, in the cervical region, of a strand of fibres, close to the posterior median fissure, called the *postero-internal strand*—fasciculus of Goll. Now, traced into the medulla, this strand becomes more prominent, and at the point where the central canal of the cord becomes the cavity of the 4th ventricle, this fasciculus enlarges, and is removed a little to one side. It lies between the posterior median and the paramedian fissures, and, when followed upwards, tapers to a point and becomes gradually lost. It is called the FASCICULUS or FUNICULUS GRACILIS—slender (fig. 48), and its enlarged upper end is known as the CLAVA—a club (fig. 48). We shall afterwards be able to trace its fibres along with those of the next fasciculus, first to their respective nuclei (nucleus gracilis and nucleus cuneatus) in the medulla, and thence to the cerebrum and cerebellum. The fibres, which pass from these nuclei—gracilis and cuneatus—to their ultimate destination in the cerebrum, decussate in the medulla in front of the central canal but behind the pyramidal decussation. They are the sensory tracts to the brain and form what is known as the *superior sensory decussation* or *superior pyramidal decussation.* They will be again referred to in treating of the grey matter of the bulb (fig. 52, page 79).

The outer division of the posterior column of the spinal cord, the *postero-external strand*—fasciculus of Burdach or cuneate fasciculus,—passes into the medulla under this latter name. It lies between the para-median and lateral dorsal sulci, and expanding above into a tubercle—the CUNEATE TUBERCLE (figs. 48, 50),—reaches upwards beyond the clava, and forms one of the lateral boundaries of the lower part of the 4th ventricle (fig. 48).

Besides the tracts just described, there are on this aspect of the medulla, two other strands known as the FUNICULUS of ROLANDO and the RESTIFORM BODY, which are not represented on the surface of the posterior column of the spinal cord; for the former is chiefly grey matter, and the latter belongs mainly to the lateral column.

(*a*) The first of these tracts, the FUNICULUS of ROLANDO, is of a greyish colour, for there is little or no white matter on its surface. It lies outside the funiculus cuneatus, between it and the line of origin of the roots of the 8th pair of nerves. Like the two tracts previously mentioned, it expands above into a tubercle—the TUBERCLE of ROLANDO (figs. 48, 50). The funiculus of Rolando is often very poorly developed especially in the adult brain, but in the medulla of children it is always well marked.

(*b*) The remaining prominence, the largest and most conspicuous on this surface of the medulla, is the

INFERIOR CEREBELLAR PEDUNCLE or RESTIFORM BODY (*restis,* a rope) (figs. 47, 48). Placed behind, and to the outer side of the lateral column of the cord, it lies above the level of the clava, the cuneate tubercle and the tubercle of Rolando, and, when looked at from the surface, seems to be incorporated with these fasciculi, though not so in reality; for, as we shall see in the next chapter, it is composed of fibres derived, for the most part, from the lateral column of the spinal cord (fig. 50).

2. The **Lateral Area** of the medulla, continuous with the lateral column of the cord, lies between the roots of the hypo-glossal nerve in front and those of the 8th nerve behind. It is wider below than above, where it is partially hidden from view by the oval eminence—the olivary body. To determine the origin of its various strands we must refer back to the constitution of the corresponding column of the spinal cord. You will recollect that, in that column, we traced three tracts—the *direct lateral cerebellar*, the *crossed pyramidal*, and the *mixed zone.*

The *crossed pyramidal tract* can be followed to the anterior pyramid of the opposite side of the medulla. The *direct lateral cerebellar tract,* on passing up into the medulla, will be seen as a superficial band of fibres (figs. 49, 50), running upwards and backwards across the line of origin of the 8th pair of nerve roots over the funiculus of Rolando, above its tubercle and across the cuneate funiculus. Then turning sharply upwards, it is joined by a set of fibres—the EXTERNAL ARCIFORM FIBRES (fig. 50), which, together with it, form the main mass of the RESTIFORM BODY or INFERIOR PEDUNCLE of the CEREBELLUM (figs. 48, 50). For a full account of the constitution of the restiform body or inferior cerebellar peduncles, see page 90.

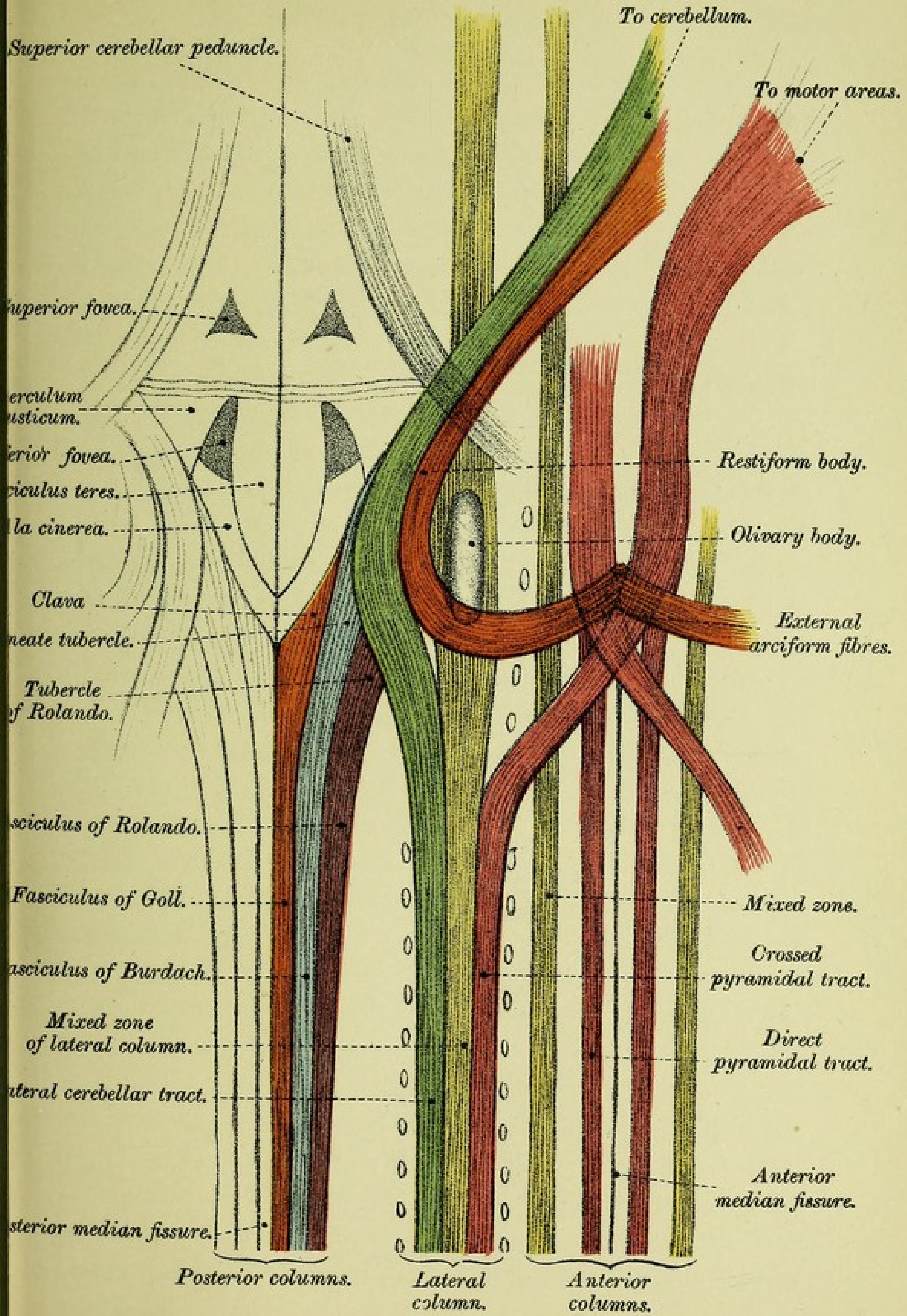
The remainder of the lateral column—the *mixed zone*—when traced upwards to the bulb is seen to dip under the olivary body, so that only a small part of it is visible on the surface of the medulla, as a narrow white strand—tract of the fillet—between the olivary body and the roots of the 8th pair of nerves. Most of the fibres of this strand go to form part of a network of fibres that will become familiar to us under the name FORMATIO RETICULARIS.

The *antero-lateral ascending tract of Gowers,* probably a crossed sensory tract from the posterior roots, also passes most likely to the cerebellum.

Thus, then, the fibres of the lateral column of the spinal cord, on reaching the medulla, are disposed of in three ways (see fig. 50): (1) Some—crossed pyramidal tract—go to the opposite anterior pyramid; (2) others —direct lateral cerebellar tract—to the restiform body, and thence to the cerebellum of the same side; (3) others—the mixed zone—pass partly behind the olive and join the tract of the olivary fillet, and partly beneath the olive to the formatio reticularis (fig. 56). The constitution and ultimate destination of these strands of fibres will be seen in plate 39.

Olivary Body—*Olivary Fillet.*—The olivary body is an oval prominence, about half-an-inch long placed at the upper end of the lateral area of the medulla. It is bounded in front by the roots of the 9th nerve, but is separated behind from those of the 8th nerve by a narrow white tract—the tract of the

FIG. 50.



J. T. MURRAY DEL^T

fillet, lemniscus, olivary fasciculus—which, as we have already seen, is part of the mixed zone of the lateral column of the cord. Above, it almost touches the lower border of the pons; below, it is crossed by delicate fibres—the external arciform fibres—already referred to. We shall afterwards see that it contains a grey core or nucleus, called the inferior olivary nucleus.

3. The **Anterior Area** of the medulla lies between the anterior median fissure and the roots of the hypoglossal nerve, which serve to separate it from the olivary body. It bears a pear-shaped prominence —the ANTERIOR PYRAMID (figs. 46, 49)—which is broader above than below, though it becomes slightly constricted before disappearing beneath the transverse fibres of the pons. The pyramids of the two sides will afterwards be traced through the pons to the cerebral peduncles, and thence to the cerebral hemispheres. To their constitution you will require to give your closest attention, for it is somewhat complicated and of the greatest importance (fig. 50).

The anterior column of the spinal cord, you will remember, had a median division, *direct pyramidal tract*, and a lateral division, *anterior root zone*—basis bundle. Now, the pyramids of the medulla are, to a small extent only, made up of fibres derived from this inner division—direct pyramidal tract—of their own side of the cord; by far their greater part is composed of fibres—crossed pyramidal tract—which come from the *opposite lateral* column of the spinal cord. This crossed tract, after leaving the opposite lateral column, passes upwards and inwards through the anterior commissure, across the anterior median fissure, where it decussates in a series of bundles, with a similar set of fibres from the other side—constituting together the decussation of the pyramids. Turning upwards it then forms the inner and by far the larger part of the opposite anterior pyramid (fig. 50); the outer and smaller part of the same pyramid being formed by the continuation upwards of the direct pyramidal tract of the same side. Thus, for example, the LEFT ANTERIOR PYRAMID is chiefly made up of the *crossed pyramidal tract* of the RIGHT LATERAL COLUMN, and to a much smaller extent by the *direct pyramidal tract* of its OWN side. We must note, however, that although the fibres of the direct pyramidal tract do not decussate in the medulla they do decussate as they pass down the spinal cord, and ultimately join the anterior nerve roots of the opposite side to that at which they left the brain.

This decussation of the pyramids explains the phenomena of crossed paralysis, by which is meant, that when one side of the brain, say the left, is injured, though the same side of the face is paralysed, loss of motion ensues not on that side but on the opposite side of the rest of the body.

The outer division of the anterior column of the spinal cord—*antero-external tract*—will afterwards be traced to the following destinations—(1) to the formatio reticularis, (2) to the posterior longitudinal bundle, and (3) to the tract of the fillet.

EXTERNAL ARCIFORM FIBRES (fig. 49, page 64).—These are a set of fibres which, as at present seen, emerge from the anterior median fissure of the medulla, cross over the surface of the anterior pyramids, over the lower part of and below the olives, and finally turn upwards, along with the lateral cerebellar tract, to form with it part of the restiform body. They will be again referred to, in treating of the grey matter of the medulla.

Summary.—Thus we see that the medulla oblongata presents four fissures, an anterior, two lateral, and a posterior; three areas, an anterior, with its pyramids and their decussation, a lateral with its olive, and tract of the olivary fillet, a posterior with its funiculus gracilis, funiculus cuneatus, and funiculus of Rolando, and their respective enlargements. Finally, we have the restiform body or inferior cerebellar peduncle.

TABLE—OBJECTS SEEN ON THE SURFACE OF THE MEDULLA.

Fissures.	Anterior median.		
	Posterior median.		
	Two lateral, with nerve roots.		
Areas.	1. Anterior area.		Pyramids.
			Decussation of pyramids.
	2. Lateral area.		Olive.
			Tract of olivary fillet.
	3. Posterior area.	Lower part.	Restiform body.
			Funiculus of Rolando and its tubercle.
			Funiculus cuneatus and its tubercle.
			Funiculus gracilis and its clava.
		Upper part.	Lower half of the floor of 4th ventricle.

External arciform fibres.

TABLE TO SHOW RELATIONS BETWEEN THE WHITE TRACTS OF THE CORD AND THEIR REPRESENTATIVES, WHEN SUCH EXIST IN THE MEDULLA.

	Cord.	*Medulla.*
Anterior column.	1. Direct pyramidal tract passes	to outer part of the anterior pyramid of the medulla of the same side.
	2. Mixed zone	to posterior longitudinal bundle. to olivary peduncle and fillet. to formatio reticularis.
Lateral column.	1. Crossed pyramidal tract	to the inner part of the pyramid of opposite side; a few fibres go to the pyramid of the same side.
	2. Direct lateral cerebellar tract	to restiform body and thence to the cerebellum.
	3. Mixed zone	to olivary fillet. to formatio reticularis.
	4. Antero-lateral ascending tract	to the cerebellum—probably crossed sensory tract.
Posterior column.	1. Postero-internal strand (Goll)	to funiculis gracilis, and to its nucleus.
	2. Posterior-external strand (Burdach)	to funiculus cuneatus, and to its nucleus. to formatio reticularis.

Funiculus of Rolando not represented in white matter of the cord.

Arciform fibres.

PLATE XVII.

Fig. 53.

a. m. f. Anterior median fissure.
a. n. Arciform nucleus.
as. gloss. Ascending root of the glosso-pharyngeal nerve.
e. a. f. External arciform fibres.
h. n. Hypoglossal nerve.
n. c. Nucleus cuneatus.
n. g. Nucleus gracilis.
n. l. Nucleus lateralis.
n. o. b. Nucleus of olivary body.
p. m. f. Posterior median fissure.
p. t. Pyramidal tract.
s. g. R. Gelatinous substance of Rolando.
5th as. Ascending root of 5th nerve.

Fig. 52.

a m. f. Anterior median fissure.
f. c. Fasciculus cuneatus.
f. g. Fasciculus gracilis.
h. n. Hypoglossal nerve.
n. c. Nucleus cuneatus.
n. g. Nucleus gracilis.
p. m. f. Posterior median fissure.
p. t. Pyramidal tract.
s. g. R. Substania gelatinosa Rolando.
s. p d. Superior pyramidal decussation.
5th as. Ascending root of the 5th nerve.

Fig. 51.

a. c. Anterior cornu.
a. m. f. Anterior median fissure.
d. p. Decussation of the pyramids.
d. p. t. Direct pyramidal tract.
f B. Fasciculus of Burdach.
f. G. Fasciculus of Goll.
m. z. Mixed zone.
p. c. Posterior cornu.
p. m. f. Posterior median fissure.

Fig. 56.

a. m. f. Anterior median fissure.
a. n. Arciform nucleus.
a. o. Accessory olive.
c. r. Corpus restiforme.
e. a. f. External arciform fibres.
g. n. Glossopharyngeal nerve.
l. or f. Lemniscus or Fillet.
n. a. Arciform nucleus.
n. am. Nucleus ambiguus.
n. f. t. Nucleus of fasciculus teres.
n. o. b. Nucleus of oblivary body.
p. l. b. Posterior longitudinal bundle.
p. t. Pyramidal tract.
v. Vagus.
5th as. Ascending root of the 5th nerve.

Fig. 55.

a. m. f. Anterior median fissure.
a. n. Arciform nucleus.
a. o. Accessory olive.
e. a. f. External arciform fibres.
f. r. Formatio reticularis.
f. s. Fasciculus solitarius.
h. n. Hypoglossal nerve.
n. am. Nucleus ambiguus.
n. c. Nucleus cuneatus.
n f. t. Nucleus of fasciculus teres.
n. g. Nucleus gracilis.
n. h. Nucleus of the hypoglossal nerve.
n. o. b. Nucleus of oblivary body.
p. t. Pyramidal tract.
r. Raphe.
v. Vagus nerve.
v. n. Vagus nucleus.
4th vent. 4th ventricle.
5th as. Ascending root of the 5th nerve.

Fig. 54.

a. m. f. Anterior median fissure.
a. n. Arciform nucleus.
a. o. Accessary olive.
e. a. f. External arciform fibres.
f. c. Fasciculus cuneatus.
f. g. Fasciculus gracilis.
f. r. Formatio reticularis.
i. a. f. Internal arciform fibres.
n. c. Nucleus cuneatus.
n. g. Nucleus gracilis.
n. l. Nucleus lateralis.
n o. b. Nucleus of olivary body.
p. m. f. Posterior median fissure.
p. t. Pyramidal tract.
s. g. R. Gelatinous substance of Rolando.
t. R. Tubercle of Rolando.
5th as. Ascending root of the 5th nerve.

FIG. 53.

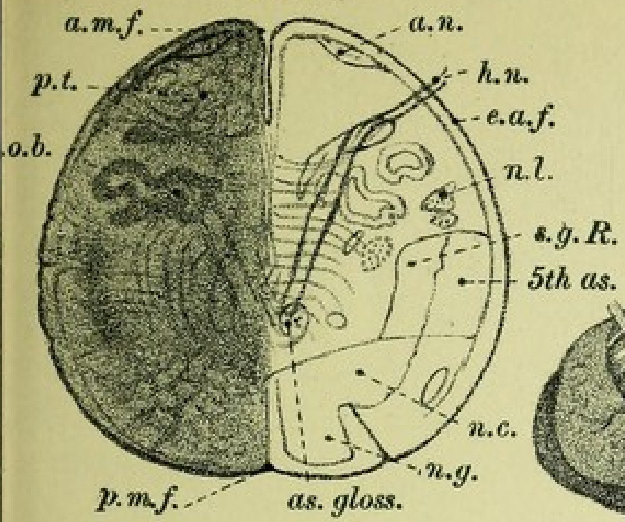


FIG. 56.

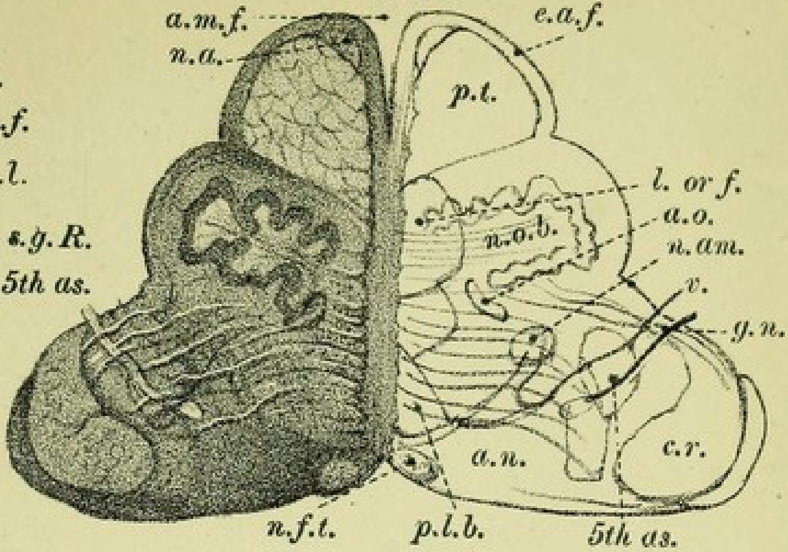


FIG. 52.

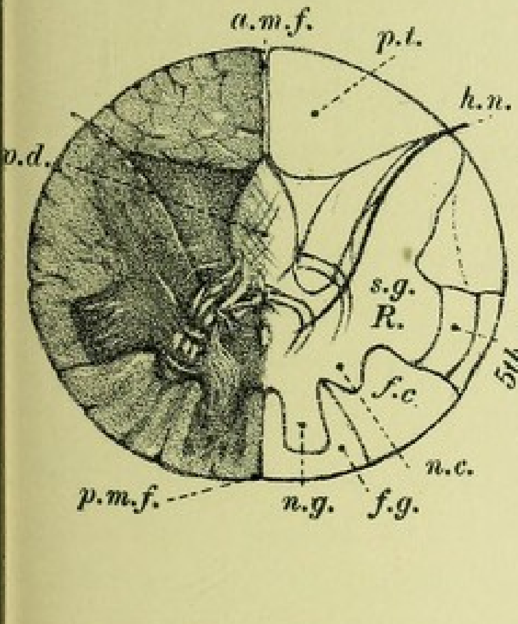


FIG. 55.

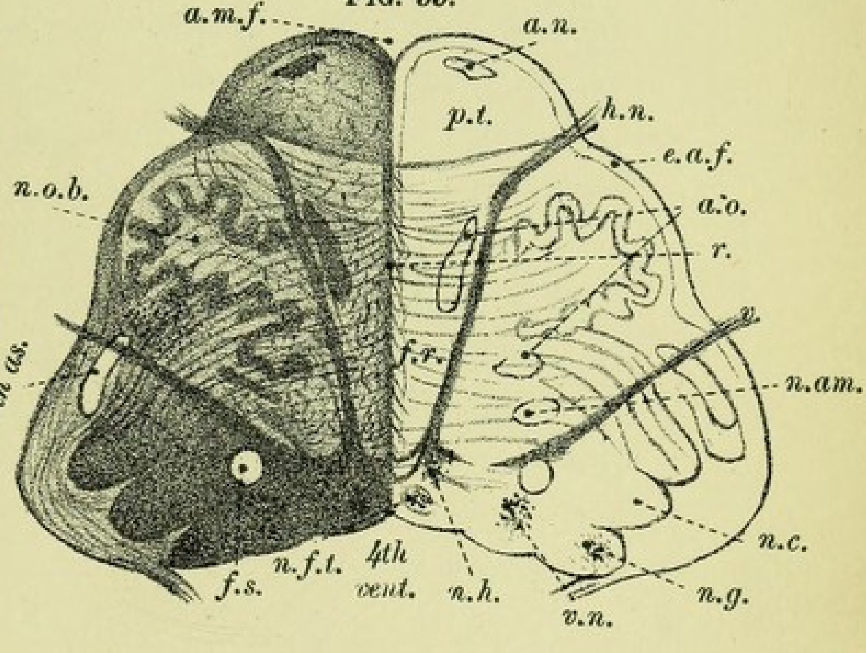


FIG. 51.

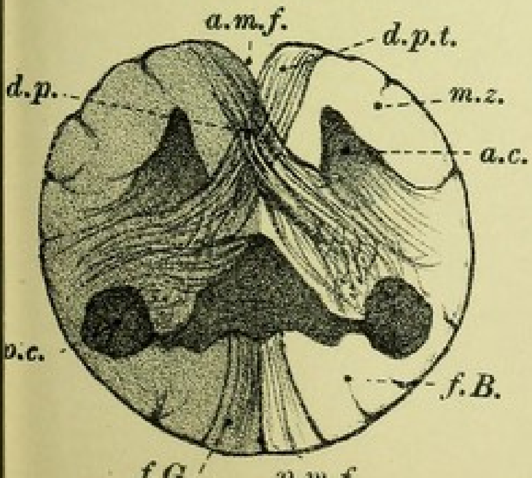
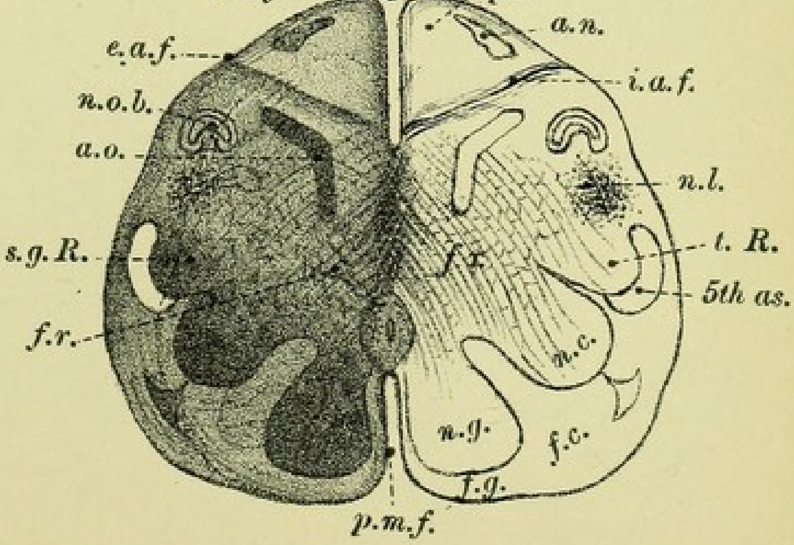


FIG. 54.



THE GREY MATTER OF THE MEDULLA.

From the white strands of the medulla, which have so far occupied our attention, we next turn to the consideration of the arrangement of its grey substance. This is far more irregular than that of the spinal cord, and for its satisfactory study you will require a special series of preparations, though it is hoped the accompanying figures will give you material assistance (figs. 51, etc.).

The grey matter of the medulla oblongata may be described under two heads—(1) that represented in the spinal cord, and derived from one or other of its grey crescents; (2) that not so represented, but forming isolated collections or nuclei not obviously connected with the grey matter of the spinal cord.

1. Grey Matter derived from the Grey Crescents.—Transverse sections of the lower part of the medulla will show you that the grey matter has an arrangement very similar to that of the grey matter of the spinal cord (figs. 51, 52); but that higher up in the medulla the appearance of the grey crescents becomes much changed (fig. 56).

(*a*) The *anterior cornu* of the spinal cord as we trace it upwards loses its characteristic shape, and, owing to the fibres of the crossed pyramidal tract cutting their way through the neck of the anterior horn, the head becomes separated from the base, and the neck is replaced by a reticulum of fibres, part of the formatio reticularis. The head of the horn, thus detached, enlarges, and, by the formaticn of the anterior pyramids between it and the anterior median fissure, is pushed from the antero-lateral aspect of the cord to the lateral aspect of the medulla, where, in sections of the lower part of the medulla, it may be seen as a distinct grey collection, the NUCLEUS LATERALIS (fig. 54).

Again, when the central canal of the cord opens out into the floor of the 4th ventricle, the grey matter which surrounds that canal is brought to the surface, and hence the *base* of the *anterior horn* appears on the ventricular floor as a narrow grey tract close to the median furrow (fig. 57). It is known as the NUCLEUS of the HYPOGLOSSAL NERVE; and in sections of the medulla at this level, the nerve may be seen as a band of fibres running from the nucleus towards the surface of the medulla (fig. 55). Close to this nucleus is another small collection of nerve cells—the nucleus of the fasciculus teres (fig. 57).

The greater part of the anterior horn, the *neck*, is replaced, as above said, by a reticulum of cells and fibres, part of these latter being the fibres of the crossed tract on their way to the opposite side of the medulla. This network constitutes the anterior part of the formatio reticularis or RETICULARIS GRISEA—grey reticulum (figs. 54, 55.)

(*b*) The grey matter of the *posterior* horn, on reaching the medulla, also takes a lateral position and increases in amount. The *head* of the horn, much enlarged, comes nearer to the surface, and appears at about the middle of the medulla as a well-marked grey nucleus, the TUBERCLE of ROLANDO (fig. 54), beneath the surface prominence of the same name. To its outer side will be seen a well-marked band of white fibres, the ascending root of the fifth nerve (fig. 54).

The grey matter of the *base* of this horn, also much increased in amount, forms between the median line and the grey nucleus of Rolando, two superficial aggregations, the inner one being the NUCLEUS of the FUNICULUS GRACILIS, the outer the NUCLEUS CUNEATUS (fig. 54). Each lies beneath the corresponding white tract on the surface. To these nuclei, as we have seen, can be traced the fibres of the fasciculus gracilis and fasciculus cuneatus. The nuclei themselves can be followed as far as the pons.

The *neck* of the posterior cornu, like that of the anterior, is replaced by a network of fibres, the RETICULARIS ALBA, which becomes continuous with the GREY reticulum, constituting together the **Formatio Reticularis** (figs. 54, 55), a network of longitudinal, oblique, and transverse fibres—arciform fibres—with nerve cells and neuroglia cells embedded amongst them. The fibres are chiefly commissural in nature, though there are reasons for thinking that sensory impulses and impulses which inhibit spinal reflexes pass through this reticulum; for from the nuclei of the funiculus gracilis and cuneatus, fibres can be traced through this reticulum (see sensory decussation) to the cerebrum (fig. 52). Some of the longitudinal fibres are derived from the mixed zone—anterior root zone—of the anterior column of the spinal cord.

2. Isolated Grey Masses or Nuclei of the Medulla.—The chief of these nuclei are—

(*a*) The *corpus dentatum* or olivary nucleus.

(*b*) The accessory olives.

(*c*) The arciform nucleus.

(*a*) The CORPUS DENTATUM or OLIVARY NUCLEUS (fig. 55), is contained in the centre of the olivary body, and is covered superficially by the external arciform fibres (fig. 55). This ganglion consists of flask-shaped, multipolar nerve cells, and neuroglia cells arranged as a zigzag lamina or crumpled sheet of grey matter, concave and open in its inner aspect. Through this opening, called the *hilum*, enters the olivary peduncle, a bundle of nerve fibres, which, after having decussated in the middle line, passes towards the anterior area of the medulla, and enters the centre of the olivary nucleus, to be there distributed in different directions—(1) some of the fibres end in the cells of the grey lamina; (2) some go through the lamina, and can be traced to the restiform body and cerebellum—they come originally from the opposite olivary body; and (3) others make to the surface, and there join the superficial (external) arciform fibres, and go along with them and the direct lateral cerebellar tract to the restiform body.

The olivary ganglion is closely connected with the corpus dentatum of the cerebellum, for any injury to this latter nucleus causes atrophy of the opposite olivary ganglion (fig. 99, plate 37).

(*b*) Two other isolated nuclei, the *accessory olives* (fig. 55), will be found, the one on the inner side of, the other behind, the corpus dentatum. They are linear in shape, and are closely connected with the olivary nucleus.

(*c*) The third nucleus—arciform nucleus—nucleus of the external arciform fibres (fig. 54), is placed amongst these fibres as they cross over the anterior pyramids of the medulla. The nucleus itself is continuous above with the nucleus pontis (see Pons).

FIG. 57.

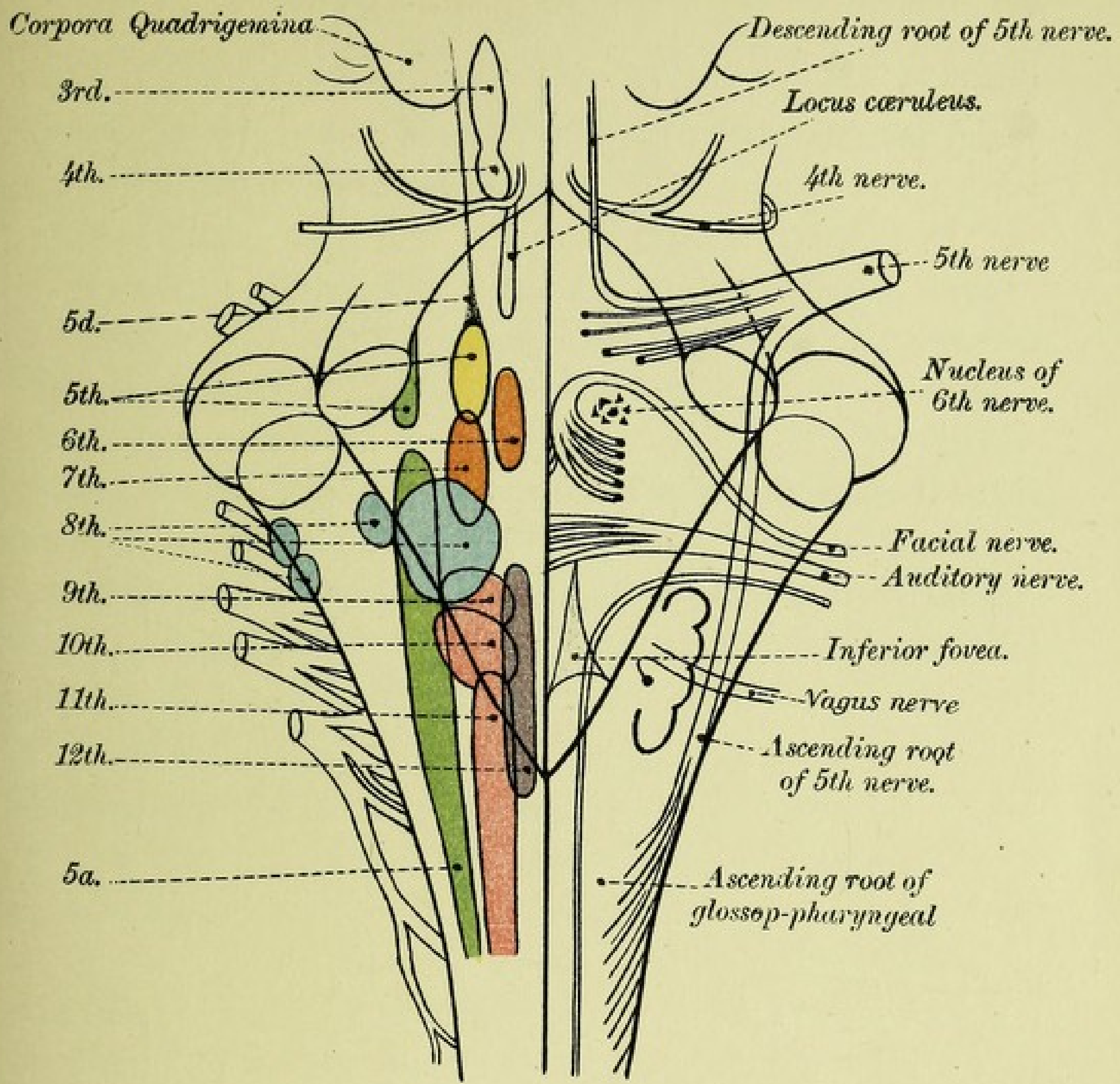
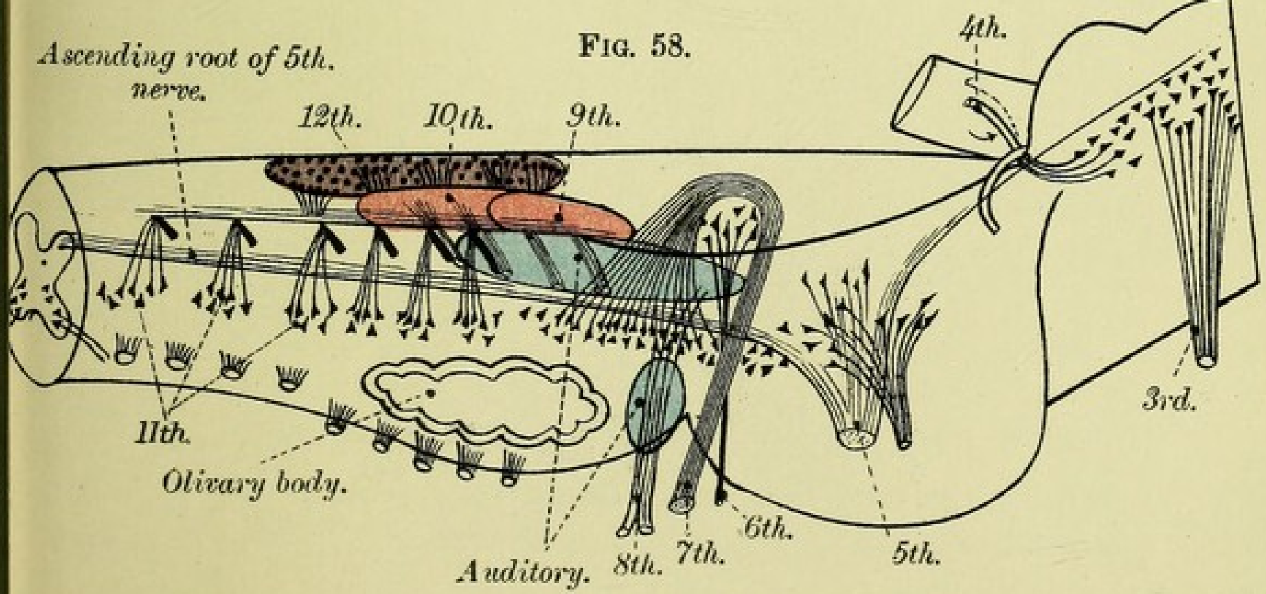


FIG. 58.



Nuclei of the cranial nerves.

The remaining nuclei—the nuclei of the several cranial nerves—will be studied in relation to the floor of the 4th ventricle (page 97).

RAPHÉ.—Above the level of the pyramidal decussation the medulla is partially divided into two lateral segments by a central median raphé or partition, which forms a thin membranous septa of nerve substance, extending from the anterior median fissure to beneath the central groove on the floor of the 4th ventricle. It consists of numerous fibres running in various directions, and interspersed with small collections of multipolar nerve cells.

In this region occurs the *superior pyramidal* or *sensory decussation* referred to at page 68. It is the sensory tract to the brain for it will be remembered that fibres can be traced from the posterior nerve roots to the nucleus gracilis and cuneatus of the posterior column. From these nuclei, fibres travel towards the anterior aspect of the medulla and decussating in the raphé, cross to the opposite side of the bulb, behind the pyramidal decussation, and, becoming longitudinal, ascend to the cerebrum in what is known as the tract of the fillet or lemniscus (fig. 96, plate 37).

Thus we see that in the medulla we have two sets of decussating fibres—(1) The *inferior pyramidal* or *motor* decussation, and (2) behind and above this the *superior pyramidal* or *sensory* decussation.

The Arciform Fibres have already been several times alluded to, so that here we shall merely collect together, for the sake of clearness, the several statements previously made. These fibres are divided into a superficial or external set and a deep or internal set.

1. The SUPERFICIAL ARCIFORM FIBRES form two groups—

(*a*) The *anterior external* arciform fibres which spring, you will remember, from the anterior median fissure, through which they can be traced to the central raphé, where they probably cross over to the posterior column of the opposite side of the medulla. Emerging from the fissure, they pass over the anterior pyramids below, and over the outer surface of the olives, across the line of origin of the 8th pair of nerves. Turning upwards, they then blend with the fibres of the direct lateral cerebellar tract, and with them form the chief part of the restiform body (fig. 50).

(*b*) The other group — the *posterior external* arciform fibres—passes from the posterior column of one side to the restiform body of the same side (fig. 99, plate 37).

2. The DEEP ARCIFORM FIBRES are a delicate network of fibres found between the olives behind the pyramids. The exact course and origin of these fibres are not yet known with certainty. Many of them are fibres derived from the nuclei of the posterior columns before mentioned (superior pyramidal decussation.) Others are fibres which, entering the centre of the olivary nucleus through its hilum, either join the cells of that nucleus, or pass through it to the restiform directly, or else first make to the surface, and then, along with the external arciform fibres, go to the restiform body.

TABLE OF GREY MATTER OF THE MEDULLA.

Cord.		*Medulla.*	
Grey Matter of the Spinal Cord.	Anterior cornu.	Head—Nucleus lateralis.	
		Neck—Anterior part of the formatio reticularis.	
		Base—Nucleus of the hypo-glossal nerve.	
	Posterior cornu.	Head—Nucleus of Rolando.	
		Neck—Posterior part of the formatio reticularis.	
		Base—	Nucleus gracilis.
			Nucleus cuneatus.
			Nuclei on floor of 4th ventricle.
Isolated grey nuclei in the medulla.		Nucleus of the olivary body.	
		Accessory olivary nuclei.	
		Nucleus of the external arciform fibres.	

Recapitulation.—Since the constitution of the medulla is so complicated, it will be well to summarise the above facts in a somewhat different order. Commencing at the anterior median fissure, we first meet on each side of that fissure—

1. The ANTERIOR PYRAMIDS OF THE MEDULLA, composed of longitudinal fibres, derived chiefly from the crossed pyramidal tract of the opposite lateral column, and from the direct pyramidal tract of the same side; they can be traced upwards through the pons and the cerebral peduncles to the cerebral hemispheres. Probably all the motor fibres coming from the brain are contained in these pyramids.

2. Superficial to the anterior pyramids are a set of fibres, which, having decussated in the middle line, pass out from the anterior median fissure, cross over the surface of the anterior pyramids and the olives to

join the restiform body. They are the *superficial arciform fibres* (figs. 55, 56), and amongst them is the ARCIFORM NUCLEUS, a collection of grey matter.

3. In the middle line behind the pyramids, between it and the central canal, are thick white bundles of fibres arranged in concentric curves. They spring from the region of the posterior columns, and form the decussation of the fillet, or SUPERIOR PYRAMIDAL DECUSSATION. Higher up in the medulla this same region is occupied by fibres which traverse the medulla in all directions—*formatio reticularis.* Neuroglia cells, and a few nerve cells are scattered amongst the fibres, many of which are known as the deep arciform fibres.

4. Outside the formatio reticularis, between it and the surface, and behind the pyramids, is the OLIVARY NUCLEUS with the OLIVARY PEDUNCLES (fig. 56). This nucleus is covered superficially by the external arciform fibres (fig. 56). Close to it are the ACCESSORY OLIVES (fig. 56).

5. Behind the olives you will see the NUCLEUS LATERALIS (figs. 53, 54), the upward continuation of the anterior cornu of the spinal cord.

6. Posterior to the nucleus lateralis appears the grey TUBERCLE of ROLANDO (figs. 53, 54), the enlarged head of the posterior horn of the spinal cord. It gives origin to the sensory fibres of the 5th nerve, which will be seen in section as a white concave band on its outer side—ascending root of the 5th nerve (fig. 54, 5th). Superficial to the tubercle of Rolando are the fibres of the DIRECT LATERAL CEREBELLAR TRACT (fig. 54), on their way, along with the arciform fibres, to the inferior cerebellar peduncles—restiform body.

7. Posterior and internal to the nucleus of Rolando is a mass of grey matter, the NUCLEUS CUNEATUS (figs. 54, 55), lying beneath the cuneate tubercle; and still nearer the middle line is another grey collection, the NUCLEUS of the FUNICULUS GRACILIS (figs. 54, 55).

In front of the nucleus cuneatus will be seen a special white rounded fasciculus, known as the *fasciculus solitarius* (fig. 55).

Close to the middle line, internal to the nucleus cuneatus, lies the nucleus of the hypoglossal nerve, from which the nerve itself may be seen running forwards to its superficial origin.

The rest of the grey matter, internal to the nucleus of the funiculus gracilis, and on each side of the posterior median groove, belongs to the floor of the 4th ventricle (fig. 57, page 78), and will be fully described with that cavity.

The next division of the brain is the pons and cerebellum.

II.—PONS VAROLII.

The **Pons Varolii** is the broad white band which crosses transversely above the upper part of the anterior aspect of the medulla oblongata, between the two halves of the cerebellum. Composed of grey and white matter, it presents an upper and a lower border; an anterior and a posterior surface. The *upper border* is arched, and from it springs the two crura cerebri or cerebral peduncles; the *lower border*, which marks the upper limit of the medulla in front, is horizontal, and is almost in contact with the upper margin of the pyramids and the olives (figs. 46, 49, page 64).

The ANTERIOR SURFACE of the pons is convex, and rests on the dorsum sellæ of the sphenoid bone. Along the middle line it presents a shallow groove, which lodges the basilar artery. At the sides it becomes narrowed, and passes as two rounded bundles, one on each side, into the cerebellum, forming its *middle peduncles.*

The POSTERIOR SURFACE of the pons has ill-defined limits. Flattened from before backwards it forms the upper part of the floor of the 4th ventricle, and will be described with that cavity (page 97).

It is interesting to note that in mammalia the size of the pons bears a direct relation to the size of the lateral lobes of the cerebellum; and that in birds, reptiles, and fishes, where we have no cerebellar hemispheres, the pons also is wanting.

When we examine transverse sections of the pons, we find that it can be divided into two portions, a dorsal portion and a ventral portion. The former, called the tegmental part, is a continuation upwards of the constituents of the spinal cord and medulla, with the exception of the pyramidal tracts. The latter, the ventral part, contains besides the proper fibres of the pons, the upward continuation of the pyramids of the medulla.

I.—WHITE MATTER OF THE PONS.

DISSECTION.—To see the arrangement of the white fibres of the pons, you will require to cut down on each side of the middle line, through the superficial transverse fibres, until you reach a longitudinal set passing upwards from the medulla. Reflect the longitudinal fibres, when a still deeper transverse set will come into view.

Fig. 59.

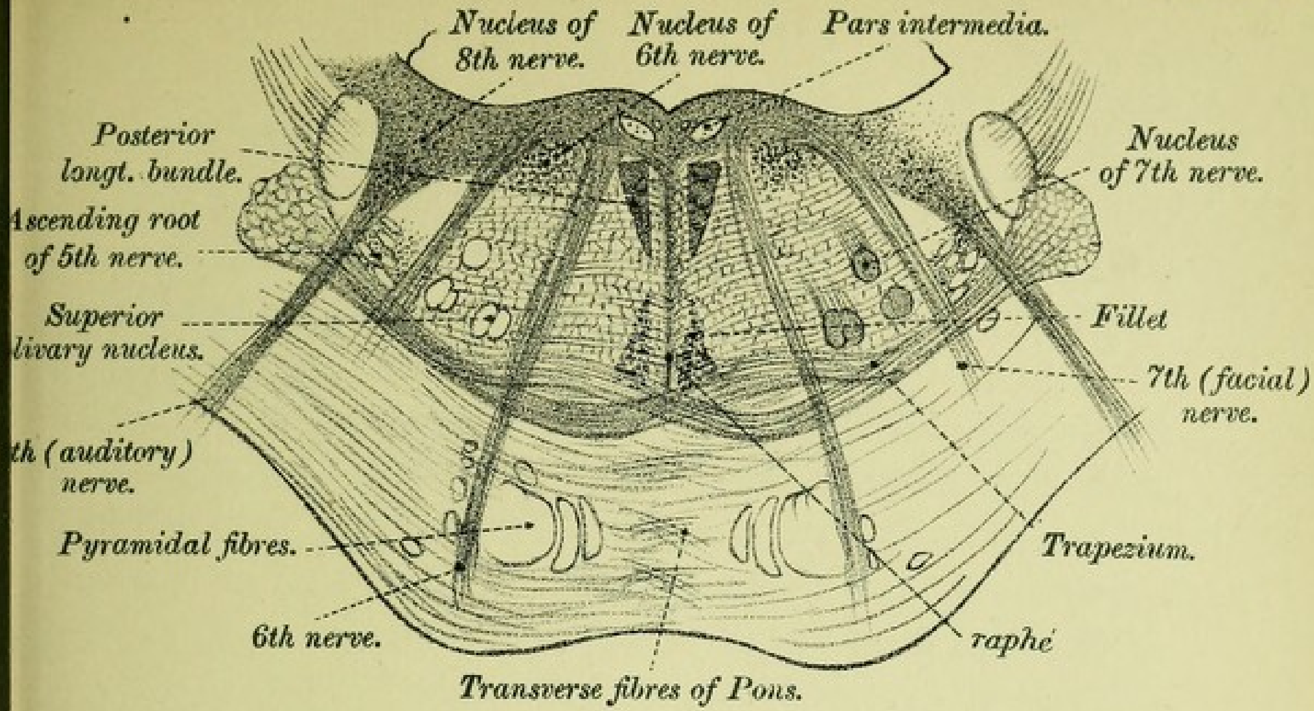


Fig. 60.

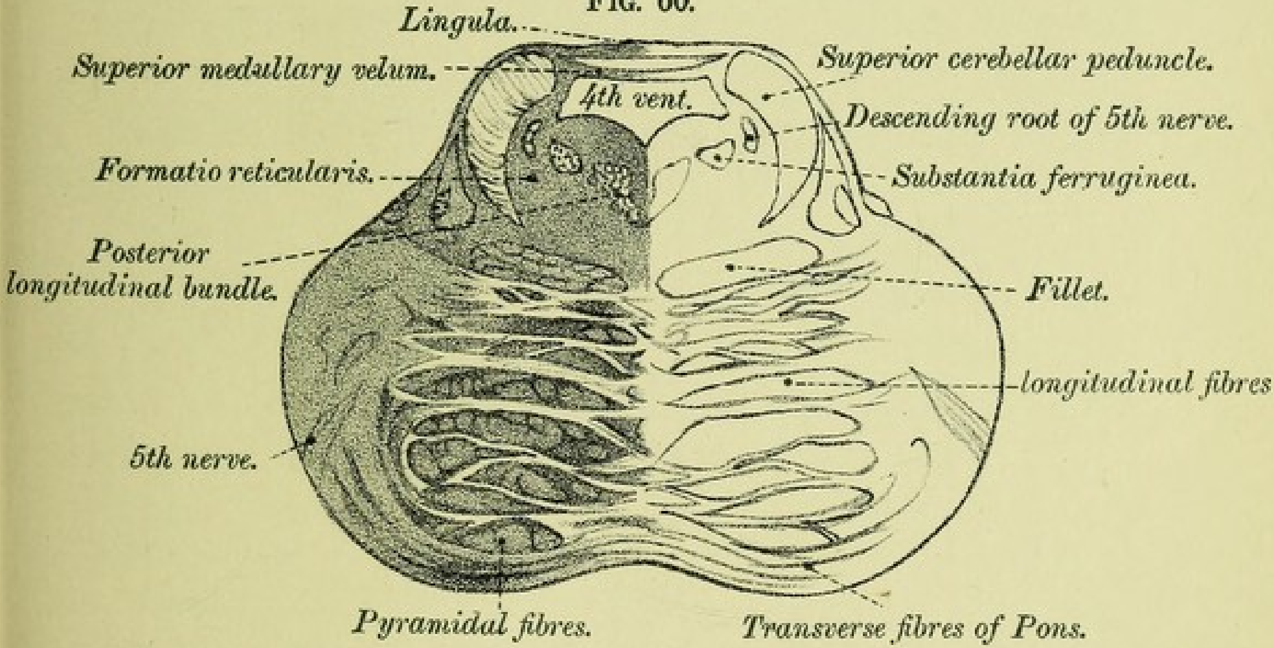
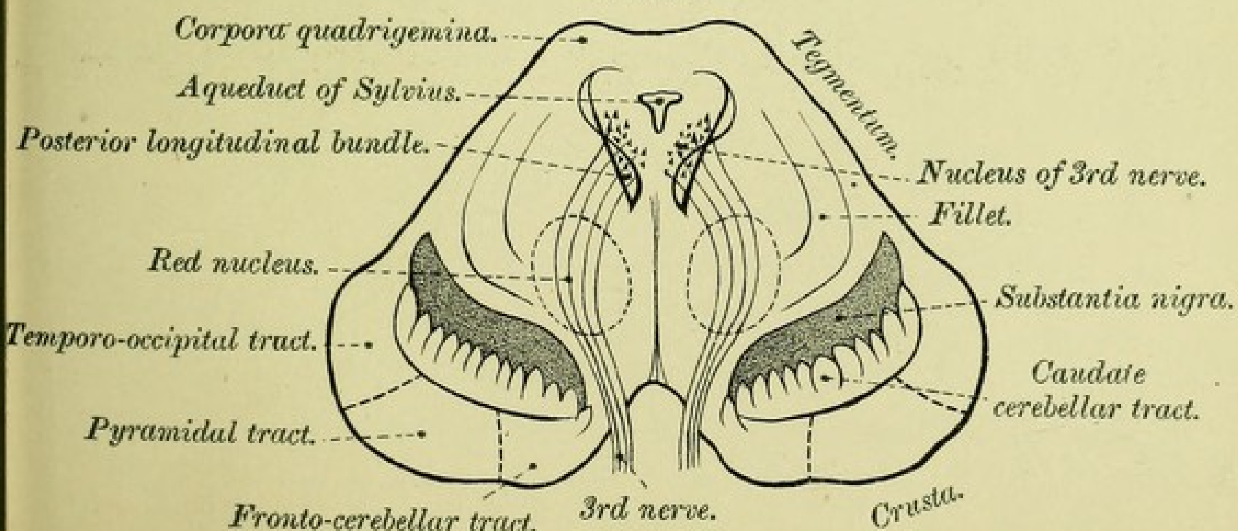


Fig. 61.



The white medullated nerve fibres of the pons are arranged in two sets, a transverse and a longitudinal, each being again divisible into a superficial and a deep group.

1. The **superficial transverse** fibres appear on the surface of the pons, and the **deep transverse** fibres lie behind the superficial longitudinal ones (figs. 59, 60, page 84). At the lower part of the pons near the medulla the deep set of transverse fibres forms a special collection, called, from their peculiar arrangement, the *trapezium* (fig. 59). Traced laterally, all the transverse fibres pass into the middle peduncle of the cerebellum.

2. The **superficial longitudinal** fibres (figs. 59, 60) are mostly the upward continuation of the anterior pyramids of the medulla, and in transverse sections are seen as two rounded bundles, behind the superficial transverse fibres, though many of them are intersected by these latter. The **deep longitudinal** bundles (figs. 59, 60) are placed near the dorsal aspect of the pons, which is chiefly made up of the formatio reticularis, and of a prolongation of the grey matter of the medulla. This longitudinal set of fibres is said to be derived from the olivary fillet, from the olivary fasciculus, and from the lateral and posterior columns of the spinal cord (see fillet and post. long. bundle, figs. 59, 60).

II.—GREY MATTER OF THE PONS.

The grey matter of the pons consists of multipolar and stellate nerve cells, either scattered or arranged in definite groups called nuclei. Thus we have—

1. The **nucleus pontis**, situated on the ventral aspect of the pons, amongst the superficial transverse

fibres. It consists of many scattered nerve cells, to which fibres from the cerebrum and cerebellum can be traced. These fibres come from the cerebrum of the one side, join these nerve cells of the pons, and then cross over, and go by the middle peduncles, to the opposite half of the cerebellum. They are called the cerebellar tract of the crura cerebri.

2. The **superior olivary nucleus** is (fig. 59) placed on the dorsal part of the pons, behind the trapezium and some little distance from the middle line, in a region which would correspond to the prolongation of the lateral area of the medulla.

3. The **nuclei of origin** of some of the cranial nerves (5th to 9th), will be described with the upper part of the floor of the 4th ventricle (page 97).

A typical transverse section of the pons will further show you the following structures (fig. 59)—

1. The facial nerve.
2. The small intermediate part of the facial nerve.
3. The nucleus of the facial nerve.
4. The large upper nucleus of the auditory nerve.
5. The large nucleus of the 6th nerve.
6. The grey substance of Rolando, with the ascending root of the 5th nerve.

Raphé of the Pons.—Behind the trapezium, and beneath the median groove on the floor of the 4th ventricle, lies a central raphé (fig. 59), the continuation of the raphé of the medulla, and like it composed of fibres, partly nervous and partly neuroglia, which cross each other in every direction.

III. CEREBELLUM.

The **Cerebellum** or Little Brain occupies the two lower fossæ of the occipital bone, and lies beneath the level of the tentorium cerebelli, which separates it from the posterior part of the cerebral hemispheres. Ellipsoidal in shape, it consists of a median division, called, from its worm-like appearance, the VERMIFORM PROCESS, and of two lateral divisions, the CEREBELLAR HEMISPHERES. By its three *Peduncles* — superior, middle, and inferior—it is brought into relation to the cerebrum, to the pons, and to the medulla and spinal cord. The median division, the vermiform process, though incorporated with the rest of the cerebellum, is quite a separate division of the little brain. This is shown by the fact that it is the only part of the cerebellum which is developed in birds, in reptiles, and in fishes. Even in many mammals the central lobe is much larger than the lateral ones.

The CEREBELLAR HEMISPHERES present two surfaces, an upper and a lower, separated from each other by a definite margin, round which runs a well-marked cleft, the GREAT HORIZONTAL FISSURE. They are darker in colour than the hemispheres of the cerebrum, and consist of numerous crescentic laminæ of grey matter with their convexities backwards (fig. 62, page 88).

The *upper surface* of each cerebellar hemisphere is concave, but along the middle line runs a slightly raised ridge, with a shallow groove on each side, indicating the position of the SUPERIOR VERMIFORM PROCESS. On this aspect the two hemispheres are continuous with each other across the middle line, there being no definite line of demarcation between them (fig. 62).

The *under surface* of the hemispheres, on the other hand, is divided into two lateral convex halves by a wide median groove or hollow, the VALLECULA, in which you will see the INFERIOR VERMIFORM PROCESS. Posteriorly, the hemispheres are separated by a notch, INCISURA CEREBELLI POSTERIOR, which receives the free anterior margin of the falx cerebelli, and in front is a wider notch, the INCISURA CEREBELLI ANTERIOR, which lodges the Pons Varolii and Medulla.

I. LOBES OF THE CEREBELLUM.

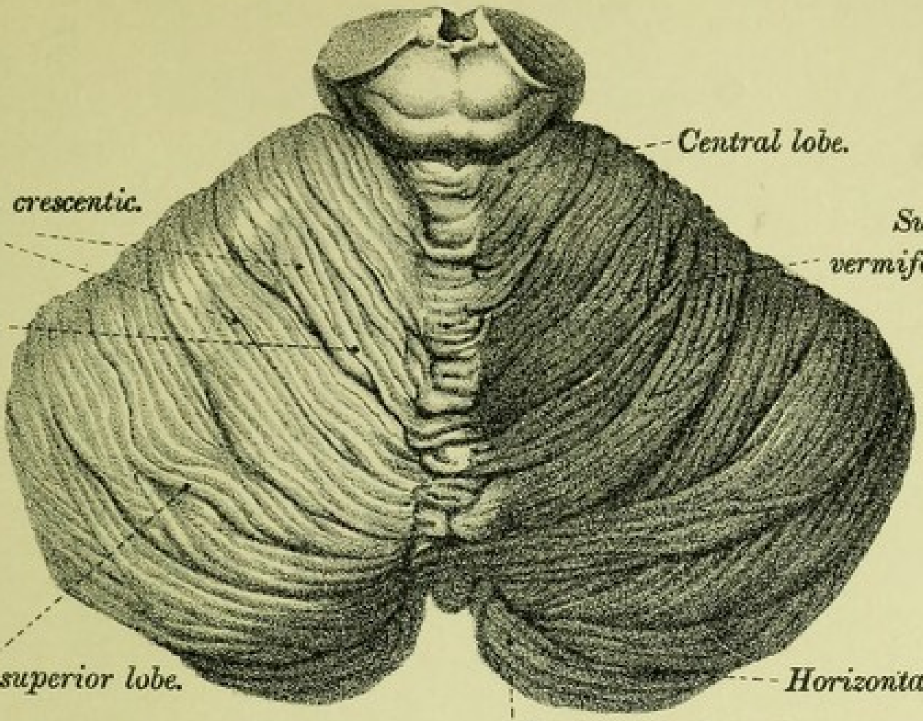
The surfaces of the cerebellar hemispheres have a laminated appearance, for they are broken up by numerous transverse furrows, varying in depth, into crescent-shaped folia, which have been grouped together under special names, though it must be confessed that the lobes they form are often exceedingly ill-defined, and are of little or no practical importance. A tabular list of them is here given for the purpose of reference.

1. On the *upper surface* of the cerebellar hemispheres are:—

(1) The CENTRAL LOBE (fig. 62), situated near the centre of the anterior margin, and consisting of a few folia, which are continued upwards on to what is known as the superior medullary velum, to be presently described.

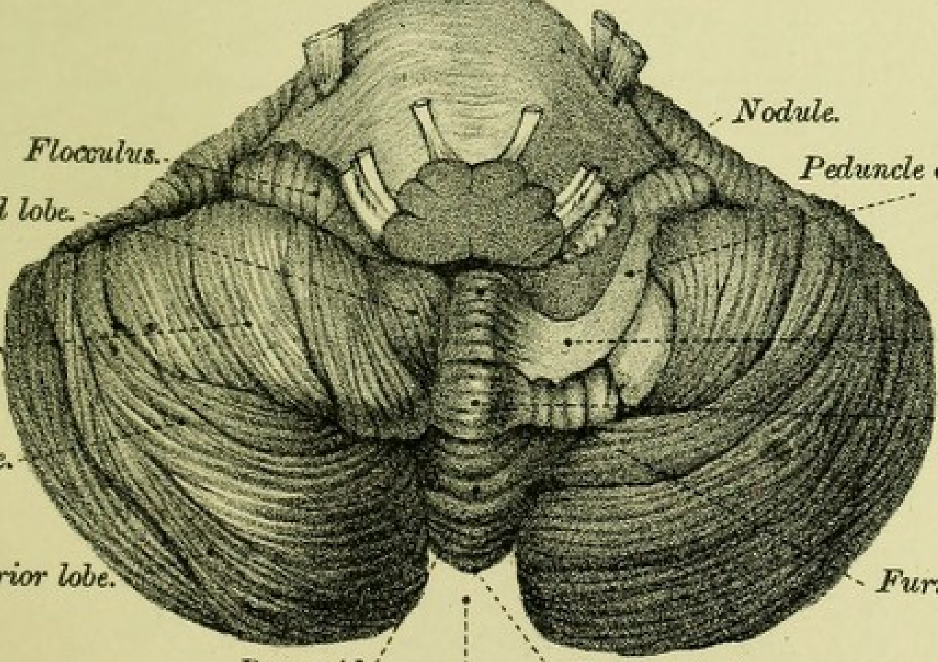
(2) The ANTERIOR SUPERIOR and (3) the POSTERIOR SUPERIOR LOBES (fig. 62), are separated from each other by a more or less distinct sulcus, which arches transversely across the surface of each hemisphere. The anterior superior is often called the QUADRATE LOBE, and is divided into an anterior portion named

FIG. 62.



UPPER ASPECT OF CEREBELLUM.

FIG. 63.



LOWER ASPECT OF THE CEREBELLUM.

the *anterior crescentic,* and a posterior portion, the *posterior crescentic* (fig. 62). Each of the lobes on the upper surface is continuous across the superior vermiform process with the corresponding ones on the opposite side.

2. On the *under surface* of the hemispheres the lobes are better marked, and more easily distinguished from each other than those of the upper surface (fig. 63). Enumerated from behind forwards they are :—

(1) The POSTERIOR INFERIOR LOBE.
(2) The SLENDER LOBE.
(3) The BI-VENTRAL LOBE.
(4) The AMYGDALOID LOBE.
(5) The FLOCCULUS.

3. On the *Superior Vermiform Process* the lobes are—an anterior, the LOBULUS CENTRALIS; a middle, the MONTICULUS CEREBELLI; and a posterior or COMMISSURA SIMPLEX.

4. On the *Inferior Vermiform Process*—

(1) The TUBER VALVULÆ (fig. 63), placed between the posterior inferior and the slender lobes of opposite sides.

(2) The PYRAMID (fig. 63), between the bi-ventral lobes.

(3) The UVULA (fig. 63) between the tonsils and connected with them by a grey band, called, from its ridged appearance, the *furrowed band* (fig. 63).

(4) The NODULE (fig. 63) or *laminated tubercle,* the pointed anterior end of the inferior vermiform process. It is placed between the

flocculi, and, projecting into the roof of the 4th ventricle, is continuous with the inferior medullary velum (page 92).

II.—PEDUNCLES OF THE CEREBELLUM.

The **Peduncles of the Cerebellum** are three for each hemisphere, the superior, the middle, and the inferior. They severally connect the cerebellum (1) to the pons—crura ad pontem; (2) to the medulla—crura ad medullam; and (3) to the cerebrum—crura ad cerebrum.

1. The **Superior Peduncles** (fig. 47, page 64), are hidden beneath the anterior part of the cerebellum, and to see them you will require to divide the cerebellum by a vertical median incision, and to draw the parts asunder. The crura ad cerebrum or superior peduncles arise in the middle of the white substance of the hemispheres, behind the inferior cerebellar peduncles, and running upwards and forwards to the under surface of the corpora quadrigemina, pass to the dorsal or tegmental part of the cerebral peduncles. At first the superior peduncles form the lateral wall of the upper part of the 4th ventricle, leaving a triangular interval between them which is bridged over by a lamina of nerve substance, the SUPERIOR MEDULLARY VELUM (fig. 48). They then meet in the middle line above, and form part of the roof of the 4th ventricle. The fibres of which they are composed come from the corpus dentatum of the cerebellum and from the cerebellar convolutions, and go to the higher parts of the brain.

2. The **Middle Peduncles** (figs. 49, 64, page 92) of the cerebellum, crura ad pontem, are best seen in front, where they form two transverse white bands between the cerebellar hemispheres. Emerging from the lateral part of the white centre of the hemispheres, in front of the inferior peduncles, they pass towards the middle line and form the superficial and deep transverse fibres of the pons Varolii. Some of these fibres pass to the opposite cerebellar hemisphere, others become connected with nuclei in the pons—*nucleus pontis*—and can thence be traced to the opposite cerebral hemisphere (see page 85).

3. The **Inferior Peduncles** (fig. 47, page 64) of the cerebellum, crura ad medullam, or restiform bodies, constitute one of the boundaries of the lower part of the 4th ventricle, and then pass upwards between the superior and middle peduncles into the white matter of the cerebellar hemispheres. Their constitution is somewhat complex for they consist of a *spinal part*, and of a *olivary part.*

(1) The Spinal part is composed of fibres—

(*a*) From the lateral column of the same side —lateral cerebellar tract.

(*b*) From the posterior column of the same side, through a set of fibres called the posterior external arciform fibres (fig. 99, plate 37).

(*c*) From the posterior column of the opposite side, through the anterior external arciform fibres (fig. 99).

(2) The Olivary part.—The restiform body receives fibres from the opposite olives—the fibres passing from, say, the right olive to the left, and thence to the restiform body—cerebello-olivary fibres (fig. 99, page 146; see also page 78).

Thus it will be seen that the peduncular fibres along with commissural bands passing from one hemisphere to the other, constitute the entire white core of the cerebellum.

III.—MEDULLARY VELA.

1. The **Superior Medullary Velum**—Valve of Vieussens (figs. 48, 60, pages 64, 84)—is a delicate sheet of nerve substance placed across the triangular interval left between the superior cerebellar peduncles before they meet in the middle line. Triangular in shape with its apex forwards, it consists of a white lamina crossed on its upper surface by several transverse grey ridges, with intervening furrows, called the LINGULA (fig. 60, page 84), not to be confounded with the *ligula* (fig. 48, page 64), the epithelial thickening along the lower margin of the 4th ventricle. The white and grey matter of the superior medullary velum are continuous at the sides with the white and grey matter of the cerebellar hemispheres.

2. The **Inferior Medullary Velum**—valve of Tarini—consists of two thin delicate semilunar folds or laminæ of nerve substance, one on each side, hidden beneath the amygdaloid lobes, which must be removed with great care to see them. By their inferior (or posterior) convex border, each of these semilunar folds blends with the white substance of the inferior vermiform process and the furrowed band; their anterior concave semilunar edge is free, or rather continuous with the layer of epithelium which lines the under surface of the pia mater which roofs over the 4th ventricle. At the sides these semilunar folds

PLATE XXI.

(page 92).

Fig. 66—Section through the Cerebellum of a dog, showing arrangement of the different layers.

A. Layer of superficial epithelial cells.

B. Horizontal bipolar cells.

C. Molecular layer.

D. Granular layer.

a. Epithelial cells.

b. Horizontal bipolar cells.

c. Triangular cells.

e. f. g. Vertical bipolar cells.

h. Purkinjé's cells on the axis-cylinder of which is a collateral (*i*), which ascends to the molecular layer and breaks up into branches.

j. n. o. s. Fibres from the medullary layer, ramifying like trees amongst Purkinjé's cells.

r.p. Moss fibres.

Plate XXI.

FIG. 64.

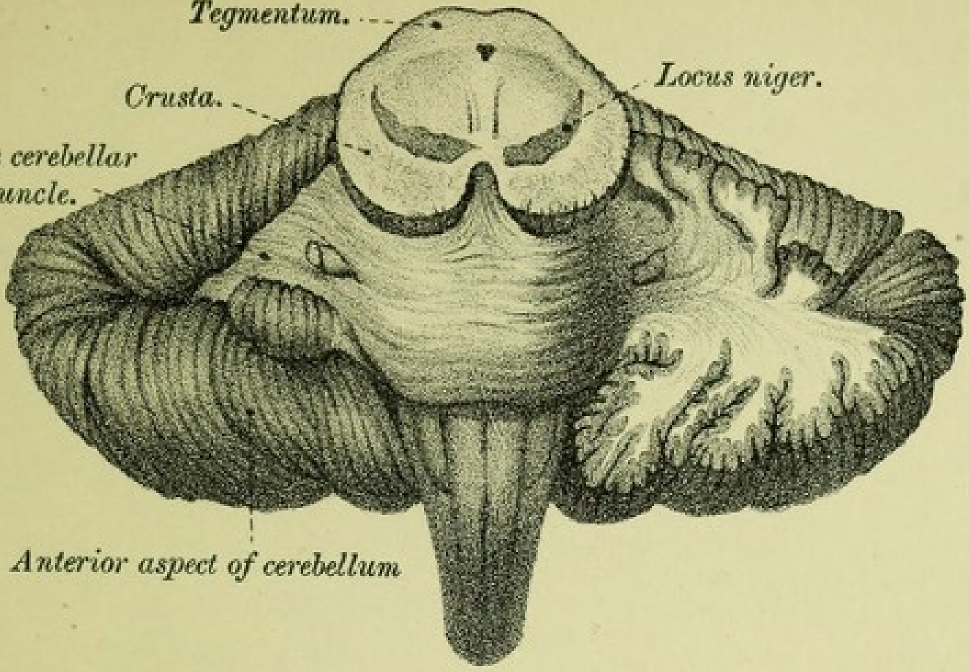


FIG. 65.

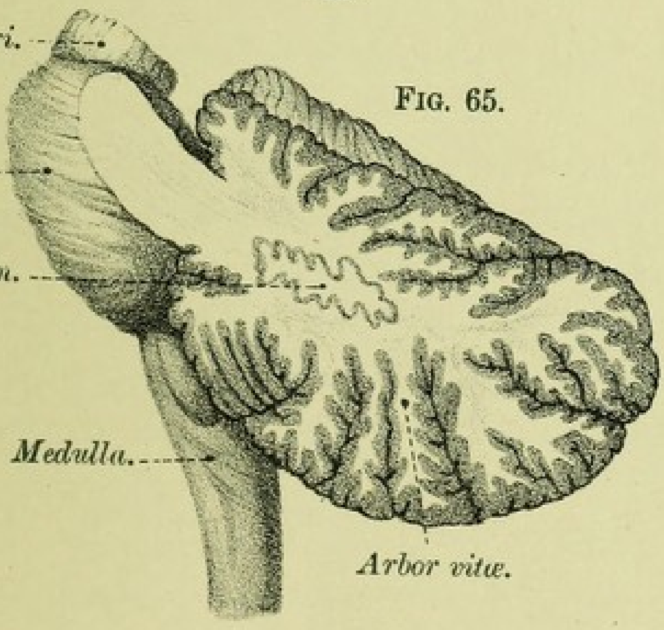


FIG. 66.

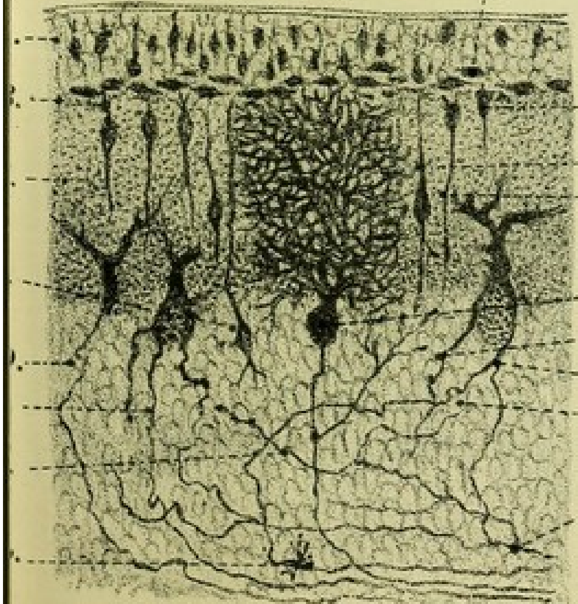


FIG. 67.

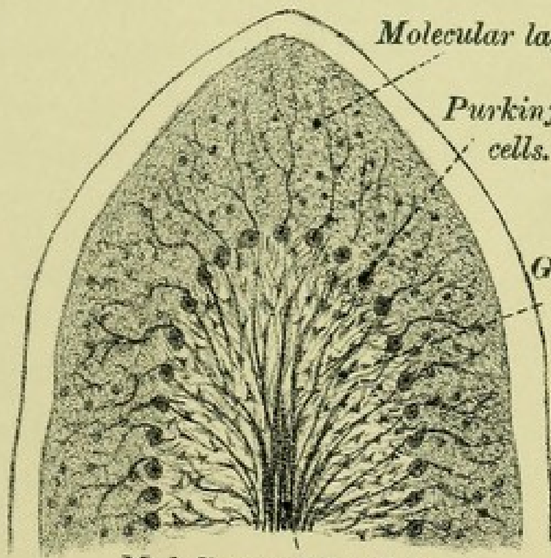


DIAGRAM OF LAYERS OF CEREBELLUM.

are attached, externally, by a white band or peduncle to the flocculus; internally, they blend with the nodule the pointed anterior end of the inferior vermiform process. Beneath this nodule the two halves of the velum are continuous with each other (fig. 63, page 88).

IV. GREY MATTER OF THE CEREBELLUM.

The grey matter of the cerebellum consists of two parts, that on the surface—the *cortex cerebelli;* that in its interior—the *grey nuclei.*

1. The grey matter of the *cortex* of the cerebellum not only covers its surface but lines the sides and passes across the bottom of its various fissures or sulci, so that in reality it forms a thin lamina folded on itself in a series of leaves or plates. A mesial vertical section will enable you to see this arrangement, and will show you the beautiful tree-like appearance, ARBOR VITÆ, of the grey and white matter (fig. 34, page 46, and fig. 65, page 92).

2. The chief masses of grey matter in the *interior* of the the cerebellar hemispheres are the CORPORA DENTATA placed one in each hemisphere. In structure they are similar to the corpus dentatum of the olivary body, and are, as you will remember, closely connected with it. They each consist of a wavy band of brown coloured nerve-substance enclosing white matter, the whole forming a pouch-like wavy lamina or capsule open at its upper and inner side (fig. 65). Through this opening, bundles of white nerve fibres pass into the centre of the corpus dentatum, and can be traced from the superior cerebellar peduncles, from the superior medullary vellum, and from the restiform body.

The other nuclei are the roof nuclei of Stilling, which lie beneath the central lobe of the superior vermiform process; and the nucleus globosus, the nucleus emboliformis, and the nucleus fastigii, which are, however, of minor importance.

Minute Structure of the Grey and White Matter of the Cerebellum.

I. Grey Matter.—The grey cortex of the cerebellum consists of three layers—(fig. 68, page 96; and figs. 66, 67, page 92).

(1) An *outer*—the molecular layer.
(2) A *middle*—the layer of Purkinjé's cells.
(3) An *inner*—the granular layer.

1. The **outer layer** — *molecular layer*—forms a clear grey stratum on the surface of the cerebellum. It is composed of a delicate matrix of neuroglia, and of nerve cells and nerve cell processes. The nerve cells are of two kinds—

(1) *Small cells,* multipolar, with many protoplasmic processes, but no axis-cylinder process.

(2) *Large cells*—placed at the deeper part of the molecular layer. They are transversely elongated, and have—

(*a*) *Protoplasmic processes,* which ramify towards the surface of the cortex; and

(*b*) An *axis-cylinder process,* which runs transversely between the molecular and granular layers, and gives off branches at right angles to its direction. These branches encircle the bodies of the cells of Purkinjé, forming basket-like networks around them—hence they are called *basket-cells* (fig. 68).

2. The **middle layer** is formed of cells which are characteristic of the grey matter of the cerebellum. They are called the CELLS OF PURKINJÉ (fig. 68), or from their shape ANTLER CELLS, and are large flask-shaped cells set at right angles to the surface of the cerebellum. Their larger ends are the deeper, and give off a single slender process — the axis-cylinder process, which sends off lateral branches. Some of these pass into the molecular layer, some spread out in the granular layer. The outer process of the cells is much larger, and breaks up into leaf-like branches, like the horns of a deer, hence the name antler cells. These branches are called protoplasmic processes, and form a rich plexus, ramifying towards the surface. These ramifications do not, however, anastomose with each other, nor with the processes of other cells, though some of them are said to be attached to the connective tissue, and to the blood-vessels, at the margin of the molecular layer.

3. The **inner or granular layer**—*rust-coloured layer* of Turner—consists of nerve cells and neuroglia cells embedded in a delicate matrix of fine interlacing fibrillæ.

Its nerve cells are of two kinds—

(1) The *small granular cells*, polyhedral in shape, whose protoplasmic processes end in little tufts of short thick branches (fig. 68). Their axis-cylinder process is very slender, and arises either from the body of the cell, or at a little distance from it, from one of the protoplasmic processes. It passes with an undulating course towards the molecular layer, where it ends in two branches which run parallel to the lamellæ of the cerebellum.

(2) *Large granular cells* which are found throughout the thickness of the granular layer; they have axis-cylinder and protoplasmic processes, the former giving off collaterals.

II. White Matter. — The white matter of the cerebellum consists of three kinds of fibres—(fig. 69).

1. The axis-cylinder processes of the cells of Purkinjé already described.

2. Fibres which, on reaching the grey matter, divide frequently, and at this point, or at some other part of their course, form little mossy tufts of short, thick branches—hence, they are called *moss fibres* (fig. 69).

3. A set of fibres which end in a plexus in the molecular layer, and appear to be prolongations of Purkinjé's cells, though not so in reality (fig. 69, f. p.).

Throughout the white matter, moreover, there are many neuroglia cells with their prolongations.

The functions of the cerebellum are as yet unknown, but the classical experiments of Fluorens point to the fact that it is a centre for the co-ordination of muscular movements, such as walking, etc. Later experiments published in Dr Courmont's thoughtful and interesting work on the "Cerebellum and its Functions" (Paris 1891), show that the cerebellum is also an organ connected with the emotions. He, moreover, produces many facts of comparative anatomy in support of his theory, and adduces a formidable mass of clinical evidence showing that, in cases of disease (tuberculosis, etc.) of the cerebellum, the emotional side of the patient's character is markedly affected, whereas the intellectual side remains intact.

PLATE XXII.

(page 96).

Figs. 68 and 69 are diagramatic views after Van Gehuchten, Professor of Anatomy, University of Louvain, of the various kinds of nerve fibres and nerve cells and neuroglia cells found in the Cerebellum. The circle represents the free surface.

Fig. 68—*P. c.* Purkinjé's cells.
s.c.m. Small cells of the molecular layer.
l.c.m. Large cells of the molecular layer.
l. g. c. Large cells of the granular layer.
s. g. c Small cells of the granular layer.
n. c. Neuroglia cells.

Fig. 69—*a.c.* Axis cylinder process of Purkinjé's cells with Collaterals, one of which ascends to the molecular layer.
m. f. Moss fibres.
f. p. Fibres which end in a plexus.

Fig. 69. Plate XXII.

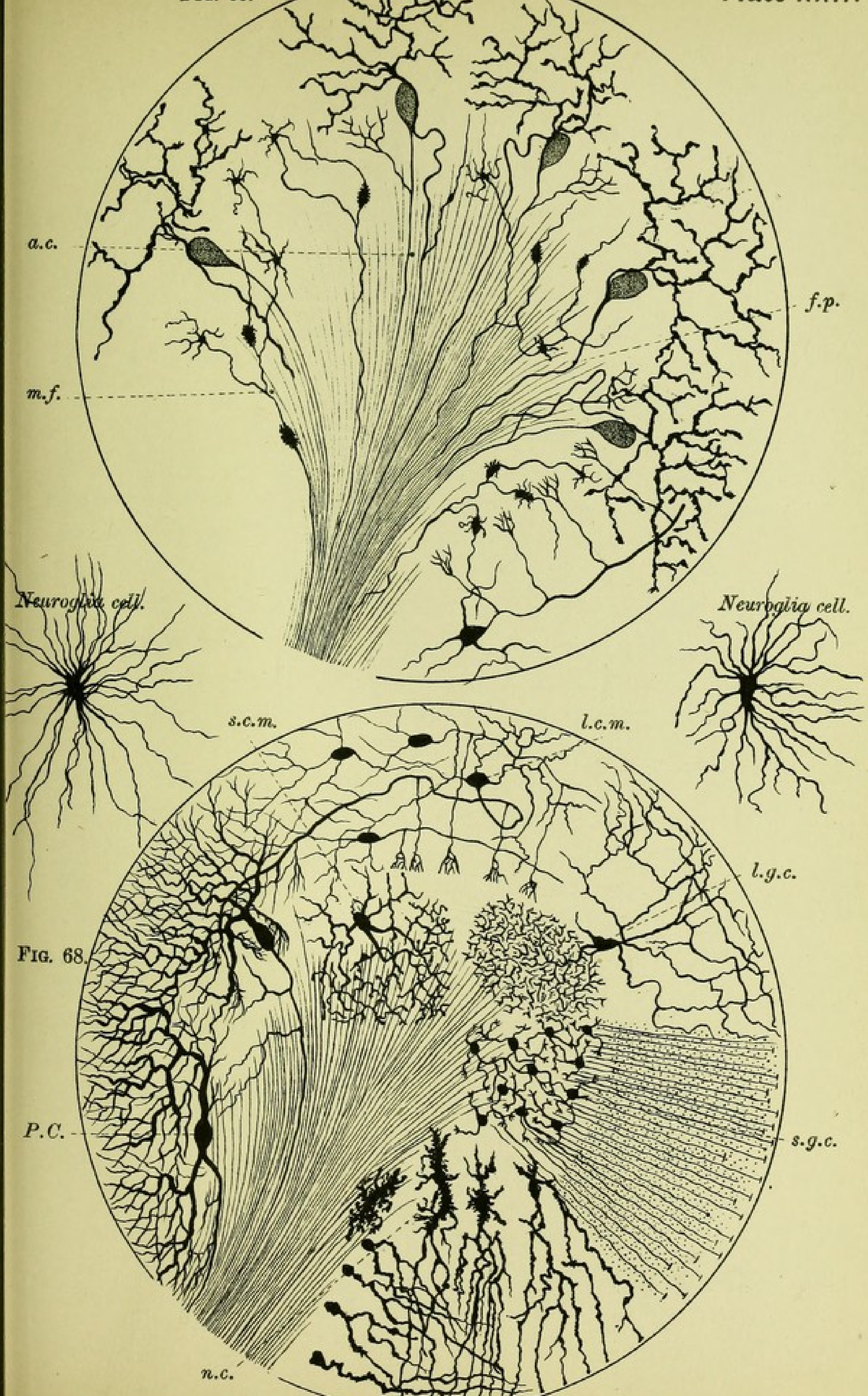


Fig. 68.

THE 4th VENTRICLE:

ITS POSITION, FLOOR, ROOF, WALLS, AND NUCLEI.

The **4th Ventricle** is a conical shaped space placed between the medulla and pons in front and the cerebellum behind. It has a quadrilateral floor and a tent-like roof, and is lodged in the fore-part of the valleculla on the under surface of the cerebellum. We shall require to examine (1) its floor, (2) its lateral boundaries, (3) its roof, (4) its lining, (5) the openings into it, (6) its choroid plexus, and (7) the various collections of grey matter or nuclei beneath the floor.

I. The Floor or Anterior Wall of the 4th Ventricle (fig. 47, page 64) is a diamond-shaped depression of the figure of an heraldic lozenge, and resembles two triangles placed base to base. It looks backwards, and its lower part occupies the back of the medulla; its upper part the back of the pons. Its formation is due to the separation of the walls of the posterior median fissure of the spinal cord, and the consequent opening out of the central canal or ventricle of the cord, thus bringing the grey matter round that canal to the surface. Of the four angles, two are lateral, right and left, and mark the widest transverse diameter of the ventricular floor; of the other two angles, the superior is on a level with the upper border of the pons, the inferior with the lower border of the olivary body. From some supposed likeness to a writing pen the apex of the lower part of the ventricular floor has been called the "calamus scriptorius." At the lateral angles the space is prolonged for a short distance between the cerebellum and medulla, the prolongations being called lateral recesses. Running across the widest part of the ventricular floor, opposite the lateral angles, are the STRIÆ ACUSTICÆ (fig. 47), which join the auditory nerve, and which, you will remember, mark the upper limit of the medulla on this aspect. They also serve to divide the ventricular floor into two divisions, a lower or medulla portion and an upper or pons portion (figs. 47, 50), both of which are again sub-divided by the vertical median groove that runs from the superior to the inferior angle into two lateral segments. Thus we get the entire ventricular floor marked out into four divisions, two above and two below the striæ acusticæ (fig. 47). On examining each of the lower divisions you will see, at about their centre, a small triangular depression called the INFERIOR FOVEA (fig. 47), the base of which is directed downwards, the apex upwards and in close contact with the striæ; while its inner and outer margins are prolonged downwards as two grooves, the inner until it meets the central median furrow near the lower angle of the ventricle, and the outer until it reaches the lateral wall of the cavity. Thus we find that each part of the lower division of the ventricular floor can be mapped out into four distinct areas.

1. One enclosed within the sides of the triangular depression—the *inferior fovea* (figs. 47, 50).

2. A raised area, which forms the lower part of the *fasciculus or eminentia teres,* often called the trigonum hypoglossi. It lies between the median furrow and the inner margin of the fovea (fig. 47).

3. The *tuberculum acusticum* enclosed between the lateral wall and the outer margin of the fovea (fig. 47).

4. The *ala cinerea* with the *eminentia cinerea,* placed below the base of the inferior fovea (fig. 47).

In like manner each of the two upper segments of the ventricular floor, which differ from those of the lower half in being covered by a thin layer of white matter, has a similar triangular depression (figs. 47, 50), the ANTERIOR FOVEA, between which and the central furrow is a prolongation of the fasciculus teres (fig 47). Extending from the apex of this fovea to the upper angle of the ventricle is a shallow depression which, from its dark aspect, is called the *locus cœruleus* (fig 47); the colour being due to a mass of pigmented nerve-cells (substantia ferruginea) lying beneath.

II. **Lateral Walls of the 4th Ventricle.**—The lateral boundaries of the lower half of the ventricular cavity is formed below by (*a*) the FUNICULUS GRACILIS and its CLAVA (figs. 48, 50); (*b*) higher up, by the tapering end of the FUNICULUS CUNEATUS (figs. 48, 50); and (*c*) highest of all by the RESTIFORM BODY or inferior peduncle of the cerebellum (figs. 48, 50). The boundary of the upper division of the floor is the SUPERIOR CEREBELLAR PEDUNCLES (fig. 48) of each side.

III. The **Roof of the 4th Ventricle.**—The lower half of the ventricular cavity is roofed over by the pia mater which at this point is reflected from the cerebellum to the back of the medulla. It is, however, deficient in the middle line—a hole, called the *foramen Majendie,* being left in the roof. Its under surface is lined by a layer of flattened epithelial cells, and a thickening of this epithelium at the lower angle of the ventricle is called the *obex* (fig. 48, page 64). A similar thickening, with the addition of a little white nervous matter, skirting the side of the lower half of the floor is called the *ligula* or *tœnia* (fig. 48). The roof of the upper portion of the ventricle is formed partly by the SUPERIOR CEREBELLAR PEDUNCLES after they meet in the middle line; and partly by the SUPERIOR and INFERIOR MEDULLARY VELA, laminæ of grey and white matter already described (page 92).

IV. **Ependyma Ventriculorum.**—The floor of the 4th ventricle is covered by a layer of grey matter—the *ependyma ventriculorum* — consisting of neuroglia derived from the central grey nucleus round the canal of the spinal cord. Upon this ependyma lies a layer of ciliated epithelial cells continuous with the epithelium lining the central canal of the spinal marrow, and the third and lateral ventricles of the brain.

V. **Openings into the 4th Ventricle.**— At the superior angle, the 4th ventricle communicates by a narrow channel, AQUEDUCT of SYLVIUS (iter a tertio ad quartum ventriculum) with the THIRD VENTRICLE (fig. 80, page 122); below, at the inferior angle, the cavity is continuous with the CENTRAL CANAL of the SPINAL CORD; behind, at the lower part of the roof, just above the inferior angle, by a small rounded opening, the FORAMEN of MAJENDIE, with the SUBARACHNOID SPACE (fig. 34, page 46); while at each side, near the lateral angles, are similar openings in the roof, between the cerebellum and medulla and behind the roots of the glosso-pharyngeal nerve. Through these openings the cerebro-spinal fluid can find its way from the subarachnoid space into the cavities of the brain and spinal cord.

VI. **Choroid Plexus.**—The choroid plexus of the 4th ventricle consists of two longitudinal vascular folds attached to the under surface of the pia mater over the roof of the 4th ventricle. These vascular fringes run along each side of the middle line of the roof projecting into the ventricle, though covered everywhere on their under surface by the epithelium of the roof, which follows all their windings and folds, and separates them from the cavity of the ventricle. Part of this plexus passes, as a vascular tuft, into each lateral recess.

VII. **Grey Matter or Nuclei beneath the Floor of the 4th Ventricle.**—Connected with the grey matter of the floor of the 4th ventricle we have the nuclei of origin of several of the cranial nerves, as well as certain physiological centres—such as the vaso-motor, respiratory, and cardiac (page 156).

1. Nuclei beneath the *lower division* of the ventricular floor (figs. 57, 58, page 78).

(1) The first of these nerve nuclei lies beneath the lower part of the surface prominence known as the *fasciculus teres,* which skirts the median furrow on the ventricular floor. This prominence, which not only occupies the lower part of this area, but also passes up under the striæ acusticæ, gives origin in its lower part to the 9th nerve, and is hence called the HYPO-GLOSSAL NUCLEUS; and in sections of the medulla at this level the fibres of the nerve may be seen running out from this nucleus towards the periphery (figs. 55, 57, pages 74, 78).

(2) The *tuberculum acusticum,* corresponding in position to tubercle of Rolando, covers the PRINCIPAL

AUDITORY NUCLEUS (figs. 57, 58). It extends beneath the striæ into the upper division of the ventricular floor (figs. 57, 58).

(3) The *ala cinerea* and its *eminentia* contain the nuclei of origin of several nerves; thus, in its lower part, we have the nucleus of the SPINAL ACCESSORY NERVE (fig. 57); in its upper part, and extending into the inferior fovea, are the NUCLEUS of the VAGUS below (fig. 57), and of the GLOSSO-PHARYNGEAL above (fig. 57).

2. The nuclei beneath the *upper division* of the ventricular floor, are the following:—

Close to the lateral recesses, are the SENSORY and MOTOR NUCLEI of the 5TH NERVE, the motor being internal, the sensory external (fig. 57). The nucleus of the 6TH NERVE (figs. 57, 58) lies under the fore part of the fasciculus teres, superficial to but higher up and nearer the middle line than the nucleus of the 7th; the 7TH NERVE (FACIAL part) is placed deeper, and internal to the 5th, but external to the 6th nerve (fig. 57). The outer or accessory nucleus of the AUDITORY PART of the 7TH lies external to the facial part.

These various nuclei will be again referred to in the section on the Superficial and deep Origins of the Cranial Nerves (page 151).

IV.—THE CEREBRUM.

General Outline.—In man the CEREBRUM is by far the largest division of the brain, and weighs on an average from 46 to 53 oz. Above, it occupies the vault of the cranium; below, at its base, it is lodged in front within the anterior and middle cranial fossæ;

but behind, it rests on the upper surface of the tentorium cerebelli. An egg-shaped mass of nervous substance, it is larger behind than in front, and is partly separated by the great longitudinal or *inter-hemispherical* fissure into two halves—the CEREBRAL HEMISPHERES—which are ovoid in shape and are each composed of a white stalk or peduncle, surmounted by a convoluted grey crust, mapped out by furrows or SULCI into a series of larger or smaller folds called CONVOLUTIONS. These hemispheres are united to each other across the middle line by a thick band of white matter called the corpus callosum.

Internally, the cerebrum consists of strands of white nerve fibres and of GANGLIONIC MASSES and COMMISSURES; and its centre is hollowed out into a large cavity, subdivided by partitions into smaller spaces called VENTRICLES.

We shall describe—(1) the EXTERIOR or cortex of the cerebrum, with its FISSURES, LOBES, and CONVOLUTIONS; (2) the BASE; and (3) the INTERIOR, with its VENTRICLES, GANGLIA, and COMMISSURAL BANDS.

I. EXTERIOR OF THE CEREBRUM.

The outer surface of the cerebrum is known as the great hemispherical ganglion, cortex, or bark of the brain. Its upper part is called the mantle or pallium; its basal part, the rhinencephalon * (Turner).

Each hemisphere presents three surfaces—an outer convex; a mesial, plane and vertical; and an irregular under surface or base. Examine—(1) the fissures, and (2) the lobes and convolutions.

* The Rhinencephalon consists of an olfactory bulb, a crus, and a lobus hippocampi.

1. Fissures of Cerebral Hemispheres.

Of the **Fissures** of the hemispheres the largest and most evident subdivide the surface of the cerebrum into lobes, and may be called INTER-LOBULAR; the smaller fissures — INTRA-LOBULAR — divide the lobes into convolutions, which, in most cases, have received definite designations.

1. The **Interlobular Fissures** are the FISSURE of SYLVIUS; the FISSURE of ROLANDO; and the PARIETO-OCCIPITAL FISSURE.

(1) The **Fissure of Sylvius,** unlike the other sulci of the hemispheres, is not a mere indentation of the cerebral cortex, but is formed by the folding upon itself of the entire cerebral substance. Beginning on the under surface of the hemisphere, at a point called the anterior perforated spot, this fissure runs upwards and outwards to the lateral aspect of the hemisphere, and there divides into two limbs, an anterior, short, *vertical*, ascending limb, and a posterior which runs horizontally backwards, hence called the *horizontal* limb (fig. 70, plate 23). Sometimes there are two short limbs, one anterior and the other vertical.

(2) The **Fissure of Rolando,** (fig. 70) found only in man and in apes, is one of the first to appear in the development of the brain. It commences above at the median longitudinal cleft or close to it, and in some cases even appears on the inner surface of the hemisphere. Descending obliquely forwards across the outer surface of the hemisphere, it ends below near the anterior part of the horizontal limb of the fissure of Sylvius, but in most cases falls short of that fissure.

FIG. 70.

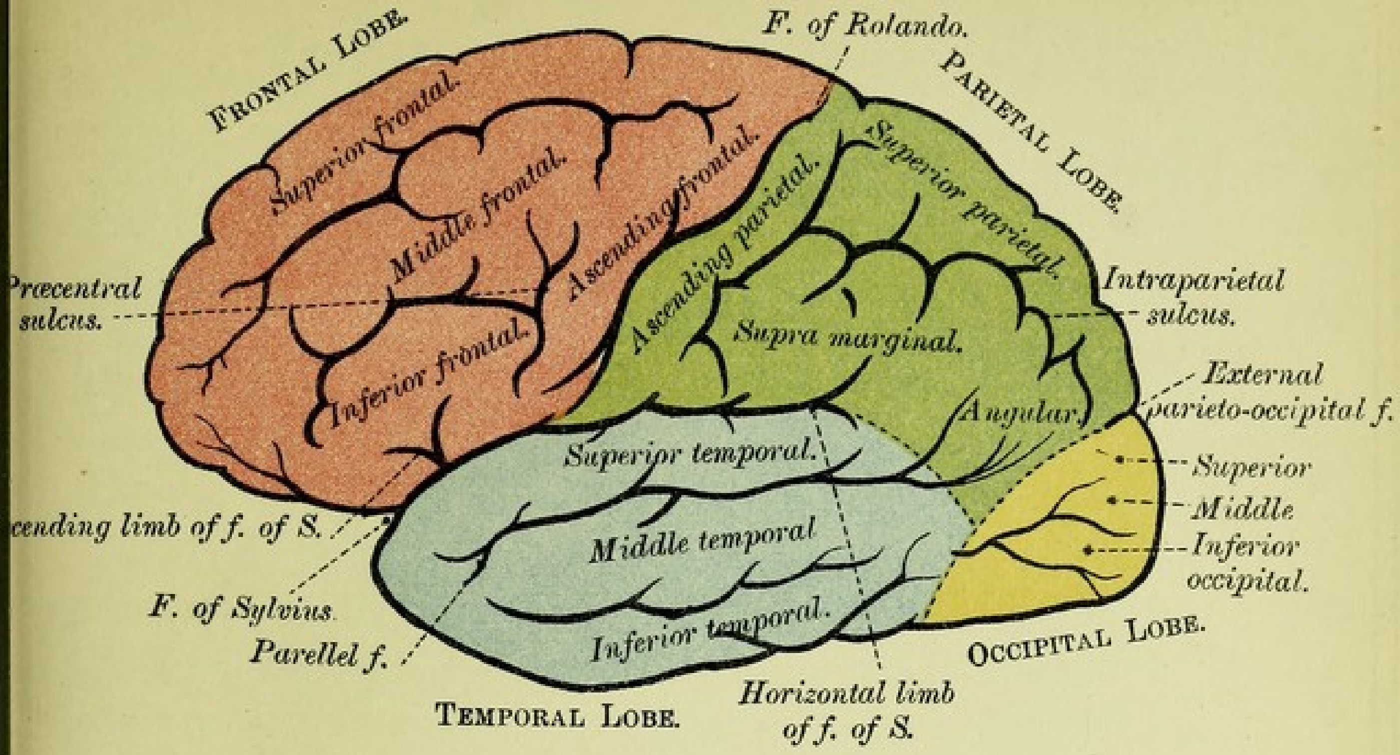
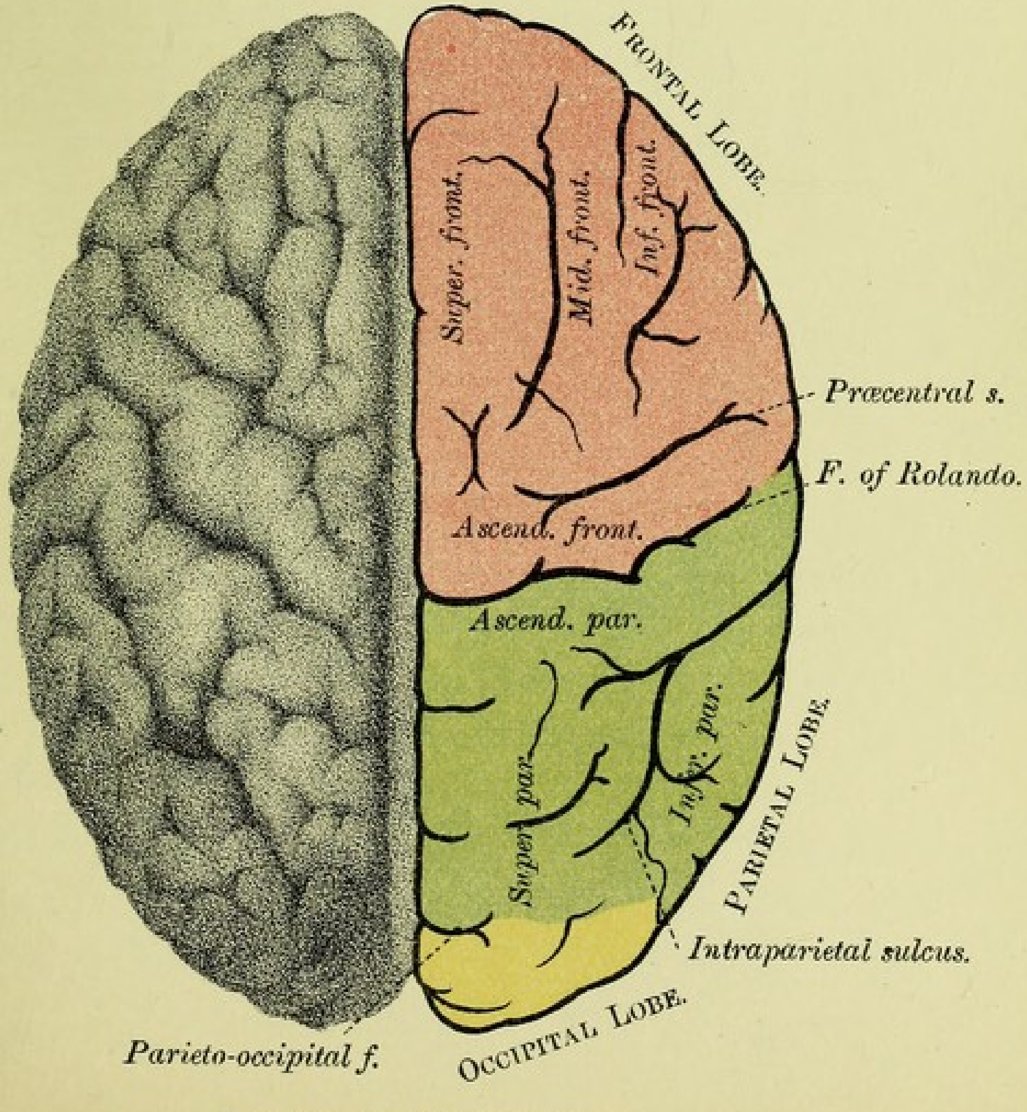


FIG. 71.



DIAGRAMS OF CONVOLUTIONS.

It is not of uniform depth throughout, being deeper below than it is in its upper part (Cunningham).

(3) The **Parieto-occipital Fissure** appears on both the outer and inner surface of the hemisphere. The EXTERNAL PARIETO-OCCIPITAL FISSURE is a short cleft on the outer aspect of the hemisphere near its hinder end (figs. 70, 71, 72); the INTERNAL PARIETO-OCCIPITAL FISSURE, continuous above with the external, is a very constant fissure, and descends vertically on the mesial aspect of the cerebrum (figs. 70, 71, 72). It will be noticed with that surface of the hemispheres.

2. The **Intra-lobular Fissures** separate individual convolutions from each other, and will be described with the convolutions which they serve to map out. Those which have received special names are—

1. Præcentral (fig. 70).	6. Callosal (fig. 72).
2. Intra-parietal "	7. Calloso-marginal "
3. Parallel "	8. Calcarine "
4. Triradiate (fig. 73).	9. Dentate "
5. Collateral (fig. 72).	

2. LOBES AND CONVOLUTIONS OF CEREBRAL HEMISPHERES.

The cerebral hemispheres are at first perfectly smooth and without convolutions. This developmental type is retained in case of many animals—*e.g.*, the insectivora. In the adult brain each cerebral hemisphere has five lobes. Of these four are bounded by the interlobular fissures, and take their names from the bones of the skull in relation to which they lie: they are the *frontal*, the *parietal*, the *occipital*, the *temporo-sphenoidal*. The fifth lobe—the *central lobe*, insula or isle of Reil—is not in contact with the bones of the skull, but is hidden within the fissure of Sylvius, the margins of which must be separated in order to see it.

I. The **Frontal Lobe** (figs. 70, 71, 72, 73,) is pyramidal in shape and is bounded behind by the FISSURE of ROLANDO, which separates it from the parietal lobe; below, by the HORIZONTAL LIMB of the FISSURE of SYLVIUS which separates it from the temporo-sphenoidal lobe; above, and in front where it passes into the inner surface of the hemisphere, by the GREAT LONGITUDINAL FISSURE; and in the rest of its extent, by the MARGINS of the HEMISPHERE. It has three surfaces—an *outer*, an *inner* or mesial, and an *inferior* or orbital.

The *outer surface* has four convolutions; one, the ASCENDING FRONTAL CONVOLUTION (figs. 70, 71), runs parallel to and in front of the fissure of Rolando, and is limited in front by the PRÆCENTRAL SULCUS (figs. 70, 71), behind by the FISSURE OF ROLANDO. The rest of the surface in front of this gyrus is mapped out by two horizontal parallel sulci into three antero-posterior gyri—the SUPERIOR, the MIDDLE, and the INFERIOR FRONTAL CONVOLUTIONS (figs. 70, 71), which have been classed together by Gowers under the term PRE-FRONTAL LOBE. The left inferior frontal convolution is often called Broca's convolution, and probably contains the centre for speech (fig. 44, page 62).

The *orbital surface* of the frontal lobe, bounded on the inner side by the longitudinal fissure and behind by the fissure of Sylvius, passes in the rest of its extent into the outer aspect of the hemisphere. At about its centre, it has a three-legged sulcus — the

TRIRADIATE FISSURE—better called intra-orbital fissure (Turner), which subdivides the surface into three gyri, an INTERNAL ORBITAL or GYRUS RECTUS (fig. 73), an ANTERIOR ORBITAL (fig. 73), and an EXTERNAL ORBITAL (fig. 73); all of which are mere prolongations, into this surface, of the convolution of the outer surface. Thus the superior frontal convolution becomes continuous with the gyrus rectus, the middle with the anterior orbital, and the inferior with the external orbital.

On the surface of the gyrus rectus, lodged in a triangular sulcus—the OLFACTORY GROOVE,—is a club-shaped body, the OLFACTORY BULB and its PEDUNCLE. Traced backwards this peduncle bifurcates behind into two white bands, the outer passing backwards towards the fissure of Sylvius where it is lost, the inner running to the side of the great longitudinal fissure (fig. 79, page 120). Between these two limbs you will see a small conical elevation — the OLFACTORY TUBERCLE, which is often looked upon as the middle root of the olfactory peduncle.

The *mesial surface* of the frontal lobe will be described with the corresponding surface of the hemisphere. (See Table of Convolutions.)

TABLE OF THE FRONTAL CONVOLUTIONS.

Frontal lobe	Outer surface	Ascending frontal.
		Superior frontal.
		Middle frontal.
		Inferior frontal.
	Inner surface	See mesial surface of hemispheres.
	Lower surface	Internal orbital (Gyrus rectus).
		Anterior orbital.
		External orbital.

II. The **Parietal Lobe** has an *inner surface* belonging to the inner aspect of the hemisphere (see mesial surface); and an *outer surface*, lateral and convex, which is bounded in front by the FISSURE of ROLANDO, separating it from the frontal lobe; behind by the PARIETO-OCCIPITAL FISSURE, separating it from the occipital lobe; and below by the HORIZONTAL LIMB of the FISSURE of SYLVIUS, separating it from the temporo-sphenoidal lobe.

This surface is furrowed by two sulci, the one is directed downwards parallel to and behind the fissure of Rolando, and forms the posterior limit of the ASCENDING PARIETAL CONVOLUTION (post central); the other, the INTRA-PARIETAL SULCUS often continuous with the last named sulcus (fig. 71), arches from before backwards through the centre of the surface, and subdivides it into an upper division—the SUPERIOR PARIETAL LOBULE (fig. 71); and a lower division—the INFERIOR PARIETAL LOBULE (fig. 71). The inferior parietal lobule is again divisible into an anterior part arching round the posterior end of the horizontal limb of the fissure of Sylvius, and called the SUPRA-MARGINAL GYRUS or CONVOLUTION of the PARIETAL EMINENCE (Turner); and a posterior part, behind the horizontal limb of the fissure of Sylvius, and round the hinder end of the PARALLEL SULCUS (fig. 71), and called the ANGULAR GYRUS (fig. 71). This latter gyrus passes below, without any line of demarcation, into the middle temporo-sphenoidal convolution (fig. 71).

The angular gyrus probably contains the centre for sight, though the occipital lobes are also closely connected with this same function. The ascending frontal and ascending parietal convolutions contain the chief motor centres (fig. 44, page 62).

TABLE OF CONVOLUTIONS OF PARIETAL LOBE.

Parietal lobe	Outer surface	Ascending parietal	
		Superior parietal	
		Inferior parietal ...	Supra-marginal.
			Angular.
	Inner surface	See mesial surface of hemispheres.	

III. The **Occipital Lobe.**—This lobe presents a greater number of individual variations in the arrangement of its convolutions than any of the other lobes. Pyramidal in shape, with the apex backwards, it has three surfaces—an *external,* in contact with the parietal bone; an *internal,* forming part of the mesial surface of the hemisphere; and an *inferior,* continuous with the under surface of the temporo-sphenoidal lobe. At present we shall notice the external surface only; the others will be described with the corresponding surfaces of the hemispheres. The *external surface* is bounded in front by the PARIETO-OCCIPITAL FISSURE, and by a line drawn downwards from this fissure across the surface of the hemisphere to its lower margin (fig. 70, page, 104 dotted line). The other boundaries of the external surface are the margins of the hemisphere. Two longitudinal sulci divide the surface into three antero-posterior convolutions, a SUPERIOR, a MIDDLE, and an INFERIOR OCCIPITAL (fig. 70,); but these are by no means constant.

The occipital lobes probably contain centres connected with sight (fig. 44, page 62).

TABLE OF CONVOLUTIONS OF OCCIPITAL LOBE.

Occipital Lobe	Outer surface	Superior. Middle. Inferior.
	Inner surface	See inner surface.
	Under surface	See next section.

IV. The **Temporo-sphenoidal Lobe** (fig. 70), occupying the middle fossa at the base of the skull, is conical in shape and has three surfaces—an *upper*, a *lower*, and an *external* or lateral.

The *external surface* is bounded—above, by the HORIZONTAL LIMB of the FISSURE of SILVIUS, which separates it from the parietal lobe; below, by the INFERIOR TEMPORO-SPHENOIDAL SULCUS, which separates it from the under surface. Behind, there is no definite line of demarcation between it and the outer surface of the occipital lobe—the line prolonged downwards from the external parieto-occipital fissure serving as its limit. This surface has three antero-posterior fissures—the SUPERIOR (or PARALLEL), the MIDDLE, and the INFERIOR TEMPORO-SPHENOIDAL—the upper two sulci separate from each other the SUPERIOR, the MIDDLE, and the INFERIOR TEMPORO-SPHENOIDAL CONVOLUTIONS. The inferior fissure is, as we have said, the boundary between the outer and the lower surface.

The *upper surface* of this lobe is hidden within the fissure of Sylvius, and is marked out by somewhat inconstant sulci into two or three indefinite gyri.

The *inferior surface* presents a transverse depression caused by the upper margin of the petrous part of the temporal bone, and this may be taken as the limit between temporo-sphenoidal and the occipital lobes—the part in front of the groove being convex and belonging to the temporo-sphenoidal lobe; the part behind the groove being concave, and belonging to the occipital lobe. These two parts are taken together under the term occipital-temporal, and their convolutions are two in number—a SUPERIOR and an INFERIOR OCCIPITO-TEMPORAL CONVOLUTION (fig. 72) —separated from each other by the COLLATERAL FISSURE (fig. 72).

TABLE OF CONVOLUTIONS OF TEMPORO-SPHENOIDAL LOBE.

Temporo-sphenoidal lobe	External surface	Superior Middle Inferior	Temporo-sphenoidal.
	Lower surface	Superior and inferior occipito-temporal.	
	Upper surface	Two or three indefinite gyri.	

V. The **Central Lobe**—Insula, Isle of Reil,—the first to be developed, lies deeply within the fissure of Sylvius, and cannot be seen unless you separate the sides of that fissure. Triangular in shape, it consists of five or six convolutions, called GYRI OPERTI (fig. 73, page 112), which are limited externally by a deep sulcus separating them from the adjacent convolutions—the OPERCULUM (fig. 73), formed by the contiguous ends of the ascending frontal, ascending parietal, and the inferior frontal convolutions. In front and behind, the isle of Reil is separated by well-marked sulci from the frontal and temporo-sphenoidal lobes respectively. Cunningham has pointed out the close relations of the convulutions of the isle of Reil with those on the lateral surface of the hemisphere.

VI. The **Fissures and Convolutions of the Median Surface of the Hemispheres** (fig. 72).—Most of the convolutions of this surface are parts of lobes already described, but it will be well to group them together under the above heading. To examine them you will require a mesial vertical section of the hemispheres.

Arching through this aspect of each hemisphere is seen the cut surface of the CORPUS CALLOSUM (fig. 72, page 112), which we shall take as our guide to the study of the gyri and sulci.

The CALLOSAL FISSURE—ventricle of the corpus callosum (fig. 72).—This fissure commences in front below the anterior end of the corpus callosum. It runs along the upper margin of the corpus callosum, and then turns round its posterior extremity and, skirting the inner border of the temporo-sphenoidal lobe, ends in the notch of the *uncus* (fig. 72). Between it and the upper margin of the hemisphere lies the CALLOSO-MARGINAL FISSURE (fig. 72), which, commencing in front beneath the anterior end of the corpus callosum, extends backwards, parallel to the margin of the hemisphere, to a level with the hinder end of the corpus callosum, when it turns upwards to the mesial border of the hemisphere, a little behind the fissure of Rolando (fig. 72). The original direction of the calloso-marginal fissure is continued by a small sulcus which, along with the calloso-marginal, separates the *gyrus fornicatus* below, from the *marginal convolution* and the *quadrate lobe* above.

The GYRUS FORNICATUS—convolution of the corpus callosum (fig. 72)—commences in front below the anterior end of the corpus callosum, and arching upwards

Plate XXIV.

FIG. 72.

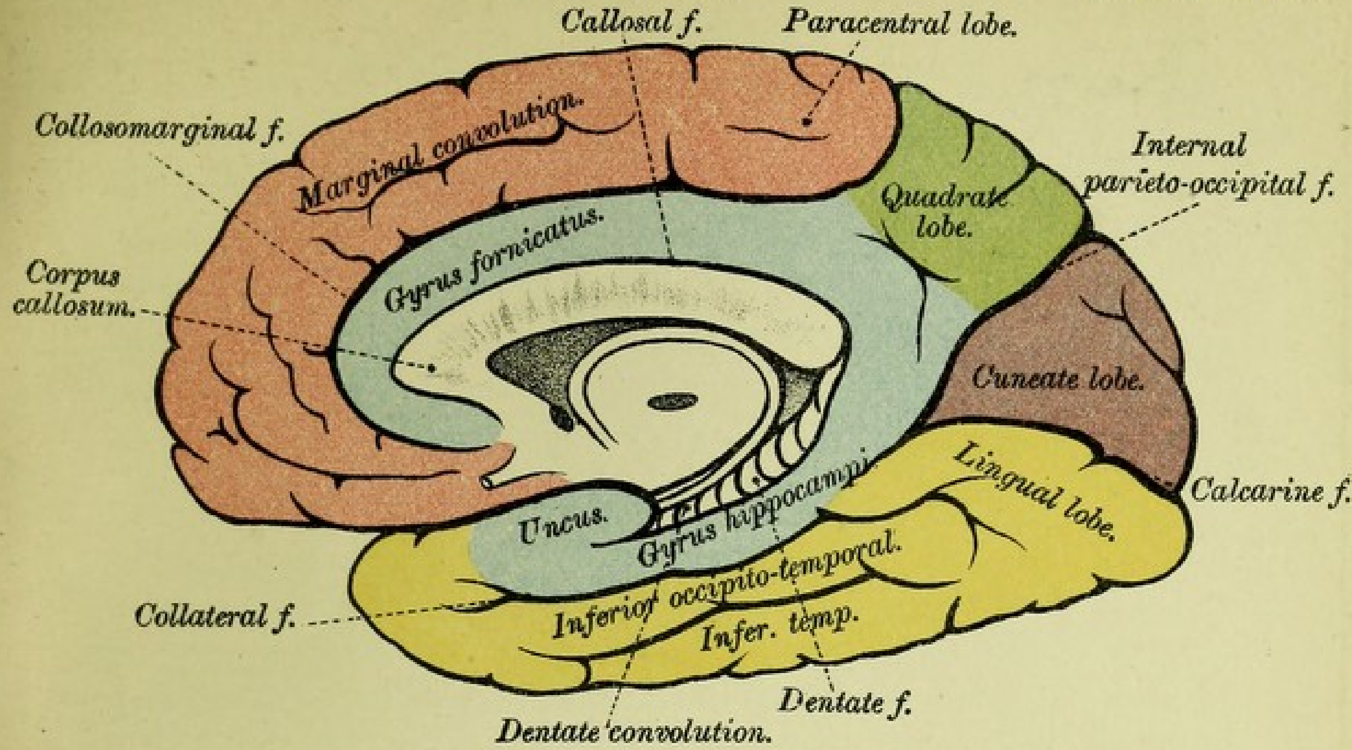
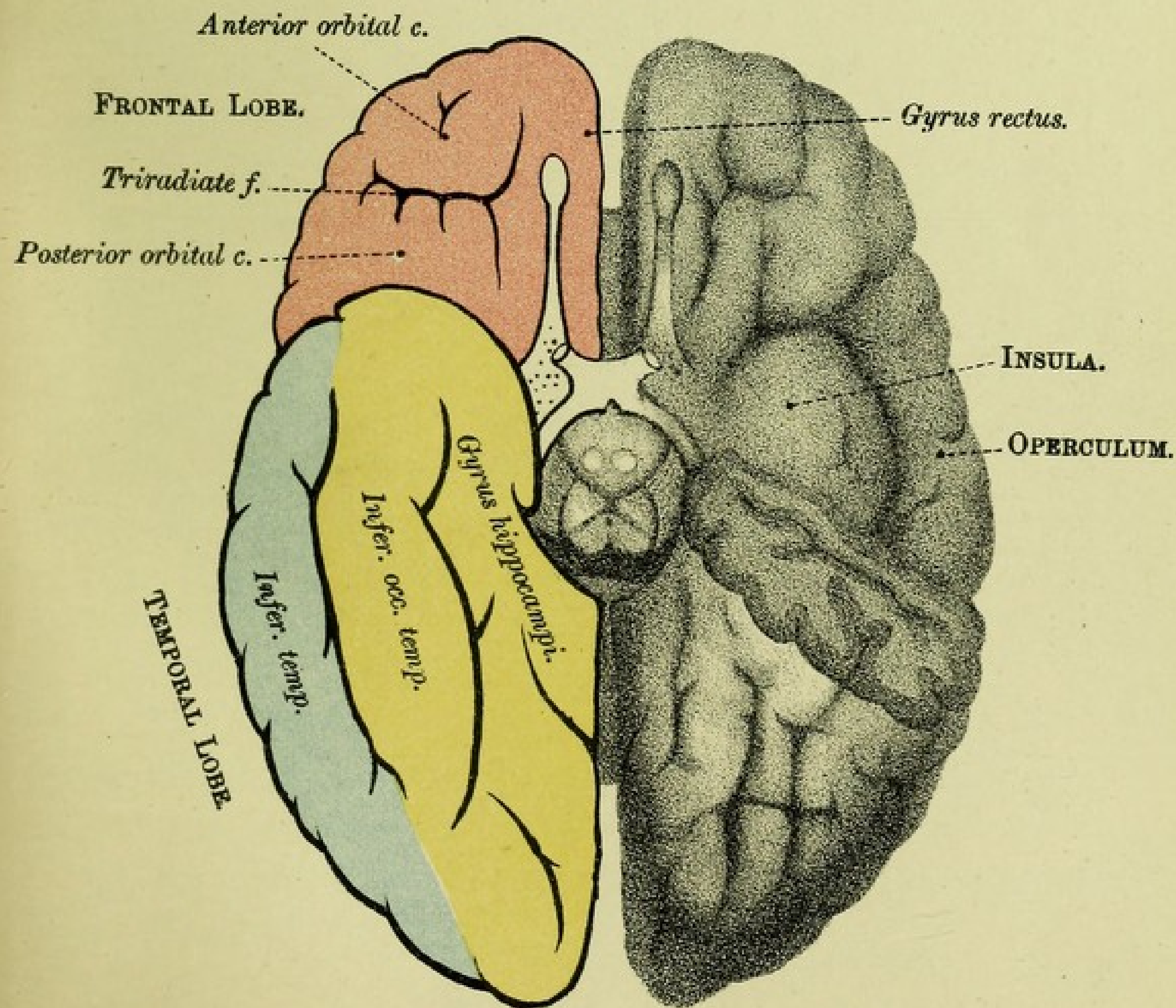


FIG. 73.



DIAGRAMS OF CONVOLUTIONS.

and backwards over its body and round its posterior end becomes slightly constricted—the isthmus —and then runs downwards and forwards on the mesial edge of the temporo-sphenoidal lobe, as the *superior occipitio-temporal convolution* or *gyrus hippocampi*, or *uncinate gyrus*, from the hook-like process—uncus gyri fornicati—in which it ends in front (fig. 72).

N.B.—There is no little confusion in the naming of these convolutions. Thus the superior occipito-temporal is often called the *uncinate* gyrus. Again, either the whole convolution, or only the posterior part of it—viz., that near the hinder end of the corpus callosum, is known as the *hippocampal* convolution; while the part beneath the calcarine fissure—or at other times the whole gyrus—is called the *lingual* lobe. The inferior occipito-temporal convolution is often called the *fusiform* lobe, though this name also is sometimes confined to the posterior part of that gyrus.

The MARGINAL CONVOLUTION (fig. 72), belonging to the mesial surface of the frontal lobe, begins at the anterior perforated spot, and running along the upper edge of the hemisphere above the calloso-marginal sulcus, becomes continuous above with the superior frontal convolution. Inferiorly, it passes into the gyrus rectus of the orbital surface, and posteriorly it is limited by the vertical part of the calloso-marginal fissure (fig. 72). The hinder part of the marginal gyrus is called the *paracentral lobule* (fig. 72); it is the mesial aspect of the ascending frontal convolution.

The INTERNAL PARIETO-OCCIPITAL FISSURE (fig. 72), lies behind the vertical part of the CALLOSO-MARGINAL FISSURE, the two enclosing between them the mesial surface of the parietal lobe, called the QUADRATE LOBE OR PRÆCUNEUS (fig. 72).

Below the internal parieto-occipital fissure will be seen the CALCARINE SULCUS (fig. 72), which runs forwards from the posterior border of the hemisphere to join the *internal parieto-occipital sulcus.* They together enclose the wedge-shaped mesial aspect of the occipital lobe, called the CUNEUS (fig. 72).

The DENTATE (hippocampal) FISSURE (fig. 72), continuous behind with the callosal sulcus, ends in front as we have already seen in the notch of the uncus. This fissure separates the *uncinate* or *hippocampal gyrus* from the *fimbria* or *tænia hippocampi,* which will be seen in the descending horn of the lateral ventricle.

The DENTATE CONVOLUTION OR FASCIA DENTATA is a notched gyrus, the free edge of the superficial grey matter of the hemisphere (fig. 72), and lies at the bottom of the dentate fissure.

Both fascia dentata and fimbria blend below with the substance of the uncus.

Passing into the lateral ventricles, through the great transverse fissure above the FIMBRIA, is a vascular inflection of pia mater known as the CHOROID PLEXUS of the lateral ventricles. These structures will be better seen when we dissect the lateral ventricles (see page 125).

TABLE OF THE CONVOLUTIONS OF THE MESIAL SURFACE.

Convolutions of Mesial Surface	Gyrus fornicatus. Marginal. Hippocampal (uncinate). Dentate. Quadrate (præcuneus). Cuneus. Paracentral lobule.

Structure of the Cortex of the Brain.

(Fig. 74, Plate 25, page 116.)

The grey matter of the cerebral cortex is arranged in several more or less distinct layers, composed of neurolgia, blood-vessels, and lymphatics, and of nerve cells and nerve fibres. Four layers are usually described which, enumerated from without inwards are—(1) The molecular or superficial layer; (2) the layer of small pyramidal cells; (3) the layer of large pyramidal cells; and (4) the layer of polymorphous cells.

1. The **Molecular Layer** consists of—

(1) A superficial stratum of neurolgia.

(2) Several kinds of nerve cells, some of which are polygonal, with a single axis-cylinder process; others are triangular multipolar cells; others are fusiform, bipolar, or multipolar cells.

(3) Finally, the molecular layer contains many nerve fibres, some of which are the protoplasmic processes of the cells of the subjacent layers; others are fine wavy varicose fibres, which radiate in all directions, but run chiefly horizontally.

2. **Layer of Small Pyramidal Cells.**—The cells of this layer are, as indicated by their names, mostly pyramidal in shape, though those cells which are situated next to the molecular layer are polyhedral or star-shaped. The axis-cylinder process of the pyramidal cells starts from the centre of the base of the cells, and can be traced as a long slender fibre to the white substance beneath. In the upper part of their course the axis-cylinder processes give off at right angles numerous side branches called collaterals, which

branch and end free in little knobs (fig. 76). From the apex and lateral angles of the pyramidal cells arise other processes called protoplasmic processes, which end in the molecular layer in branches which are beset with small short spines (fig. 74).

3. **Layer of Large Pyramidal Cells.**—In this layer the cells are much larger than those of the last layer. They are mostly polyhedral in shape, and their axis-cylinder process descends from the centre of the base of the cell towards the subjacent white substance. On its way it gives off many collaterals, which run horizontally and branch dichotomously. These branches are granular, and at their free ends are knobbed or enlarged. The lower part of the axis-cylinder process has a tortuous course and does not give off collaterals. From the apex and sides of the cells arise the protoplasmic processes, which are beset with short thick spines (figs. 74, 76). The horizontal branches cross and recross each other and form a dense network. All the branches end free in little knobs or thickenings.

4. **Layer of Polymorphous Cells.**—In this layer the cells vary much in size and shape. Many are globular, others are fusiform. They have ascending and descending protoplasmic processes. Their axis-cylinder process, sinuous in its course, gives off collaterals and ends in the white substance, either by bending at right angles to its direction, or by **T** or **Y** shaped junctions with the fibres of the white substance (fig. 74).

Besides the several kinds of nerve cells just described, there are scattered throughout the grey matter two other kinds of cells:—

PLATE XXV.

(page 116).

Fig. 74.—*M.L.* Molecular layer.

S.P. Layer of small pyramidal cells.

L.P. Layer of large pyramidal cells.

P.C. Layer of polymorphous cells.

W.S. White substance.

a. Bunches of fibres of the pyramidal cells.

b. Small pyramidal cell.

c. Axis cylinder of small pyramidal cells.

d. Large pyramidal cell.

e. Axis-cylinder of large pyramidal cell.

f. Cell with ascending axis-cylinder process.

g. Sensitive cells of Golgi.

Fig. 75 — Pyramidal cell with axis - cylinder process and collaterals, and their terminal swellings.

Fig. 76—Terminal branches of the apical process of a pyramidal cell.

Plate XXV.

Fig. 74.

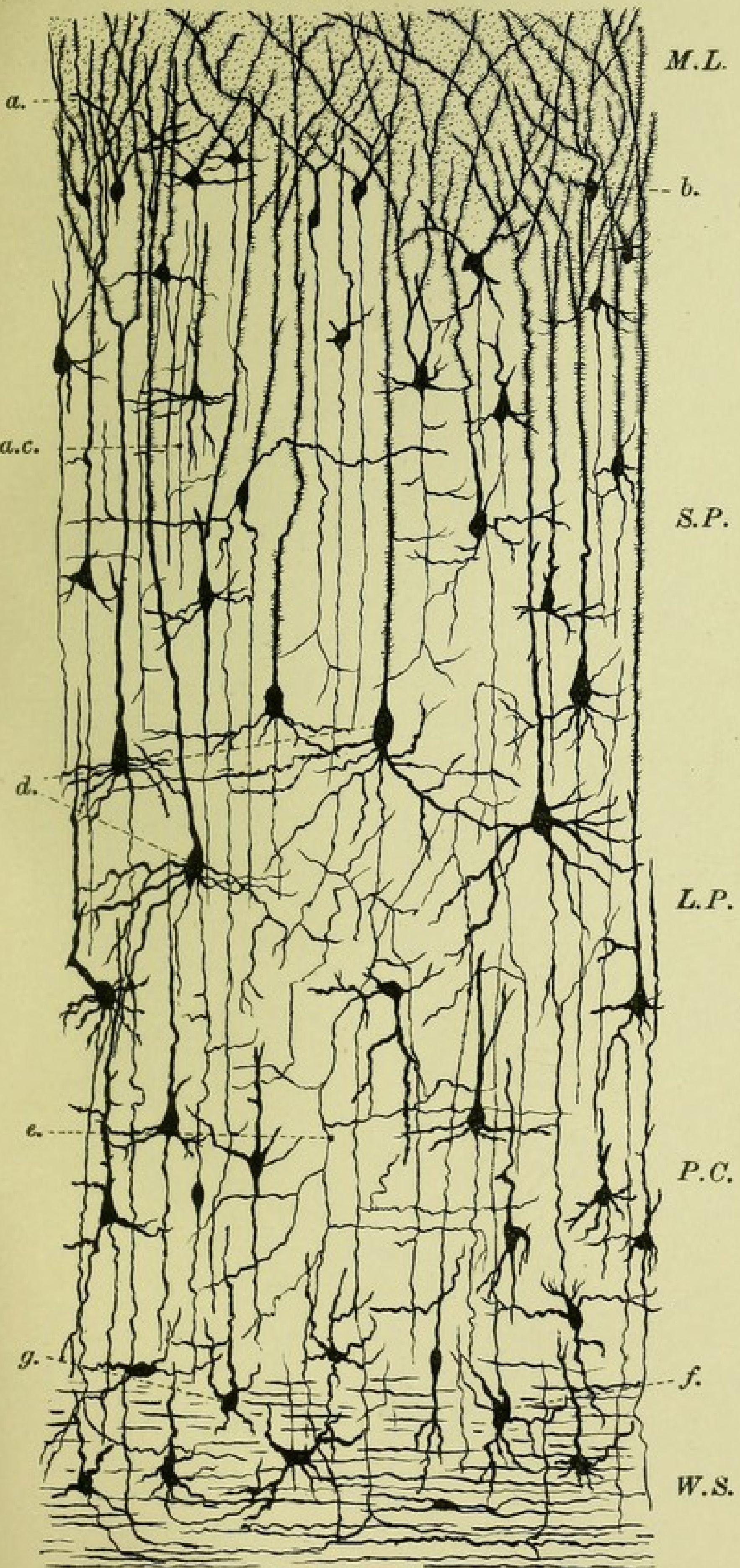


Fig. 76.

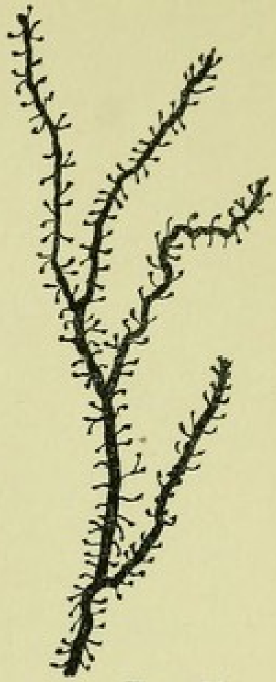
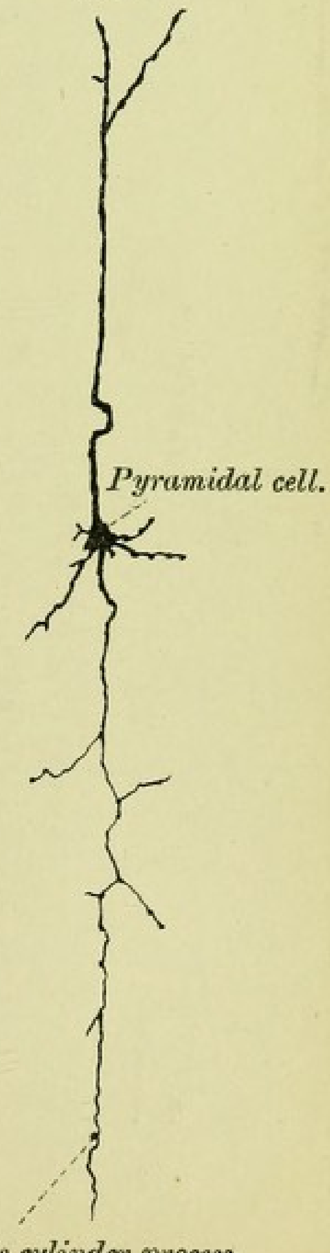


Fig. 75.



1. The *sensitive cells of Golgi*—star-shaped cells with branching protoplasmic processes, and an axis process, which, after a short course, ends free in dense tree-like branches.

2. The second kind of cells are fusiform or globular in shape, and have an axis-cylinder process which ascends from the apex of the cell towards the cortex, giving off collaterals on its way (fig. 74). Ultimately this process ends in tree-like branches beset with small spines and knobed at their extremities.

Beneath the grey matter lies the white nerve substance of the brain, which, like that of the spinal cord, is composed of white or medullated nerve fibres. These radiate in various directions, called systems, and in structure resemble the white nerve fibres of the spinal cord, though they are finer and somewhat smaller in size.

The above may be regarded as the typical structure of the chief part of the cerebral cortex, but there are differences in different regions which space will not allow us to describe.

Rules for Finding the Relations of the Chief Fissures to the Skull and Scalp.

I. Fissure of Sylvius—(figs. 77, 78, page 118).

1. *Relation to Skull.*—The commencement of this fissure, on the outer aspect of the hemisphere, corresponds with the pterion—*i.e.*, the point of meeting of the great wing of the sphenoid, the squamous part of the temporal bone, the frontal and the parietal bones. From this point the anterior limb of the fissure ascends almost vertically, nearly parallel to and a little behind the coronal suture. The posterior or horizontal limb passes backwards along the upper margin of the squamous suture, and ends beneath the parietal eminence.

2. *Relation to Scalp.*—The fissure of Sylvius is found by drawing a line on the scalp from a point one and a quarter inches behind and one-quarter of an inch above the external angular process of the frontal bone, and prolonging it backwards and upwards for about three inches through a point about three-quarters of an inch below the most prominent part of the parietal eminence. The anterior three-quarters of an inch of this line corresponds to the main fissure, the rest to the horizontal limb. The ascending limb starts at a point on this line, about two inches behind the external angular process, and thence it ascends for about an inch upwards and forwards.

II. **Fissure of Rolando**—(figs. 77, 78).

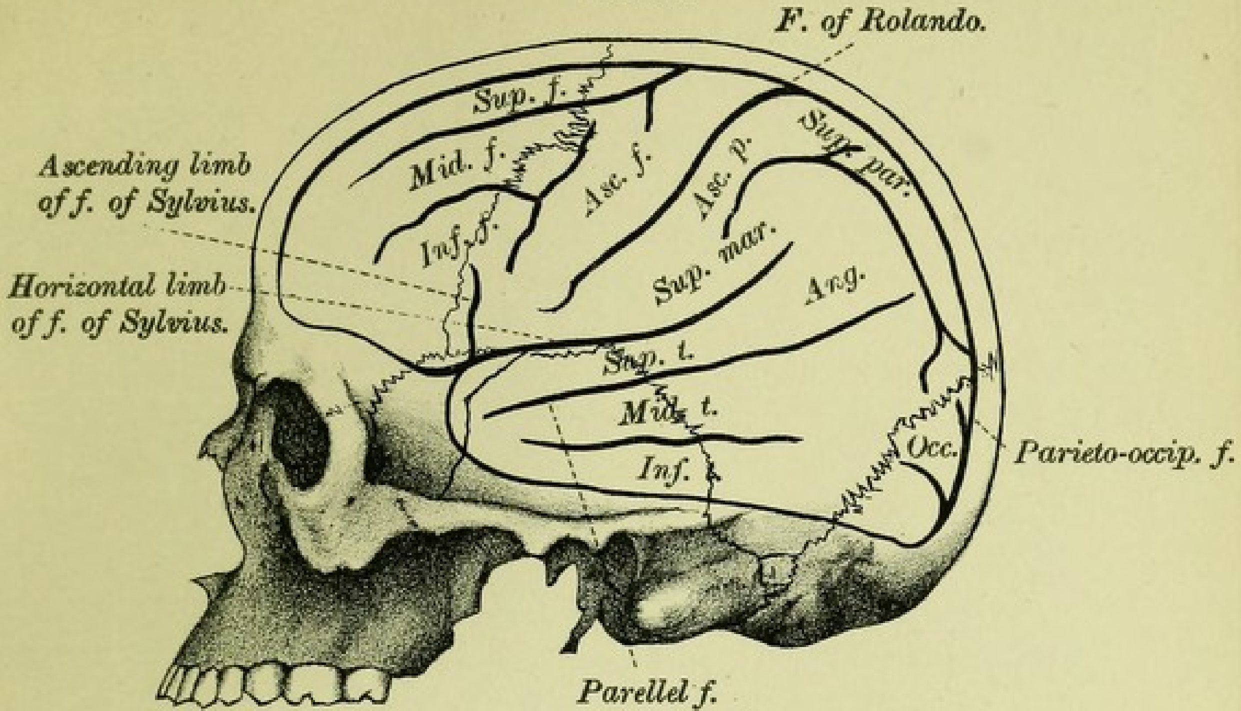
1. *Relation to Skull.*—This fissure begins at the vertex of the skull, a little behind the coronal suture, and thence runs downwards and forwards nearly parallel to that suture, being a little less than two inches behind it above, and between one and a third to one and a half inches behind it below. It makes an angle of 670° with the median line of the skull.

2. *Relation to Scalp.*—The relation of the fissure of Rolando to the scalp is determined by finding the bregma—the junction of the saggital and coronal sutures—by drawing a vertical line over the vertex, from one external auditory meatus to the other. The upper end of the fissure of Rolando will be found 55 mills. behind the bregma. The lower end of the fissure is determined by taking a point 7 cents.* behind, and 3 cents. above the external angular process of the frontal bone.

Another method is to take a point at the vertex of the skull, about half-an-inch behind the mid-point between the root of the nose (naso-frontal suture) and

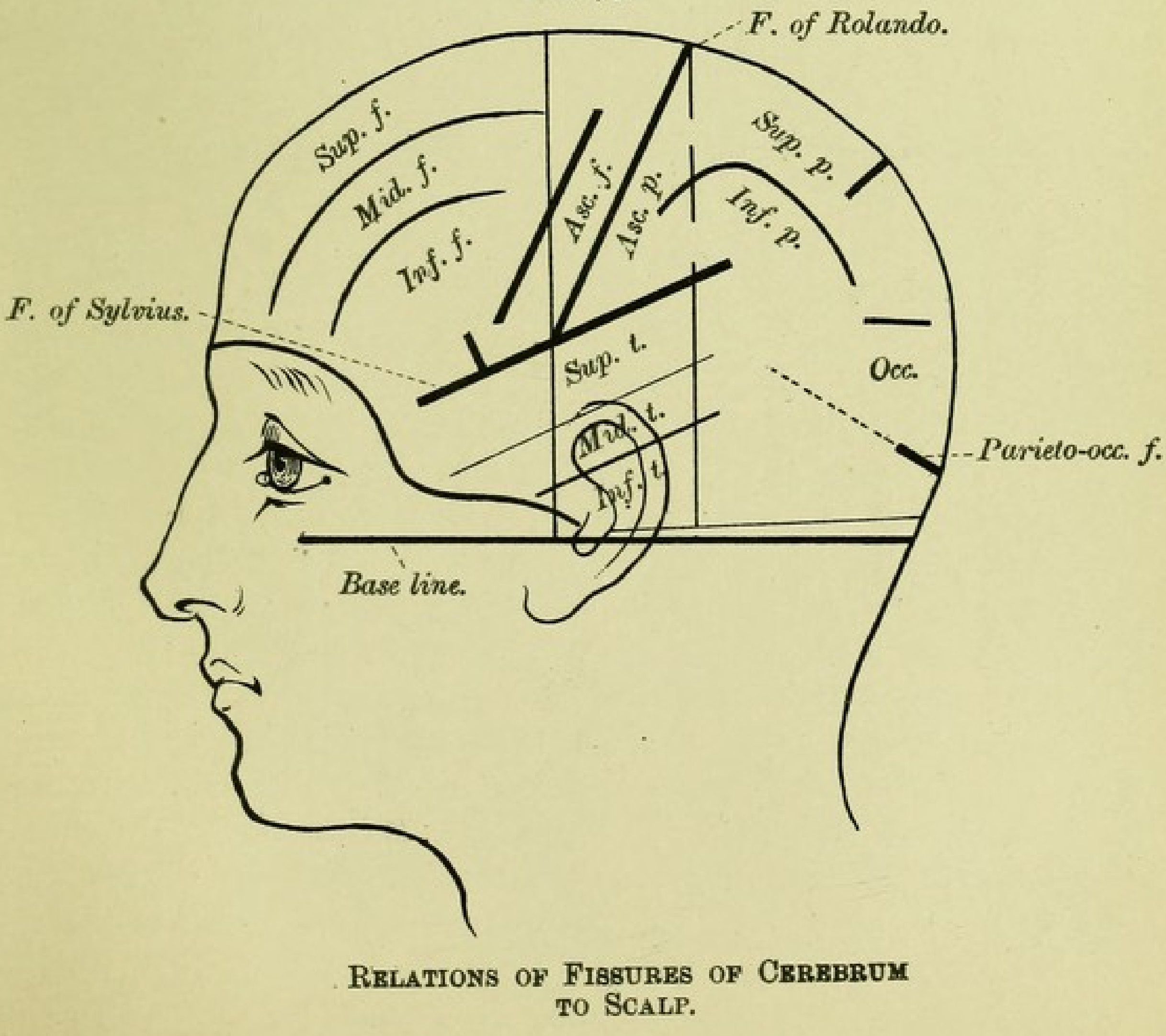
* 55 mills. $= 2\frac{1}{5}$ inches. 5 c.m. $= 2$ inches.

FIG. 77.



RELATIONS OF FISSURES OF CEREBRUM TO SKULL.

FIG. 78.



RELATIONS OF FISSURES OF CEREBRUM TO SCALP.

the external occipital protuberance. This determines the position of the upper end of the fissure. The lower end lies in close relation to the horizontal limb of the fissure of Sylvius, being about one inch behind the point of bifurcation of that fissure.

A third method is to draw a base line from the lower margin of the orbit backwards through the centre of the external auditory meatus. From this base line raise two perpendicular lines, one from the posterior border of the mastoid process of the temporal bone, the other from the depression in front of the external auditory meatus. A diagonal line drawn from the point at which the posterior perpendicular line cuts the middle line of the vertex to the point at which the anterior perpendicular line meets the line indicating the position of the horizontal limb of the fissure of Sylvius, gives the position and the direction of the fissure of Rolando.

III. **Parieto-Occipital Fissure** (figs. 77, 78).

1. *Relation to Skull.*—The parieto-occipital fissure lies in the upper posterior parietal area of the brain, a little in front (·7 to ·8 inches) of the lambda. From this point the fissure is directed downwards and outwards for about an inch.

2. *Relation to Scalp.*—The lambda is found by taking a point in the middle line of the vertex, two to three inches above the external occipital protuberance, and drawing a line, about an inch long, downwards and outwards, from a point a little in front of the lambda. The fissure may also be approximately indicated by a continuation backwards of the line representing the horizontal limb of the fissure of Sylvius.

IV. The **Intra-Parietal Sulcus** lies under the parietal eminence, and its position is indicated on the scalp by drawing a line in front of the parietal eminence, and carrying it upwards and backwards along the upper limit of that eminence.

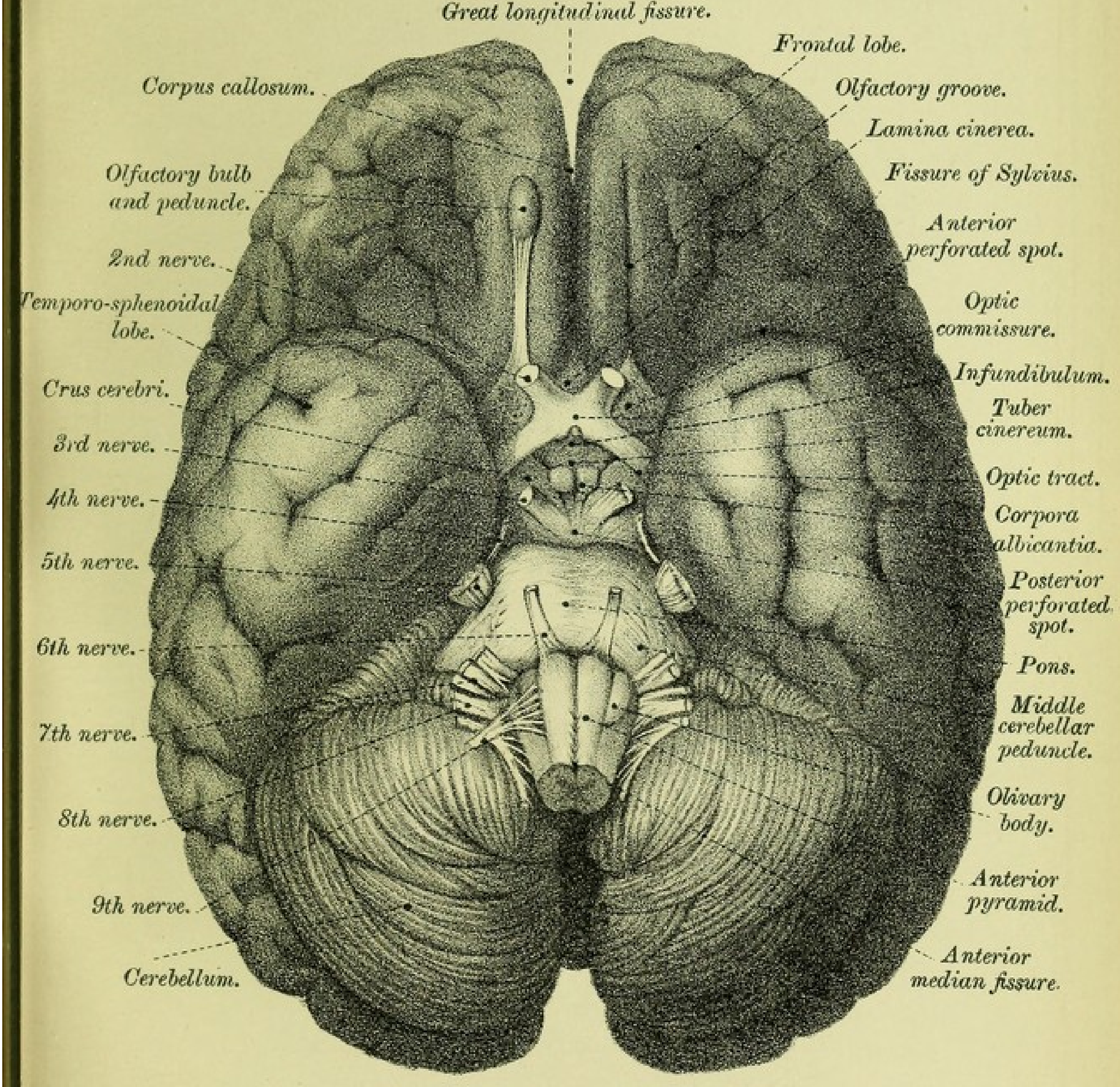
II. BASE OF THE CEREBRUM.

The base or under aspect of the brain is, as we have already seen, very irregular in shape, and in connection with it we recognise the following structures: (1) The medulla, (2) the cerebellum, (3) the pons Varolii (4) the crura cerebri, (5) the under aspect of the frontal and temporo-sphenoidal lobes, (6) part of longitudinal fissure and fissure of Sylvius, and finally the anastomising circle of blood-vessels known as the circle of Willis.

If we now examine more particularly that part of the base of the brain which lies between the great longitudinal fissure in front, the under surface of the frontal and temporo-sphenoidal lobes on each side, and the crura cerebri behind (fig. 79), we shall find an irregular shaped interval—the **interpeduncular space**, within which are contained the following structures:—

Commencing in front, at the longitudinal fissure, we see—(1) the ANTERIOR END of the CORPUS CALLOSUM —the ROSTRUM—hidden within the fissure, and passing backwards and outwards from it, towards the fissure of Sylvius, are two narrow white bands; (2) the PENDUNCLES of the CORPUS CALLOSUM, between which lies a thin grey lamina; (3) the LAMINA CINEREA. Passing across the middle line, behind the median fissure, is a white band of nerve fibres, (4) the OPTIC COMMISSURE, which is prolonged forwards at the sides into two rounded bundles, (5) the OPTIC NERVES, and backwards as flattened white strands, (6) the OPTIC TRACTS, which curve inwards round the outer sides of the crura cerebri.

FIG. 79.



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External to the optic commissure, at the root of the fissure of Sylvius, and behind the olfactory peduncles, are two triangular shallow depressions, one on each side—the ANTERIOR PERFORATED SPOTS (fig. 79), greyish laminæ, perforated for the passage of blood-vessels into the interior of the brain. At the inner sides, these perforated grey laminæ are continuous with the lamina cinerea; externally, with the hemisphere. Across them pass the peduncles of the corpus callosum. In the middle line, behind the optic commissure, is a small grey elevation, (7) the TUBER CINEREUM (figs. 79, 80), which is continuous (in this position of the brain), beneath the optic commissure, with the lamina cinerea.

Projecting downwards from the tuber cinereum is a funnel-shaped process, (8) the INFUNDIBULUM (figs. 79, 80), to the apex of which is attached (in the entire brain) the posterior of the two lobes of the (9) PITUITARY BODY. This body is usually left in the sella turcica when removing the brain. It is of a reddish colour, and consists of two lobes, an anterior, which in structure resembles the thyroid body, and a posterior, which originally was a hollow prolongation from the pharnyx but subsequently becomes solid.

Behind the tuber cinereum, between it and the crura cerebri, are two small rounded white pea-shaped nodules, (10) the CORPORA ALBICANTIA (figs. 79, 80), which we shall afterwards see are closely connected with the anterior pillars of the fornix (fig. 80). Behind the corpora albicantia, and between the diverging cerebral peduncles, lies (11) the POSTERIOR PERFORATED SPOT—pons Tarini (fig. 79)—a grey lamina similar to the anterior perforated spot, and, like it, for the passage of blood-vessels into the interior of the cerebrum.

Besides the above structures there will be seen, on the inferior aspect of the brain, the superficial origins of the following cranial nerves:—

ENGLISH METHOD.		GERMAN METHOD.
1st pair,	Olfactory,	1st nerve.
2nd pair,	Optic,	2nd nerve.
3rd pair,	Oculomotor,	3rd nerve.
4th pair,	Patheticus or Trochlearis,	4th nerve.
5th pair,	Trigeminus or Trifacial,	5th nerve.
6th pair,	Abducens,	6th nerve.
7th pair,	1. Facial,	7th nerve.
	2. Auditory,	8th nerve.
8th pair,	1. Glosso-pharyngeal,	9th nerve.
	2. Vagus,	10th nerve.
	3. Spinal Accessory,	11th nerve.
9th pair,	Hypo-glossal,	12th nerve.

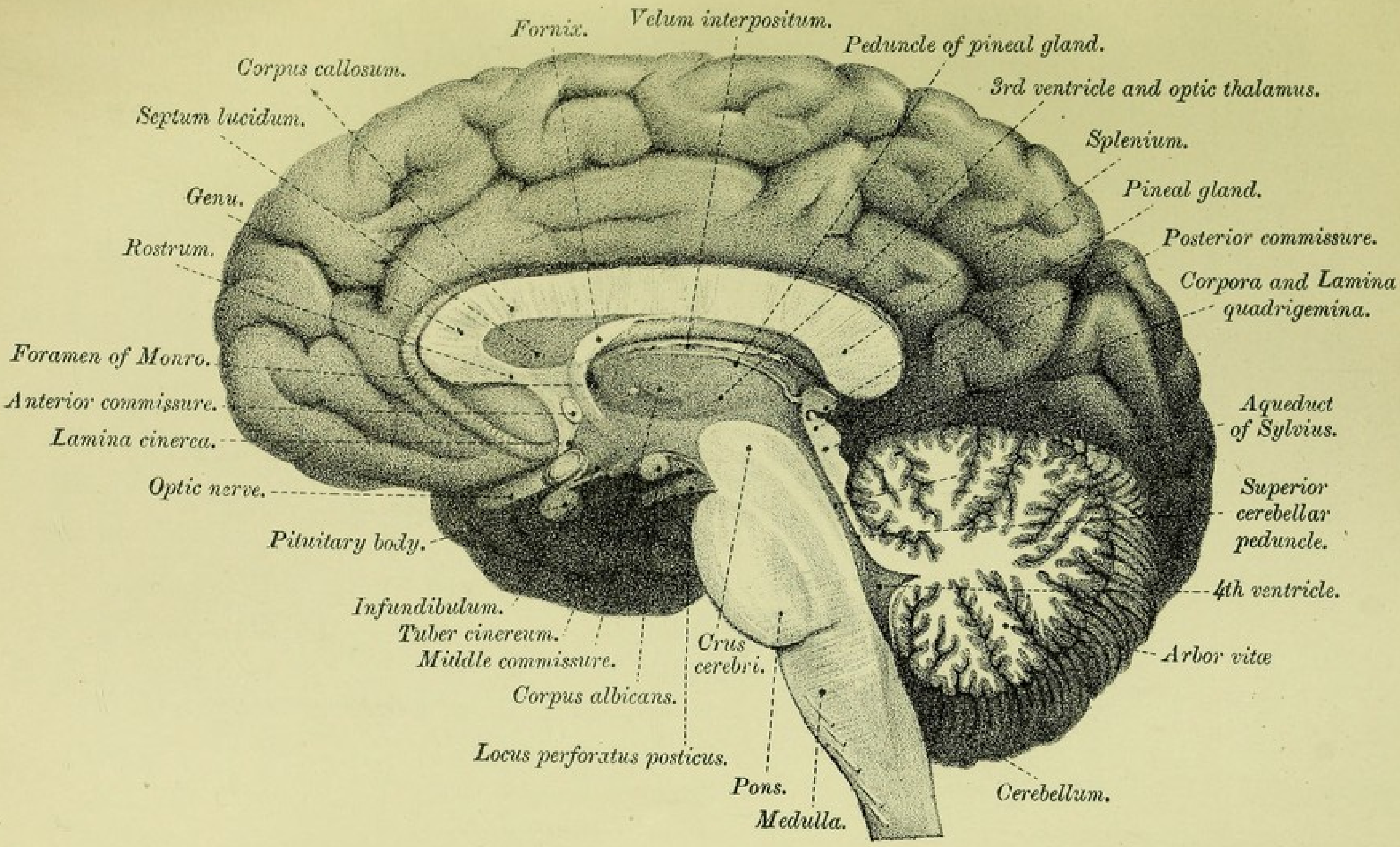
For the further account of these nerves, see "Superficial and Deep Origins of the Cranial Nerves," page 151.

Table of Objects seen on the Base of the Brain.

1. The Medulla.
2. The Cerebellum.
3. The Pons.
4. The Crura Cerebri.
5. Interpeduncular Space, with—
   (1) Posterior perforated spot.
   (2) Corpora albicantia.
   (3) Pituitary body.
   (4) Infundibulum.
   (5) Tuber cinereum.
   (6) Anterior perforated spots.
   (7) Optic commissure.
   (8) Optic tracts.
   (9) Optic nerves.
   (10) Lamina cinerea.
   (11) Peduncles of the corpus callosum.
   (12) Rostrum of the corpus callosum.

Plate XXVIII.

Fig. 80.



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6. The Cranial Nerves (see Table, page 122).
7. Under aspects of Frontal and Parietal Lobes.
8. Fissure of Sylvius and part of great longitudinal fissure.
9. Blood-vessels—Circle of Willis.

III. INTERIOR OF THE CEREBRUM.

When we examine by means of horizontal sections the interior of the cerebrum, we find that, above the level of the corpus callosum, each hemisphere consists of a solid white central core—*centrum ovale*—surrounded externally by a wavy edge of grey matter—the *cerebral cortex.*

Ventricles.—Below the level of the corpus callosum, however, the centre of the cerebrum is occupied by an irregular cavity, the remains of the original cerebro-spinal embryonic canal (see Section III., "Development"). This cavity, somewhat T-shaped in coronal section (figs. 93, 94, page 144), is subdivided by partitions or septa into smaller spaces called ventricles. Thus we have (1) the 3RD VENTRICLE, a vertical mesial longitudinal cleft-like space—represented by the upright part of the T—lying beneath the corpus callosum, and extending below to the base of the brain; and (2) the LATERAL VENTRICLES, two lateral diverticula—the cross stroke of the T—hollowed out in the substance of the hemispheres. Uniting these various ventricles with each other are narrow passages or channels, constricted portions of the tube from which the brain and spinal cord were developed. Thus, in front is the FORAMEN of MONRO, which connects the lateral ventricles with the 3rd ventricle and with each other (fig. 80, page 122); and behind is the AQUEDUCT of SYLVIUS, or iter a tertio ad quartum ventriculum (fig. 80).

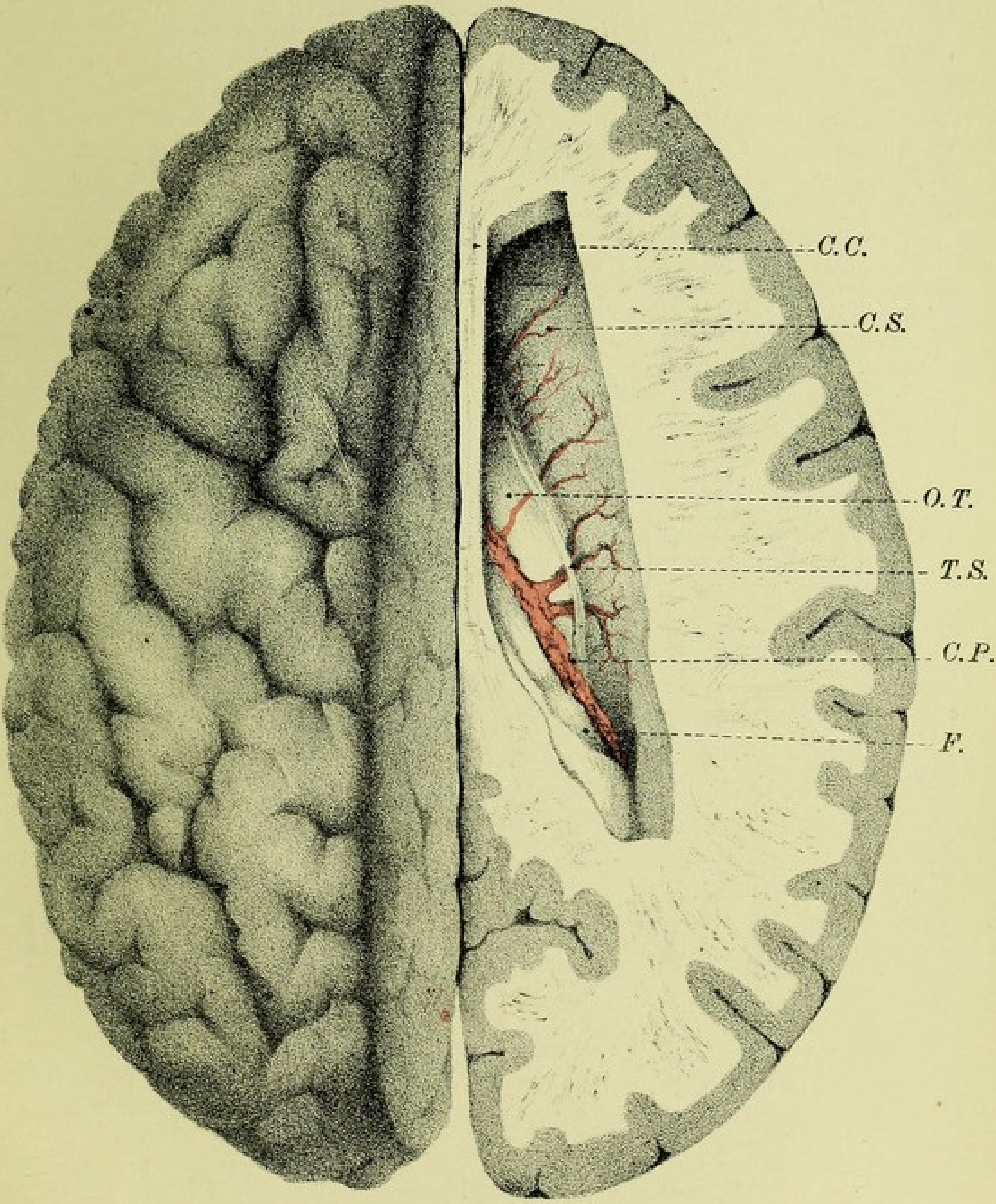
Basal Ganglia.—Besides the white nerve matter and the central cavity, which corresponds to the central canal of the spinal cord, the interior of the cerebrum is occupied by large ganglionic masses — the basal ganglia—the chief of which are the CORPORA STRIATA and the OPTIC THALAMI. Each hemisphere, therefore, forms a kind of shell enclosing and overlapping the basal ganglia. Other smaller ganglionic masses are the CORPORA QUADRIGEMINA and the CORPORA GENICULATA, which occupy the region of the brain known as the mid-brain.

Commissures.—Finally, uniting the cerebral hemispheres and their ganglia are longitudinal and transverse bands or commissures—the CORPUS CALLOSUM, the ANTERIOR, POSTERIOR, and MIDDLE COMMISSURES, and the FORNIX.

We shall describe—(1) The VENTRICLES, with their communications and septa; (2) the BASAL GANGLIA, the CORPORA QUADRIGEMINA, and GENICULATA; (3) the COMMISSURES—the corpus callosum, the fornix, and the three minor commissures; but before doing so we shall give seriatim the dissections required to expose these several parts, so that the subsequent description may be less disconnected and the more easily understood.

DISSECTION—*A.* **To expose the Corpus Callosum.** —Place the brain upon its base with the convex surface uppermost. Take a large sharp knife, moistened in spirit, and cut from the right hemisphere a horizontal slice about half-an-inch in thickness. This will expose an oval-shaped central white mass of nervous substance in the hemisphere—the *centrum ovale minus*, studded here and there with small red spots—*puncta vasculosa*—the cut ends of the blood-vessels. Surrounding the

Fig. 81.



C.C.	*Corpus callosum.*
C.S.	*Corpus striatum (nucleus caudatus).*
O.T.	*Optic thalamus.*
T.S.	*Tænia semicircularis.*
C.P.	*Choroid plexus*
F.	*Posterior part of fornix.*

white centre is the wavy grey edge, about one-eighth of an inch thick, the cerebral cortex before referred to.

Remove a series of slices similar to the first, until you reach the level of the upper surface of the corpus callosum, then, with one sweep of the knife, cut off the opposite hemisphere to this same level, when you will see the *centrum ovale magus,* under which term is included the whole area now exposed. The upper surface of the corpus callosum is marked by a mesial groove, the *raphé,* and by median and lateral *longitudinal striæ.* Procure, if possible, a second brain, and make a mesial section of it, to enable you the better to examine the corpus callosum and the parts beneath.

B. **To expose the Lateral Ventricles.—**

1. THE BODY—Cut through the corpus callosum a little on each side and parallel to the middle line, and with the back of the knife raise its fibres, being careful not to injure the parts seen in the floor of the cavity beneath. Enumerated from before backwards, these parts are—

(1) The nucleus caudatus (fig. 81, page 124).
(2) The tænia semicircularis " "
(3) The optic thalamus " "
(4) The choroid plexus " "
(5) The edge of the fornix " "

2. CORNUA.—Next trace the cavity, forwards and outwards, as it winds round the front of the caudate nucleus into the frontal lobe—this is the *anterior horn ;* then follow it backwards into the occipital lobes —the *posterior horn;* and downwards and outwards into the temporo-sphenoidal lobe—the *descending* or *lateral horn.*

In the posterior horn you will see the *hippocampus minor* (figs. 82, etc.); in the descending horn, the *hippocampus major* the *pes hippocampi* (fig. 82), the *tænia hippocampi,* and part of the *choroid plexus* of the lateral ventricles (fig. 82).

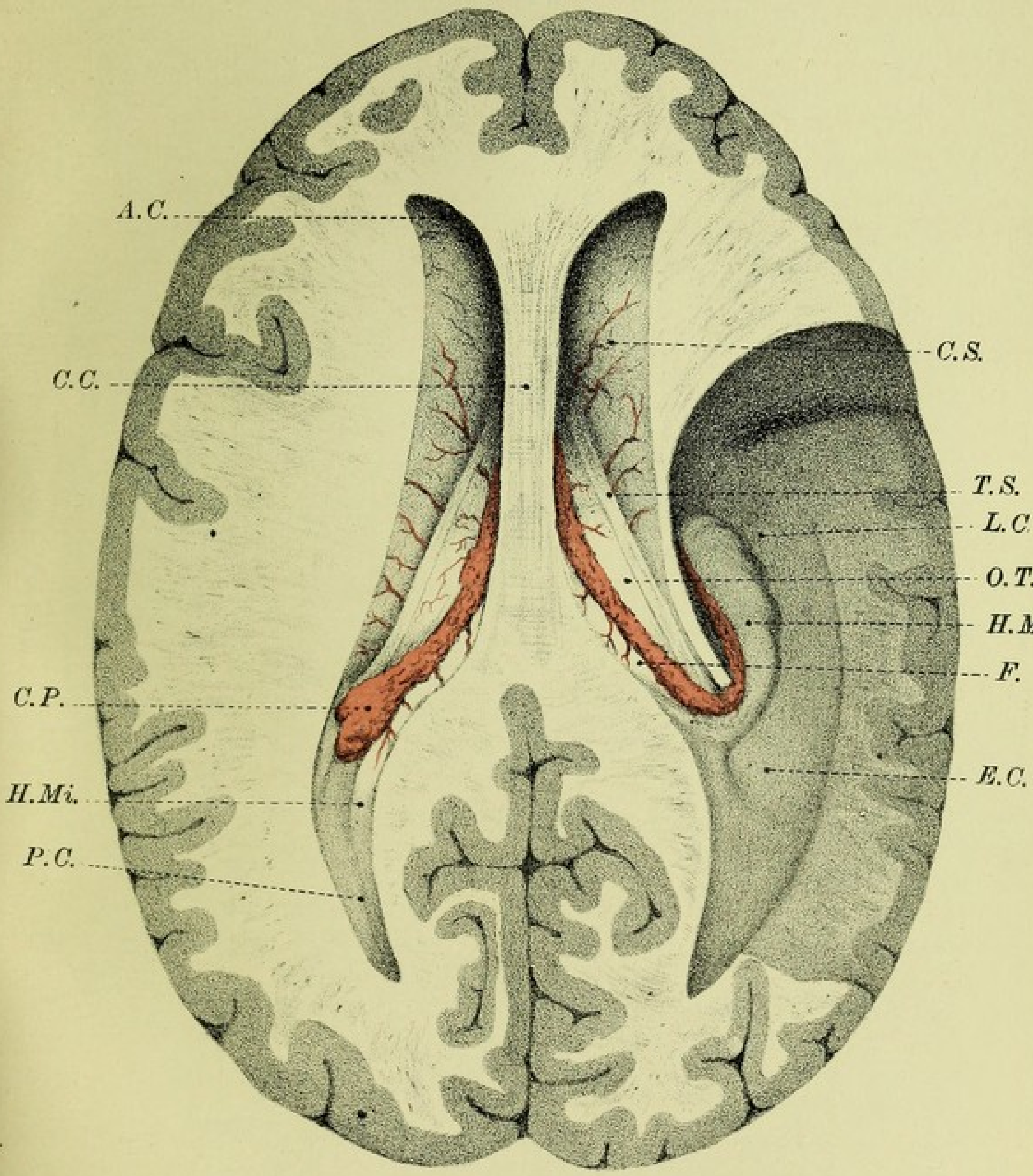
C. **To expose the Fornix, the Septum Lucidum, and the 5th Ventricle** (figs. 83, 84).—Make a transverse incision through the centre of the corpus callosum, and turn its ends backwards and forwards. Pass a sharp knife along the fore part of the under aspect of the corpus callosum, and sever its attachment to the the septum lucidum. Lift up the anterior part of the corpus callosum, when you will expose the SEPTUM LUCIDUM, and the cavity enclosed between its two layers—the 5TH VENTRICLE. Next reflect the posterior half of the corpus callosum, detaching it with the greatest care from the subjacent fornix where they are blended together. This will expose the BODY OF THE FORNIX.

D. **To expose the Velum Interpositum and the 3rd Ventricle** (figs. 84, 85).—Cut transversely through the middle of the fornix, and turn back the cut ends; the VELUM INTERPOSITUM, a delicate process of pia mater, will thus be brought into view. Examine this velum, and then detach it in front and throw it back, so that it may be again replaced if needed. The 3RD VENTRICLE will be seen beneath it, extending to the base of the brain between the optic thalami. In front are the *anterior commissure*, the *anterior pillars of the fornix*, and the *foramen of Monro;* behind are the *pineal gland* and its *peduncles;* the *posterior commissure*, the *corpora quadrigemina*, and the *aqueduct of Sylvius;* while crossing the space transversely is the *middle commissure.*

I. VENTRICLES OF THE BRAIN.

The Ventricles of the Brain are five in number—four, viz., the TWO LATERAL (1st and 2nd), the THIRD and the FOURTH ventricles are the remnants of the cerebro-spinal embryonic canal, and are continuous with each other and with the ventricle or central canal of the

Fig. 82.



A.C. *Anterior cornu.*
C.C. *Corpus callosum.*
C.P. *Choroid plexus.*
H.Mi. *Hippocampus minor.*
P.C. *Posterior cornu.*

C.S. *Corpus striatum (nucleus caudatus).*
T.S. *Tænia semicircularis.*
L.C. *Lateral cornu.*
O.T. *Optic thalamus.*
H.Ma. *Hippocampus major.*
F. *Fornix.*
E.C. *Eminentia collateralis.*

spinal cord. The 5TH VENTRICLE, on the other hand, belongs to a different category to the rest, and the term ventricle as applied to it is somewhat misleading, for it has none of the characters of the other ventricles, being neither a part of the original medullary canal, nor lined by the same epithelium as the rest, nor in any way connected with them in the adult. It will be noticed along with the septum lucidum. The 4th ventricle has already been described (page 97).

THE LATERAL VENTRICLES
(1st and 2nd).

The LATERAL VENTRICLES, or ventricles of the hemispheres (right and left) are two irregular crescent-shaped cavities hollowed out in the substance of the cerebral hemispheres (figs. 81, 82). Placed back to back, each ventricle consists of a central part or BODY, and of three prolongations or recesses—the ANTERIOR, the POSTERIOR, and the descending or LATERAL HORNS (fig. 82).

The **Body of the Ventricles** is the highest and largest portion, and, whether looked at from above or in coronal section, is triangular in shape. It is deeper in front than behind, and deeper near the middle line than at the sides where the roof and sloping floor meet and blend with the substance of the hemispheres,

1. The *roof* of the lateral ventricles is formed by the CORPUS CALLOSUM and the contiguous part of the hemisphere.

2. The *floor* presents from before backwards—(1) a small part of the CORPUS CALLOSUM where it turns down in the longitudinal fissure; (2) a club-shaped

eminence — the NUCLEUS CAUDATUS of the corpus striatum; (3) an oval grey mass—the upper surface of the OPTIC THALAMUS, which is separated from the nucleus caudatus by a shallow groove in which lies (4) the TÆNIA SEMICIRCULARIS. Resting on the optic thalamus is (5) the vascular fringe—the CHOROID PLEXUS of the lateral ventricles; and, finally, close to this fringe, nearer the middle, is (6) the thin sickle-shaped free edge of the BODY OF THE FORNIX.

3. The *inner wall* of the ventricle is formed in front by a thin double vertical mesial partition—the SEPTUM LUCIDUM, which extend between the corpus callosum and the fornix. Behind the septum, the floor (the fornix) and the roof (the corpus callosum) blend together.

4. *Externally*, the floor and wall meet in the mass of the hemispheres.

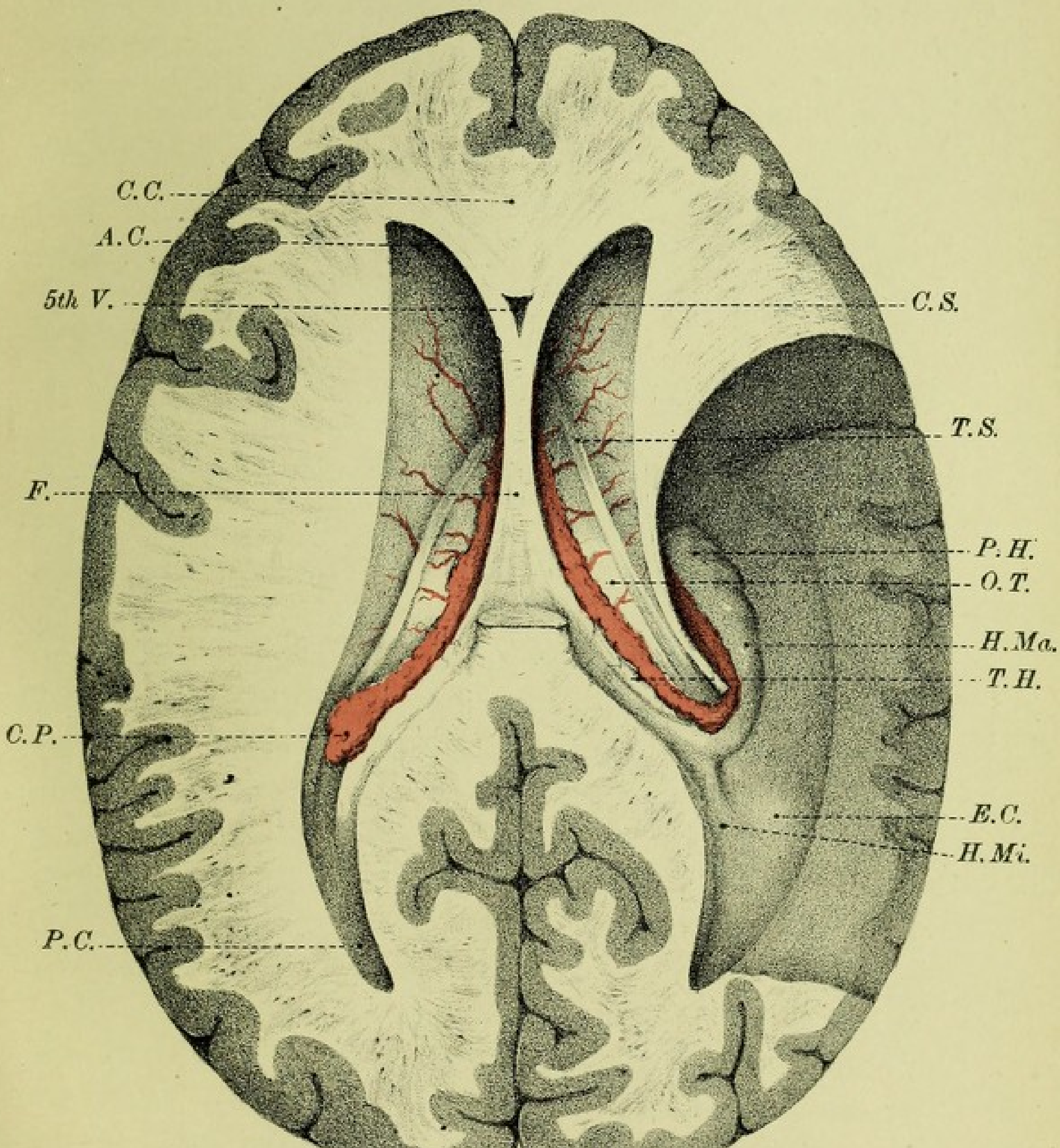
The **Cornua of the Ventricles** are, as we have said, three in number, anterior, posterior, and lateral or descending (figs. 82, etc.).

1. The **Anterior Cornu** is a short triangular horn-shaped cavity, which passes forwards and outwards from the fore part of the body of the ventricle round the anterior end of the nucleus caudatus into the substance of the frontal lobe.

Its *roof* and *anterior wall* are formed by the CORPUS CALLOSUM; its *floor* by the substance of the FRONTAL LOBE; its *inner wall* by the septum lucidum; while both *behind* and *below* is the NUCLEUS CAUDATUS.

2. The **Posterior Horn** is a similar recess, passing outwards, backwards, then inwards into the substance of the occipital lobe.

FIG. 83.



C.C.	*Corpus callosum.*
A.C.	*Anterior cornu.*
5th V.	*5th ventricle.*
F.	*Fornix.*
C.P.	*Choroid plexus.*
P.C.	*Posterior cornu.*
C.S.	*Corpus striatum (nucleus caudatus).*
T.S.	*Tænia semicircularis.*
P.H.	*Pes hippocampi.*
O.T.	*Opticus thalamus.*
H.Ma.	*Hippocampus major.*
T.H.	*Tænia hippocampi.*
E.C.	*Eminentia collateralis.*
H.Mi.	*Hippocampus minor.*

Its *roof* is formed by the CORPUS CALLOSUM; its *floor*, by an oval prominence—the HIPPOCAMPUS MINOR, an elevation (figs. 82, 86) caused by the calcarine sulcus on the mesial surface of the hemisphere.

3. The **Lateral Horn**—descending horn—curves round the posterior end of the optic thalamus as a bent finger-like passage, convexity outwards, which runs first backwards and outwards, then downwards, forwards, and finally inwards (B.O.D.F.I.) in the substance of the temporo-sphenoidal lobe (figs. 82, etc.).

In its *roof* are—the CORPUS CALLOSUM; the posterior extremity of the OPTIC THALAMUS; the TÆNIA SEMICIRCULARIS; and, finally, the tapering end of the NUCLEUS CAUDATUS, which, at the anterior end of the horn, swells out and passes into the nucleus amygdalus.

In the *floor* of the passage lies a curved elongated projection following the bend of the horn, and called the HIPPOCAMPUS MAJOR (cornu ammonis). This prominence is caused by the hippocampal (dentate) fissure on the surface of the brain. Below, at the apex of the horn, the HIPPOCAMPUS ends in an enlarged, grooved, paw-like, extremity—the PES HIPPOCAMPI; while along its inner concave margin lies a thin, white, tapering band of fibres—the TÆNIA HIPPOCAMPI or FIMBRIA, the prolongation of the posterior pillars of the fornix. Above the fimbria is the CHOROID PLEXUS of the lateral ventricles, which at this point enters the ventricular cavities through the lateral part of the *great transverse fissure.* Below the fimbria is the free edge of the grey matter of the cortex, which, from the notched appearance caused in it by the entrance over its free edge of the choroidal artery, receives the name FASCIA

DENTATA. This artery carries with it into the lateral ventricles a process of pia mater called the *velum interpositum,* in the free margin of which it breaks up into the choroid plexus of the lateral ventricles (see "Velum Interpositum").

At the point where the lateral and posterior horns diverge from each other you will see a slight eminence —the EMINENTIA COLLATERALIS—varying in size in different subjects, and caused by the collateral fissure on the surface of the brain (figs. 82, 83, 86).

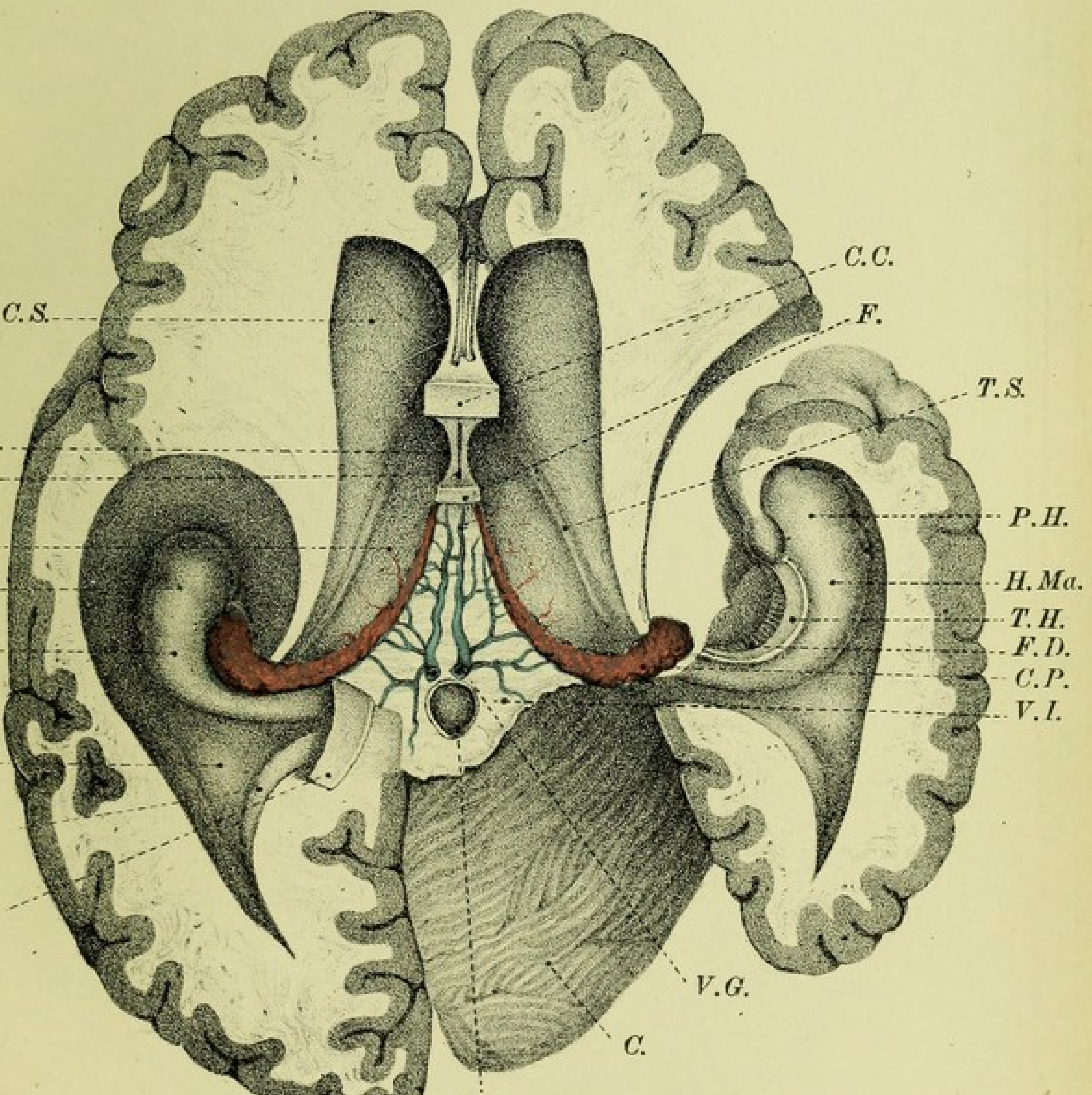
Ependyma Ventriculorum.—The lateral ventricles are lined by a layer of neuroglia (ependyma) covered on the surface by columnar ciliated epithelium, continuous with the epithelium of the other ventricles.

Communications.—The two lateral ventricles communicate with each other and with the 3rd ventricle through the FORAMEN of MONRO, which lies between the anterior pillars of the fornix and the optic thalami (fig. 80, page 122). Inferiorly, this passage is single and mesial where it leads into the 3rd ventricle, but above it is bifid, consisting of two limbs, right and left, one passing to each lateral ventricle. Through this foramen, as we shall afterwards see, the choroid plexuses of the lateral ventricles become continuous with those of the 3rd ventricle.

THE 3rd VENTRICLE.

The 3RD VENTRICLE (fig. 85, page 132; fig. 93, page 144) is the narrow, vertical, cleft-like space, situated in the middle line between the optic thalami. It lies beneath the body of the fornix and extends down to the base of the brain, being deeper in front than behind.

FIG. 84.



C.S.	Corpus striatum (nucleus caudatus).	C.C.	Corpus callosum.
S.L.	Septum lucidum.	F.	Fornix (anterior pillars) cut.
5th V.	5th ventricle.	T.S.	Tænia semicircularis.
O.T.	Optic thalamus.	P.H.	Pes hippocampi.
P.H.	Pes hippocampi.	H.Ma.	Hippocampus major.
H.Ma.	Hippocampus major.	T.H.	Tænia hippocampi.
E.C.	Eminentia collateralis.	F.D.	Fascia dentata.
H.Mi.	Hippocampus minor.	C.P.	Choroid plexus.
F.	Fornix cut.	V.I.	Velum interpositum.
P.G.	Pineal gland.	V.G.	Veins of Galen.
		C.	Cerebellum.

Boundaries.—The *roof* is formed by the VELUM INTERPOSITUM, covered on its under surface by a layer of flattened epithelial cells.

In its *floor* are the structures contained within the inter-peduncular space at the base of the brain (fig. 98, page 146)—viz., the LOCUS PERFORATUS POSTICUS, the CORPORA ALBICANTIA, the TUBER CINEREUM, the INFUNDIBULUM, the OPTIC COMMISSURE, and the LAMINA CINEREA.

In *front*, the ventricle is limited by the ANTERIOR PILLARS of the FORNIX and the ANTERIOR COMMISSURE; *behind*, by the POSTERIOR COMMISSURE and the AQUEDUCT of SYLVIUS, above which is the PINEAL GLAND and four rounded nodules—the CORPORA QUADRIGEMINA. At the *sides* the walls of the cavity are formed by the OPTIC THALAMI, along each of which runs a bundle of white fibres—the PEDUNCLES of the PINEAL GLAND. Crossing the centre of this space, between the optic thalami, is a broad, grey band—the middle, soft, or GREY COMMISSURE.

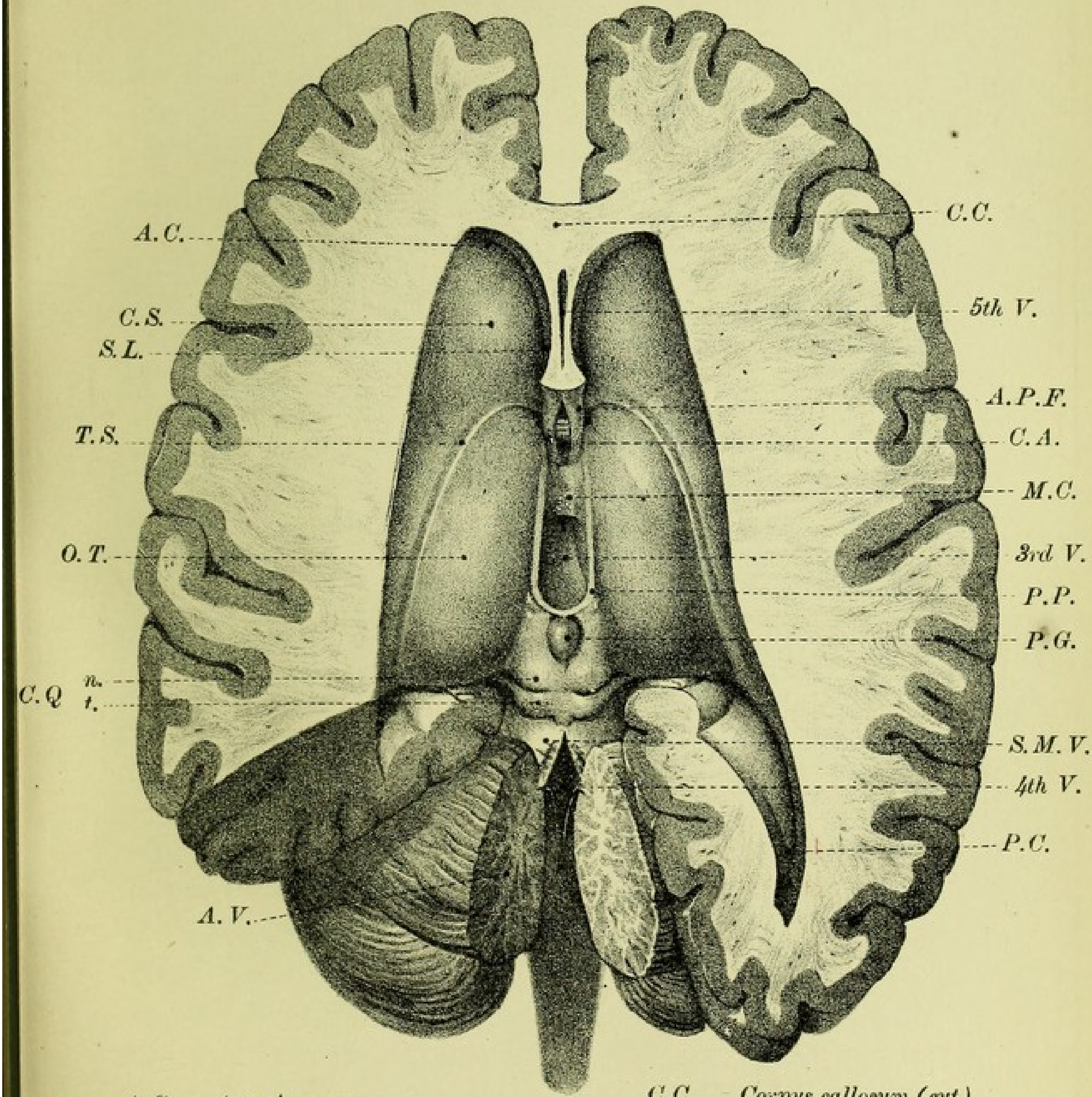
The 3rd ventricle is lined by epithelium similar to, and continuous with, that of the other ventricles. On the roof, however, the epithelium is flattened, and follows all the folds of the vascular fringes—the choroid plexuses — which hang down along the middle line from the under surface of the velum interpositum. The lateral walls of the ventricle are covered by a layer of ependyma, and the floor consists of grey matter continuous with the grey matter of the aqueduct of Sylvius. At the posterior perforated spot, and at the tuber cinereum and lamina cinerea, this grey matter comes to the surface at the base of the brain.

Communications.—The 3rd ventricle communicates in front, through the FORAMEN of MONRO, with the lateral ventricles; behind, through the AQUEDUCT of SYLVIUS, with the 4th ventricle; and below, at the fore part of the floor, by a conical-shaped passage with the infundibulum—ITER AD INFUNDIBULUM.

The **Aqueduct of Sylvius** is the narrow passage between the 3rd and 4th ventricles (fig. 80, page 122). Above, it is roofed over by a thin lamina—lamina quadrigemina—so called because it supports the corpora quadrigemina. Its floor and lateral walls are formed by the dorsal part of the cerebral peduncles. Internally it is lined by ciliated columnar epithelium, outside which is a thick layer of grey matter continuous with that (locus cæruleus) of the 4th ventricle. From this grey matter arises the 3rd, the 4th, and part of the 5th nerves.

The **Septum Lucidum** (Dissection, page 126) is the thin, double, vertical, mesial partition which separates the lateral ventricles from each other (fig. 85; fig. 80, page 122; fig. 93, page 144). Triangular in shape, it fills up the interval between the concavity of the knee-shaped bend of the corpus callosum and the front of the fornix. Broader in front than behind, it gradually tapers to a point where the corpus callosum and fornix come in contact with each other, and it contains, between the two layers of which it is composed, a narrow slit-like cavity, the 5TH VENTRICLE, or ventricle of the septum. Internally, next the cavity of the 5th ventricle, each lamina of the septum is composed of a thin layer of grey matter, derived originally from the

FIG. 85.



A. C.	*Anterior cornu.*
C. S.	*Corpus striatum (nucleus caudatus).*
S. L.	*Septum lucidum.*
T. S.	*Tænia semicircularis.*
O. T.	*Optic thalamus.*
C. Q	*Corpora quadrigemina.*
	n. Nates.
	t. Testes.
A. V.	*Arbor vitæ.*
C. C.	*Corpus callosum (cut).*
5th V.	*5th ventricle.*
A. P. F.	*Anterior pillars of fornix.*
C. A.	*Anterior commissure.*
M. C.	*Middle commissure.*
3rd V.	*3rd ventricle.*
P. P.	*Peduncles of pineal gland.*
P. G.	*Pineal gland.*
S. M. V.	*Superior medullary velum.*
4th V.	*4th ventricle.*
P. C.	*Posterior cornu.*

grey matter of the cortex. Externally, next the cavity of the lateral ventricles, each lamina of the septum consists of white matter representing the medullary or white matter of the hemispheres. This aspect is covered by a layer of ependyma and epithelium. The cavity of the 5th ventricle itself is not lined by epithelium like the other ventricles, nor, in the adult, does it in any way communicate with them.

As we shall see in the last Section, the septum lucidum was originally part of the wall of the cerebral vesicle which becomes cut off from the general surface by the development of the corpus callosum and fornix.

The **Velum Interpositum** (Dissection, page 126) is a thin horizontal partition, which, as you already know, roofs over the 3rd ventricle, and appears in the floor of the lateral ventricles (fig. 84, page 130). It is the central part of pia mater which penetrates the lateral ventricles through the great transverse fissure of the cerebrum. Triangular in shape, with the apex forwards, the velum has the same extent as the body of the fornix, so that it reaches from the foramen of Monro in front to the splenium of the corpus callosum behind, beneath which, after investing the pineal gland, it passes to become continuous with the rest of the pia mater on the cerebrum and cerebellum (fig. 84). At the sides, the free edge of the velum projects into the floor of the lateral ventricles, and rests on the upper surface of the optic thalami, round the hinder ends of which it passes down the descending horns of the lateral ventricles, to become continuous with the pia mater at the base of the brain.

Choroid Plexus (figs. 84, 94, page 144).—Projecting downwards along the middle line of the under aspect of the velum interpositum are the two vascular fringes—the choroid plexuses of the 3rd ventricle, covered everywhere, however, by the epithelium which forms the roof of that cavity. In each lateral margin are similar vascular fringes—the choroid plexuses of the lateral ventricles, which extend from the foramen of Monro in front (through which they are continuous with the plexuses of the 3rd ventricle), to the apex of the descending cornu of the lateral ventricles, where the velum becomes continuous with the rest of the pia mater through the great transverse fissure.

The choroid plexuses consist of tortuous ramifications of small blood-vessels, and are covered with vascular papillæ, over which is a layer of epithelium.

Veins of Galen.—Along the centre of the upper surface of the velum interpositum run two veins side by side—the veins of Galen—which receive blood from the interior of the ventricles, and discharge it into the straight sinus.

The Great Transverse Fissure of the Cerebrum.

The **Great Transverse Fissure** (fig. 80, page 130), is the large artificial cleft made into the lateral ventricles when the pia mater and choroid plexus, with the epithelium covering them, are torn away from the posterior part of the brain beneath the fornix, and from the descending cornua. The fissure thus formed is horse-shoe shaped; its central part corresponds to the base of the body of the fornix, its lateral parts to the descending horns of the lateral ventricles. Through this fissure the pia mater and choroid plexus enter the ventricles.

1. SUPERIORLY, it is bounded (*a*) *near the middle line* by the posterior part of the corpus callosum and fornix; (*b*) *on each side* by the free margins of the hemisphere—viz., the fimbria and the fascia dentata.

2. INFERIORLY, it is bounded (*a*) *near the middle line* by the corpora quadrigemina and cerebral peduncles; (*b*) *on each side* by the posterior part of the optic thalami.

II. BASAL GANGLIA.

Under this heading are usually described the two large grey masses at the base of the brain—the *corpora striata* and the *optic thalami.* They are, however, quite distinct in their origin. The term, moreover, is often made to include the corpora quadrigemina, the corpora geniculata, and the locus niger. For convenience we shall describe them at this stage.

1. The **Corpora Striata** are two in number, and are each subdivided into two parts—an INTRA-VENTRICULAR portion, which appears in the floor of the lateral ventricles; and an EXTRA-VENTRICULAR portion, hidden in the substance of the hemisphere (fig. 86, page 136).

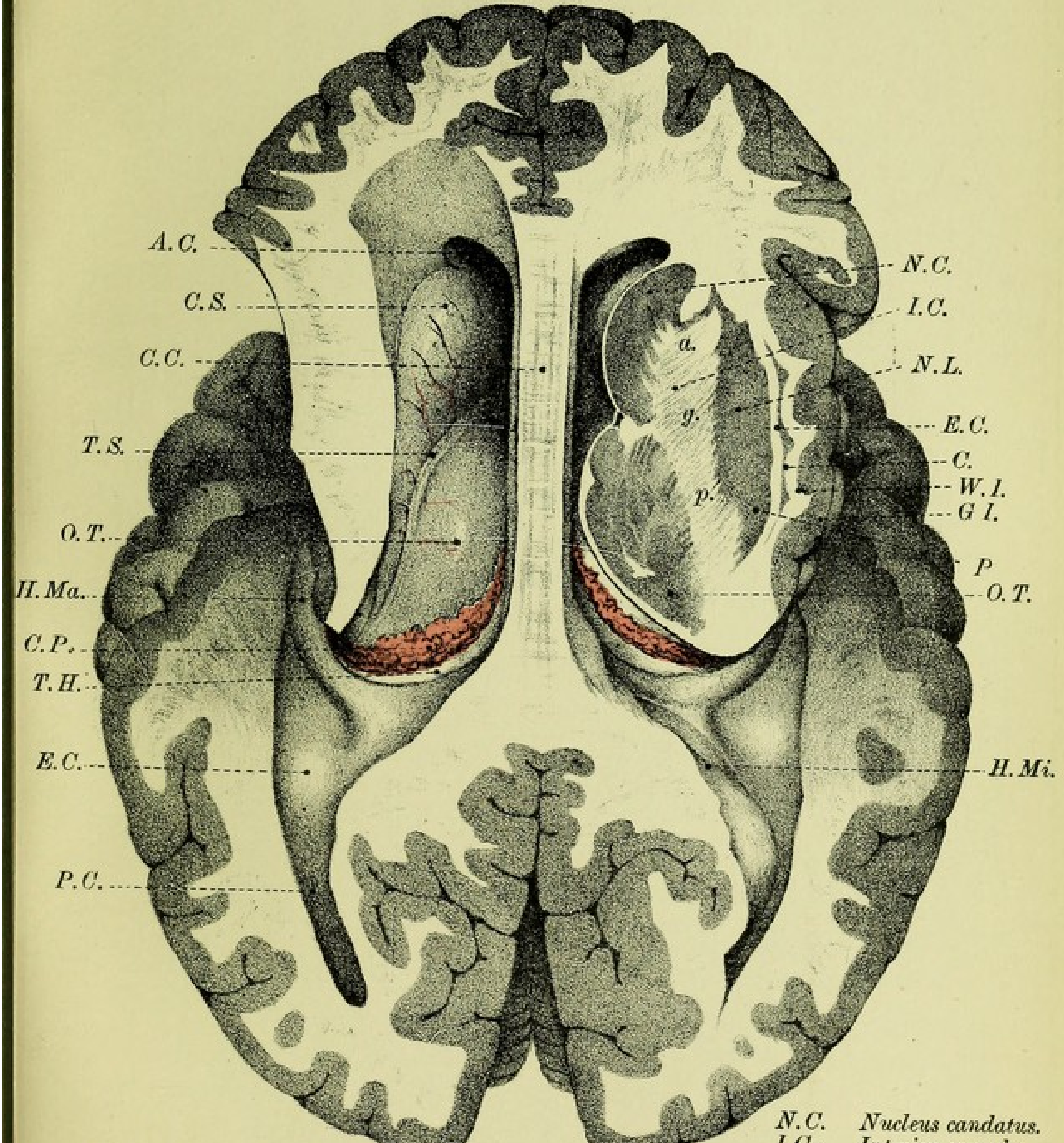
The **Nucleus Caudatus**—the INTRA-VENTRICULAR portion of the corpus striatum—so called from its shape, has been described as a pear-shaped, kite-shaped, pyriform or pyramidal eminence, of a pinkish grey colour, which appears in the fore part of the body of the lateral ventricles. Covered on the surface by a layer of white substance, each nucleus consists of a grey core streaked with white fibres, hence the name corpus striatum. Its larger end or head is directed forwards, and its posterior end or tail, gradually tapering to a point, pass backwards outside the optic thalamus into the roof of the descending horn of the lateral ventricle, and can be traced as far as the tip of the tempero-sphenoidal lobe. It may thus be said to form an arch, the anterior part of which is formed by the head of the nucleus, the posterior part by its tail (Hill) (fig. 90, page 140).

The **Nucleus Lenticularis** — the EXTRA-VENTRICULAR part of the corpus striatum—can only be seen in sections of the hemispheres (fig. 86, page 136; fig. 93, page 144). In horizontal sections it appears as a longitudinal grey mass, shaped like a double convex lens (lenticularis). It is placed external to the nucleus caudatus, and is separated from it by a strand of white nerve fibres, called the *inner capsule* (figs. 86, 93; fig. 100, page 148). In vertical transverse section it is triangular in shape, and is intersected by two white laminæ, which divide it into three parallel strands, internal, middle, and external, of a somewhat different colour (figs. 86, 93). The internal and middle are pale in colour, hence the name *globus pallidus* applied to them; the external segment is darker and is called the *putamen* (clippings, shells) (fig. 93).

Claustrum.—External to the nucleus lenticularis will be seen a narrow band or streak of grey matter—the CLAUSTRUM—separated from the nucleus lenticularis by a white strand of fibres, the *outer capsule*

Plate XXXIV.

FIG. 86.



A.C. *Anterior cornu.*
C.S. *Corpus striatum (nucleus caudatus).*
C.C. *Corpus callosum.*
T.S. *Tænia semicircularis.*
O.T. *Optic thalamus.*
H.Ma. *Hippocampus major.*
C.P. *Choroid plexus.*
T.H. *Tænia hippocampi.*
E.C. *Eminentia collateralis.*
P.C. *Posterior cornu.*

N.C. *Nucleus candatus.*
I.C. *Interior capsule.*
 a. *Anterior limb.*
 g. *Genu.*
 p. *Posterior limb.*
N.L. *Nucleus lenticularis.*
E.C. *External capsule.*
C. *Claustrum.*
W.I. *White matter of Isle of Reil.*
G I *Grey matter of Isle of Reil.*
P. *Putamen.*
O.T. *Optic thalamus.*
H.Mi. *Hippocampus minor.*

(fig. 86), and from the contiguous grey matter of the isle of Reil by a second white strand. Thus, enumerated from within outwards, we have—

1. The nucleus caudatus.
2. The inner capsule.
3. The nucleus lenticularis.
4. The outer capsule.
5. The claustrum.
6. A strand of white fibres—white matter of the isle of Reil.
7. The grey matter of the isle of Reil.

Both the nucleus lenticularis and the claustrum are continuous below and in front with the amygdaloid nucleus, which is a thickened part of the cortex of the tempero-sphenoidal lobe. It is seen at the anterior end of the descending horn of the lateral ventricles.

The **Optic Thalami** are two large, oval, convex prominences placed above the crura cerebri, but behind and internal to the corpora striata from which they are separated by the tænia semicircularis. Forming part of the floor of the lateral ventricle and the wall of the 3rd ventricle, each optic thalamus consists of a central grey core, covered on the surface by a stratum of white matter, and, where they enter into the ventricular cavities, by ependyma and epithelium. Their anterior end is rounded—ANTERIOR TUBERCLE, and their posterior and external extremity swells out into a prominence—the POSTERIOR TUBERCLE or PULVINAR, which overhangs not only the brachia of the corpora quadrigemina (fig. 98, page 146), but also two oval nodules called the corpora geniculata interna and externa (fig. 98).

The *upper surface* of the thalami optici appears in the floor of the lateral ventricles, and resting upon it are the velum interpositum, the choroid plexus, and the edge of the fornix. The *under surface,* in its hinder part, is placed on the crus cerebri (tegmentum) and forms part of the roof of the descending horn; in front it lies over the corpus albicans and tuber cinereum.

The *inner (mesial) surfaces* of the optic thalami form the lateral walls of the 3rd ventricle, and along them run the peduncles of the pineal gland. Passing transversely between them is the grey or soft commissure. *Externally,* the optic thalami blend with the substance of the hemispheres, their outer limit being the inner capsule.

In front of the optic thalami are the anterior pillars of the fornix (fig. 80, page 122, and fig. 85, page 132), passing to the base of the brain; and between the optic thalami and the pillars of the fornix is the foramen of Monro (figs. 80, 85).

Behind the optic thalami are the posterior pillars of the fornix, winding down the descending horn of the lateral ventricle (figs. 83, 86).

STRUCTURE.—The optic thalami are chiefly composed of grey matter arranged as three nuclei—anterior, outer, and inner (fig. 86). The course and relations of its white tracts are not yet understood.

"The Function of Basal Ganglia are as yet undecided. Anatomical appearances seem to be in harmony with the view that these ganglia are terminal stations of certain tracts of the cerebral peduncles, co-ordinate with, but not subordinate to, the grey matter of the cortex" (Ferrier).

The optic thalami in man may probably take the place of the corpora quadrigemina in the frog, and like them exercise a restraining influence on the reflex centres of the spinal cord.

Corpora Geniculata.—Below and external to the pulvinar, are, as we have said, two pairs of oval eminences—the CORPORA GENICULATA INTERNA and EXTERNA—the internal being below and mesial to the external, and separated from them by a band of white fibres, one of the roots of the optic tract (fig. 98, page 146).

They consist of grey matter internally, and from each proceeds a white band to join the optic tracts. Similar tracts connect the external bodies to the nates and the internal to the testes.

The **Corpora Quadrigemina** (fig. 85), are four rounded tubercles separated from each other by two grooves, the one longitudinal, the other transverse. They are placed in pairs, on each side of the middle line, behind the pineal gland and above the aqueduct of Sylvius; the anterior pair are called the nates, the posterior pair, the testes, and they rest upon a thin lamina—the lamina quadrigemina—beneath which passes the aqueduct of Sylvius. Laterally, each pair is prolonged into two white bands or cords—the ANTERIOR and POSTERIOR BRACHIA (fig. 98)—the anterior passing between the corpora geniculata interna and externa, and thence to the optic tracts of which they are the direct roots; the posterior brachia run forwards and outwards, and are lost between the corpora geniculata interna (fig. 98).

STRUCTURE.—The anterior pair of corpora quadrigemina consist of several layers of grey and white matter; the posterior pair of a central grey core and of a white cortex. Homologues of the corpora quadrigemina exist in all vertebrata. They invariably give origin to the optic nerves, and in size bear a direct relation to the animal's power of sight.

In birds there are only two corpora, but they are very large, especially in those birds which have great powers of sight. In the mole the posterior pair are well developed, the anterior pair are rudimentary.

Injury to the optic nerves causes the anterior pair to waste, but leaves the posterior pair unaltered.

The **Pineal Gland** (or Body) is a reddish, vascular, oval body, situated in the middle line above the aqueduct of Sylvius and in front of the corpora quadrigemina. Firmly attached to the velum interpositum, which gives it a special covering (fig. 84), this so-called gland is connected to the cerebrum by two white bands —the PEDUNCLES—which, as we have already seen, run one along the inner surface of each optic thalamus. The peduncles end in front by joining the anterior pillars of the fornix. Posteriorly, the pineal gland is connected with the posterior commissure.

In STRUCTURE the pineal gland is composed of follicles, separated by connective tissue, and filled with cells, calcareous particles (brain sand), and corpora amylacea. It is probably a rudimentary eye.

III. THE COMMISSURES.

The commissures of the brain are two-fold, longitudinal and transverse. The longitudinal commissure is the fornix; the transverse ones are the corpus callosum, the anterior, middle, and posterior commissures.

Plate XXXV.

Fig. 87.

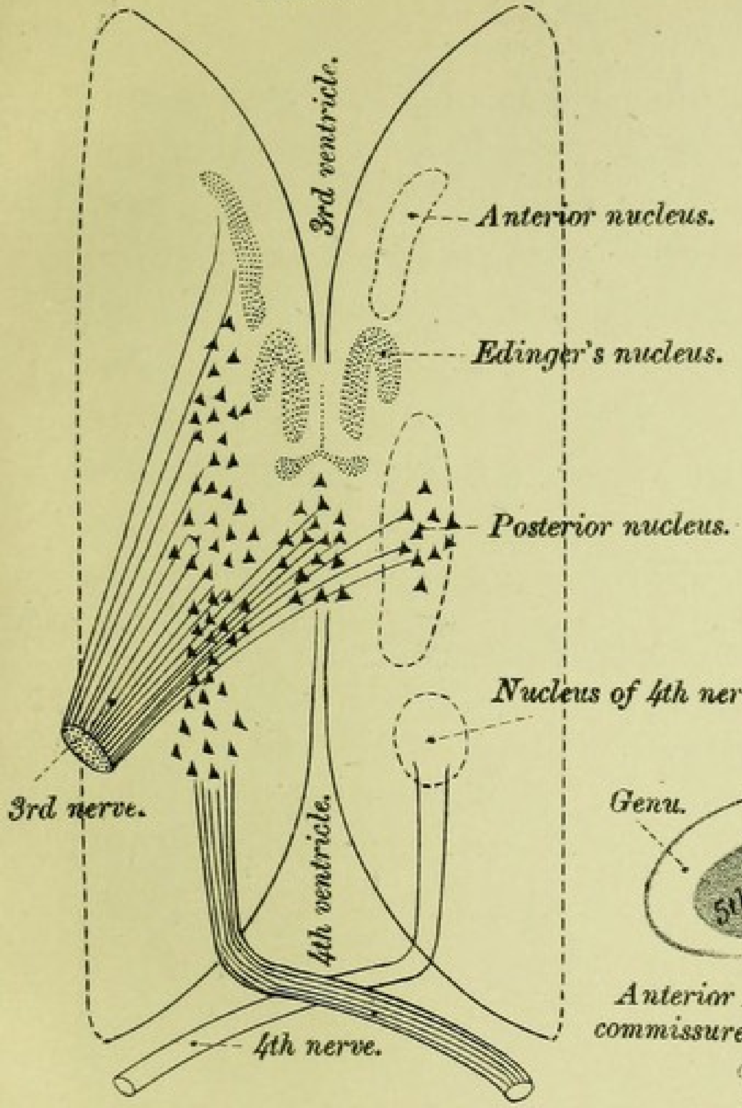


Diagram of Nuclei of 3rd and 4th Nerve.

Fig. 88.

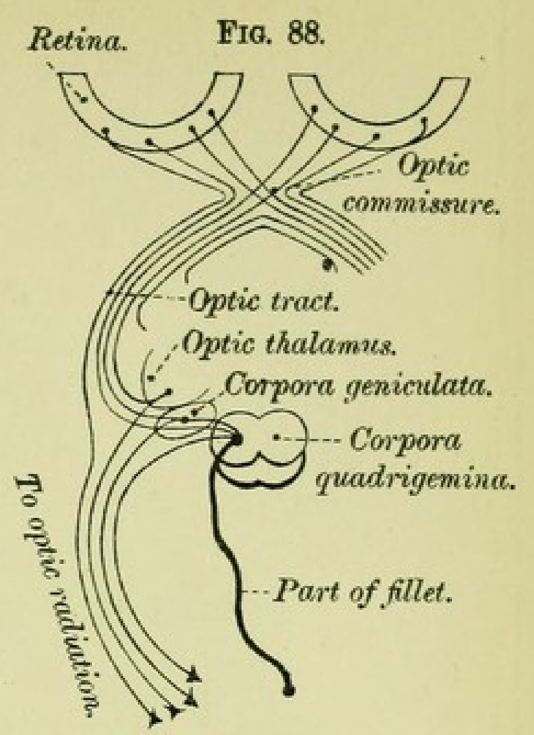


Diagram of Optic Nerves and Optic Tract.

Fig. 89.

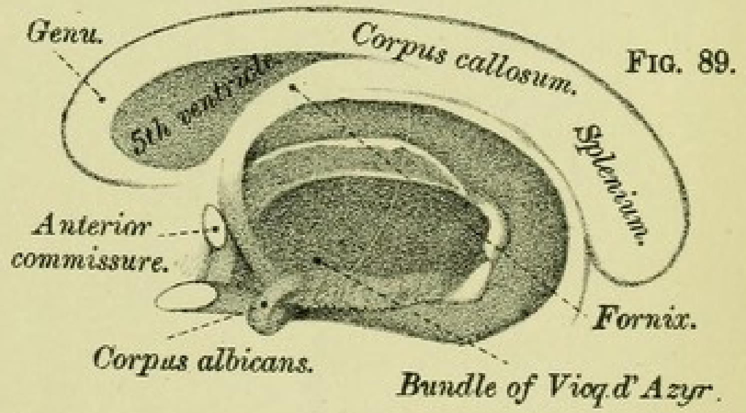


Fig. 90.

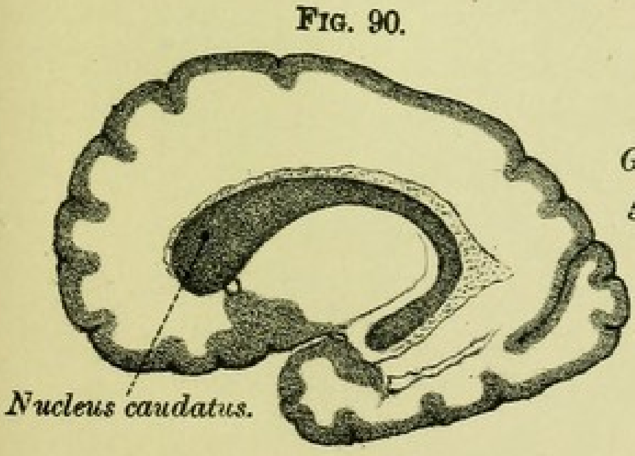


Fig. of the shape of the nucleus caudatus.

Fig. 91.

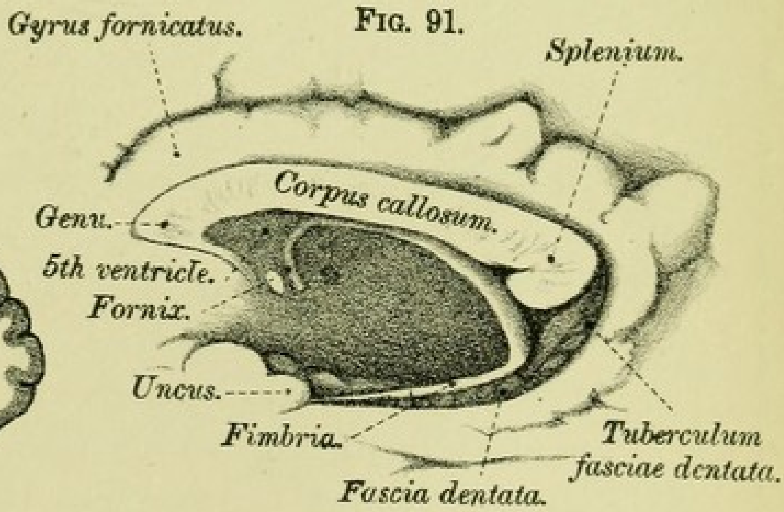


Fig. of Fornix—the Optic Thalamus removed.

The **Corpus Callosum.**—As you already know, the corpus callosum is the white transverse band of nerve fibres, which arches from before backwards in the middle line between the cerebral hemispheres and connects them together. About four inches long, it forms the floor of the great longitudinal fissure and the roof of the lateral ventricles, and reaches further forwards than backwards. It is thicker at the ends than in the middle of its extent, and is thickest and widest behind.

Anteriorly, it turns downwards and backwards upon itself in the great longitudinal fissure, making a knee-shaped bend—the GENU (fig. 80, page 122). Becoming gradually smaller it then forms a narrow median band—the ROSTRUM (fig. 80)—which ends below at the base of the brain by bifurcating into two tapering processes—the PEDUNCLES—which, you will remember, could be traced to the anterior perforated spot at the root of the fissure of Sylvius, and were there lost.

Posteriorly, on the other hand, the corpus callosum ends in a thickened, free, rounded border or base—the SPLENIUM (fig. 80)—from the outer ends of which diverge two horn-shaped bundles of fibres into the occipital lobes.

The *upper surface* of the corpus callosum is marked along the middle line by a longitudinal groove—the RAPHÉ—on each side of and parallel to which you will see two or more faint lines—the MEDIAN LONGITUDINAL STRIÆ (nerves of Lancisi). Externally, under cover of the overhanging edge of the gyrus fornicatus, are similar longitudinal striæ—LATERAL LONGITUDINAL STRIÆ (tæniæ tectæ, covered band). The median striæ, when traced forwards, are joined in front by a prolongation of the lateral striæ, and pass with them round the anterior end of the corpus callosum to the anterior perforated spot; behind, the striæ diverge into the occipital lobes.

The *under surface* of the corpus callosum rests, in the posterior half of its extent, upon the body of the fornix, to which it is closely adherent, especially near the splenium. In its anterior half, it is connected below with the vertical mesial partition—the *septum lucidum*—filling up, as we have seen, the space left between the fornix and concavity of the knee-shaped bend of the corpus callosum (fig. 89, page 140).

Laterally, the transverse fibres of the corpus callosum form the roof of the lateral ventricles, and diverge into the white substance of the hemispheres.

STRUCTURE.—The corpus callosum consists of white nerve fibres which are in the main transverse, a few only being longitudinal. As they pass into the hemispheres they diverge in all directions, and probably go along with the fibres of the *corona radiata* to the grey matter of the cortex. The fibres which radiate out from the genu into the frontal lobes are called the forceps anterior; those that radiate out into the occipital lobes are called the forceps posterior (major and minor).

It is worthy of note that the corpus callosum may be absent without any ill effect (Holden).

The **Fornix** (fig. 89, 91, page 140).—Beneath the corpus callosum, and more or less blended with it, especially behind, is a longitudinal system of commissural fibres—the FORNIX. It is an arched white band which connects the hippocampi with each other, and with the optic thalami. The fibres of which it is composed spring as two riband-like bands—the POSTERIOR PILLARS of the FORNIX or FIMBRIA—one on each side, from the free surface of the hippocampus major, in the descending horn of the lateral ventricles (fig. 91). Ascending from the concave edge of the hippocampus the two pillars pass round the posterior ends of the optic thalami, and converging towards each other, meet in the middle line to form a wide, flattened, triangular-shaped band—the BODY of the fornix—which has its apex directed forwards and its base backwards towards the splenium.

Superiorly, the body of the fornix is in contact with the under surface of the corpus callosum; *inferiorly*, it lies on the delicate lamina—the velum interpositum. *Behind*, it blends with the splenium. *In front*, its fibres diverge and pass downwards and forwards from the apex of the body, as two cylindrical processes—the ANTERIOR PILLARS—lying side by side. They can be traced downwards, in front of the optic thalami but behind the anterior commissure, to the base of the brain, where, twisting on themselves like a figure of 8, they form the cortex of the *corpora albicantia*, and then re-ascend to the anterior tubercles of the optic thalami as the bundle of Vicq d' Azyr (fig. 89, page 140).

At *the sides* the fornix appears as a thin, free, sickle-shaped edge, which rests upon the velum interpositum and the optic thalamus, and enters into the formation of the floor of the lateral ventricles.

Originally the fornix consisted of two separate divisions, right and left, but these ultimately fuse in the middle line to form the body, their ends remaining free as the anterior and the posterior pillars of the fornix.

Where the posterior pillars of the fornix diverge from each other, there will be found a triangular space filled up by transverse fibres of white matter. It is called the *lyra*. Sometimes the fornix is entirely blended with the posterior part of the under surface of the corpus callosum; at other times a small interval called the *ventricle of Verga* is left between them.

The **Tænia Semicircularis** is the narrow white band which lies in the groove between the nucleus caudatus and the optic thalamus. In front, it joins the corresponding pillar of the fornix; behind it passes into the substance of the roof of the descending horn of the lateral ventricle.

The *Anterior, Middle,* and *Posterior Commissures* are connected with the 3rd ventricle (fig. 80, page 122).

The **Anterior Commissure** is a round white cord which passes transversely across the middle line in front of the anterior pillars of the fornix. It connects together the corpora striata, and its fibres can be traced through those bodies, and below the nucleus lenticularis to the tempero-sphenoidal lobe and occipital lobes. Other fibres pass towards the olfactory lobes.

The **Middle (Grey) Commissure** crosses the 3rd ventricle between the optic thalami. It is a delicate band of grey matter connected with the grey matter of the thalami optici.

The **Posterior Commissure**, situated in front of and below the pineal gland, but above the commencement of the passage into the 4th ventricle, is a rounded band which stretches between the optic thalami. Some of its fibres are said to come from the fillet (derived from the tegmentum of the crura cerebri) and to pass through the thalami to the hemispheres.

FIG. 92.

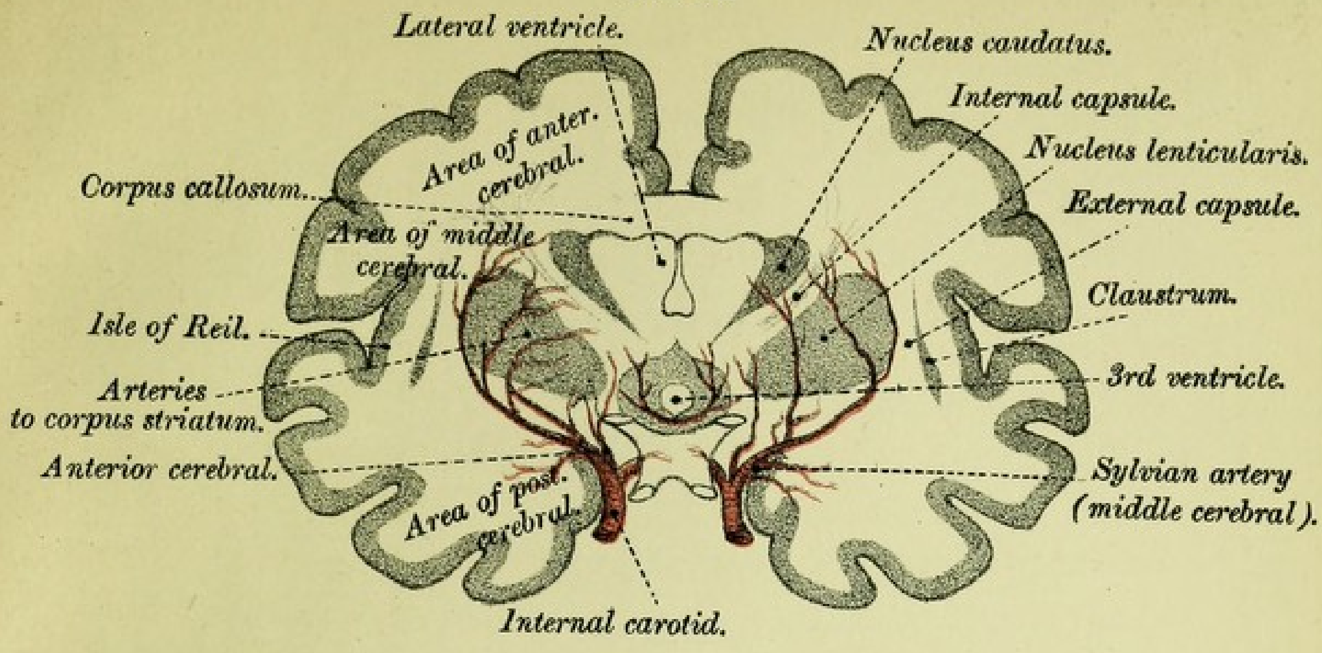


FIG. 93.

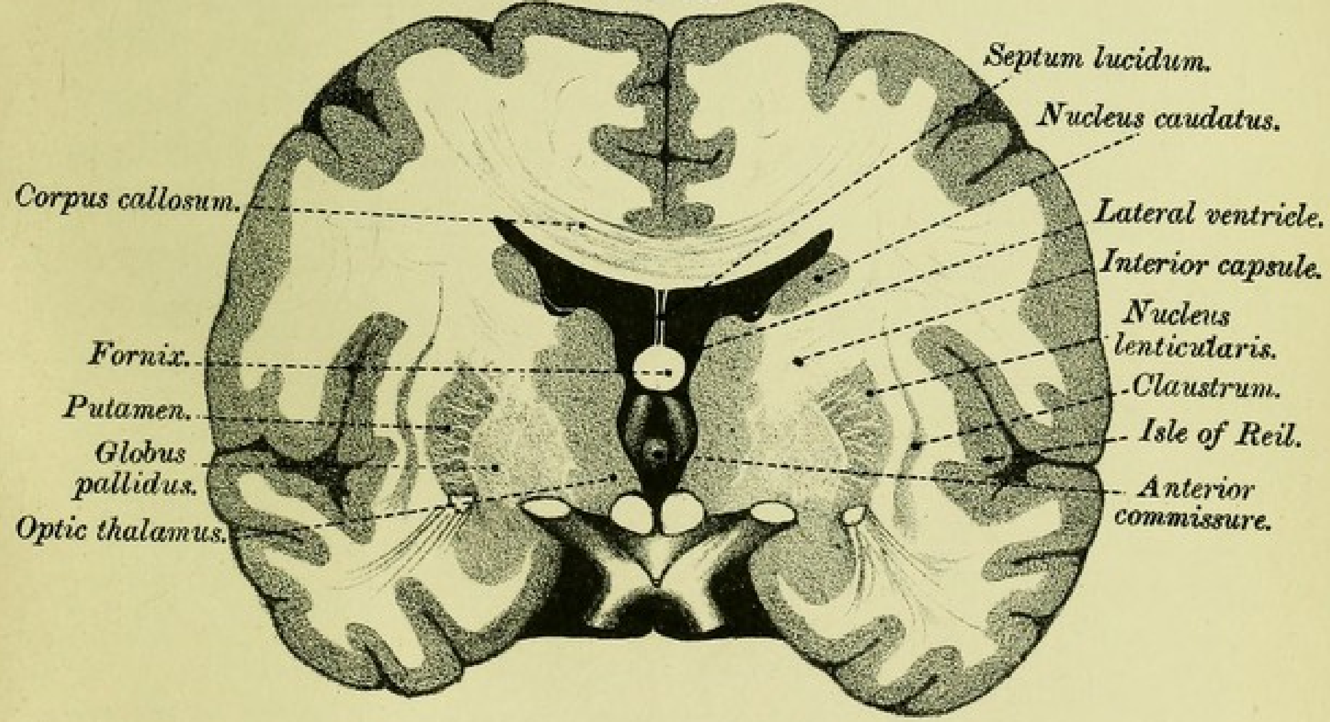


FIG. 94.

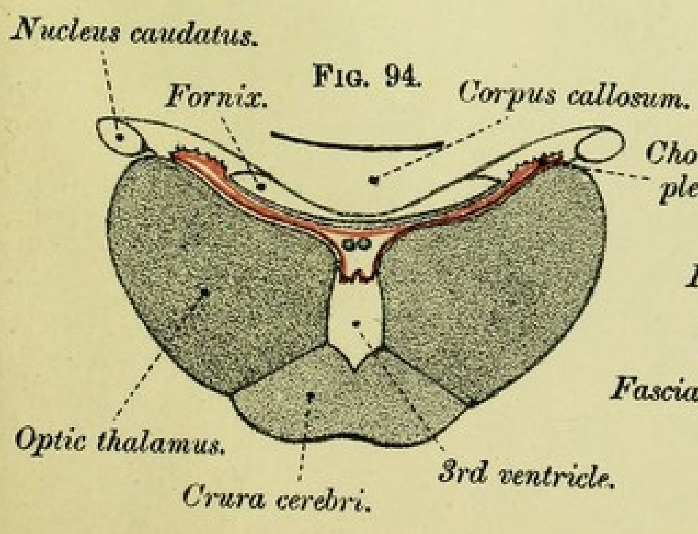
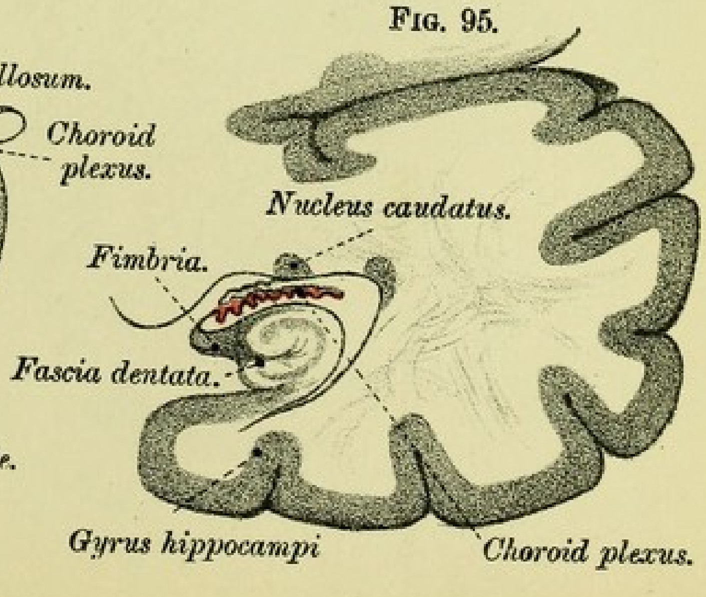


FIG. 95.



The Crura Cerebri, or Cerebral Peduncles.

The **Cerebral Peduncles** (fig. 46, page 64), are the two rounded masses which spring, in front, from the upper margin of the pons, and, diverging from each other, soon enter the base of the cerebral hemispheres.

Between the peduncles, where they diverge from each other, lie the posterior perforated spot and the corpora albicantia (fig. 98, page 146); winding round their outer side are the optic tract; on their inner side is a groove, the oculomotor groove, from which the 3rd nerve takes its superficial origin; and on the dorsal aspect are the corpora quadrigemina, with the lamina quadrigemina, beneath which passes the aqueduct of Sylvius.

Structure.—A section at right angles to the crura will show you that they each consist of two portions, a posterior or dorsal, called the TEGMENTUM, and an anterior or ventral, called the PES, BASIS, or CRUSTA. These two parts of the crura are separated from each other by a narrow stratum of grey matter, called, from its dark colour, the LOCUS NIGER (substantia nigra), the position of which is indicated on the surface by the oculomotor groove internally, and by another slight groove, the lateral sulcus, externally (fig. 61, page 84).

1. The **Tegmentum** (fig. 61) is the larger division of the crus, and, like the formatio reticularis of the medulla and pons, is composed of a reticulum of longitudinal and transverse fibres interspersed with grey matter.

(1) The *grey matter* of the tegmentum consists of scattered cells, and of a definite collection lying beneath the anterior part of corpora quadrigemina, and known as the RED NUCLEUS or NUCLEUS TEGMENTI (fig. 61), a collection of multipolar nerve cells. This nucleus is probably the primary termination of the superior cerebellar peduncles.

(2) The *white matter.*—The longitudinal fibres come from the anterior and lateral columns of the spinal cord, and form the superior cerebellar peduncles. The best marked tracts are the POSTERIOR LONGITUDINAL BUNDLE and the TRACT OF THE FILLET; the former appearing in sections of the crura as two well marked strands on each side of the aqueduct of Sylvius; the latter, the fillet, appears as a tract of oblique white fibres on the outside of the red nucleus (fig. 61). The transverse fibres are as yet little understood.

2. The **Pes, Basis, or Crusta**—the ventral part of the peduncles—lies in front of the locus niger, and is chiefly composed of the pyramidal tracts of the medulla, though others are superadded, for transverse sections of the pes, are much larger than those of the pyramids. The following are the various tracts of fibres of the crusta:—

(1) The *pyramidal fibres.*

(2) The *fronto-pontine tract,* which passes from the frontal lobes to the pons and cerebellum.

(3) The *temporo-occipital tract,* from the temporal and occipital lobes.

(4) The *caudate cerebellar fibres* or boundary layer of the pes. They probably come from the caudate nucleus.

FIG. 96.

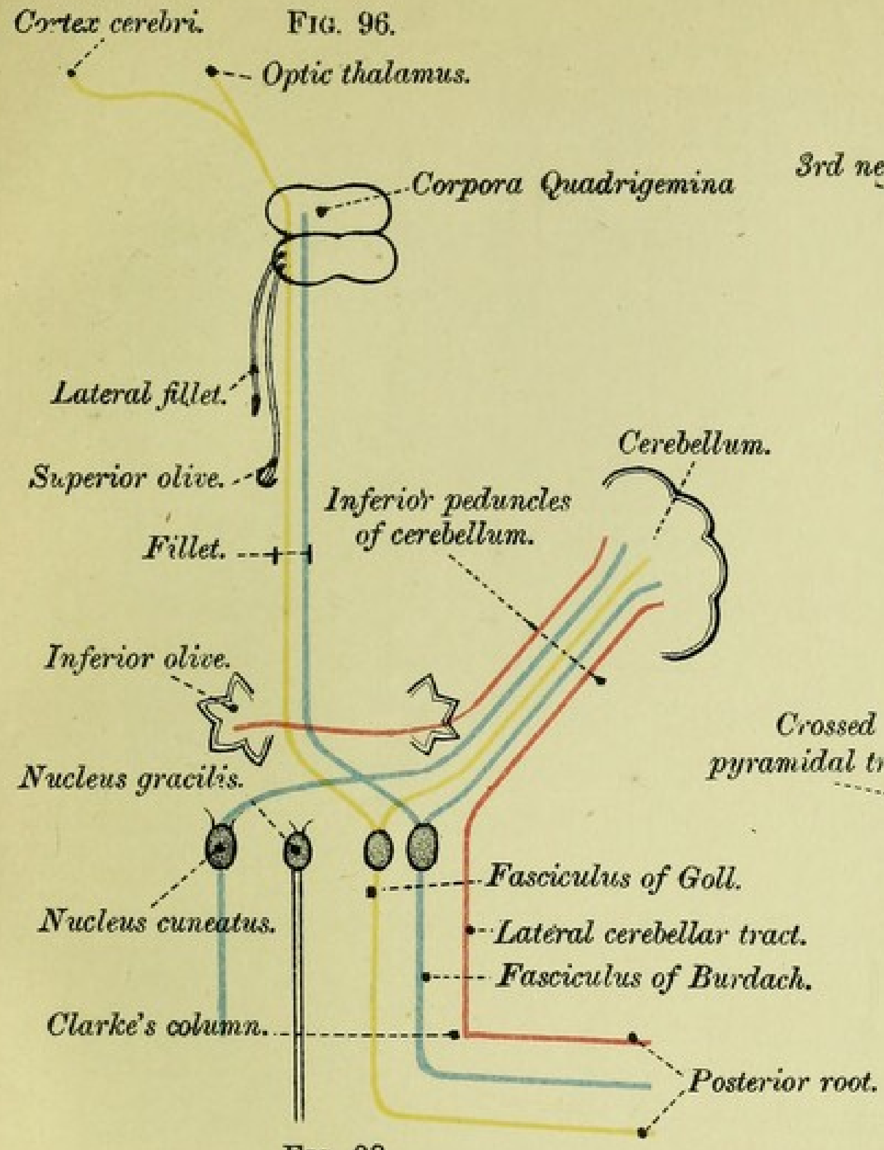


FIG. 97.

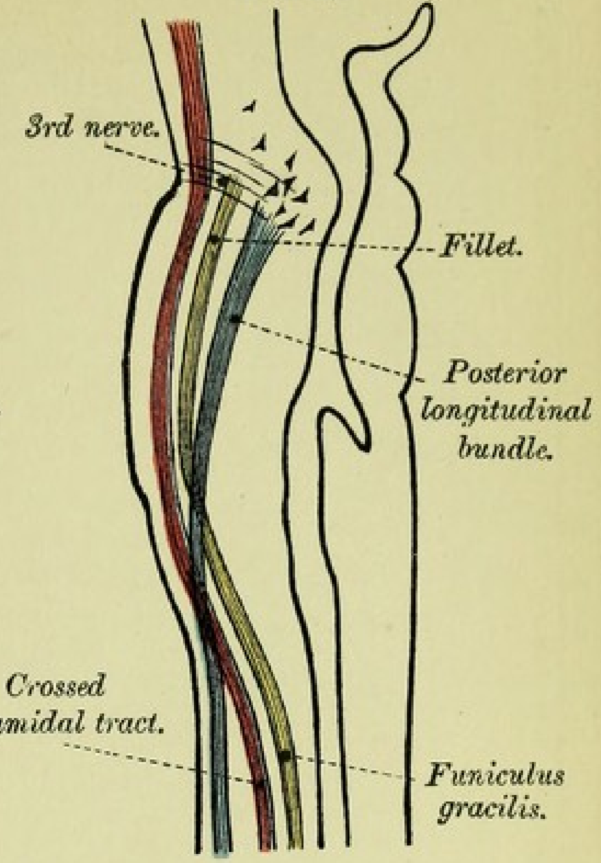


FIG. 98.

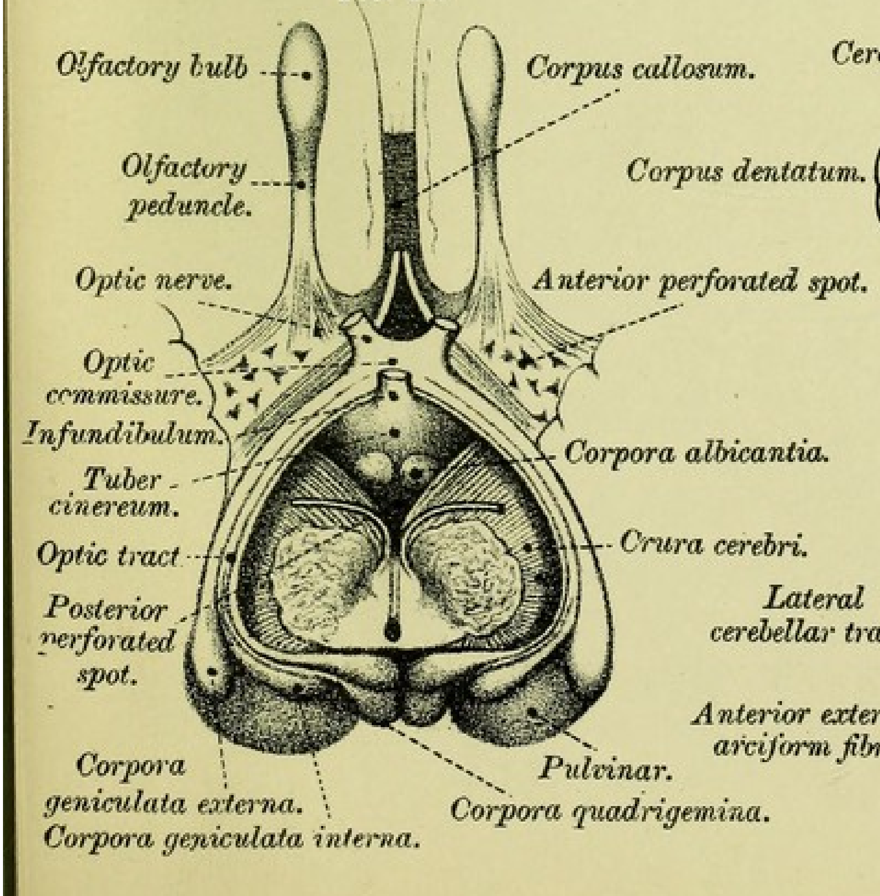
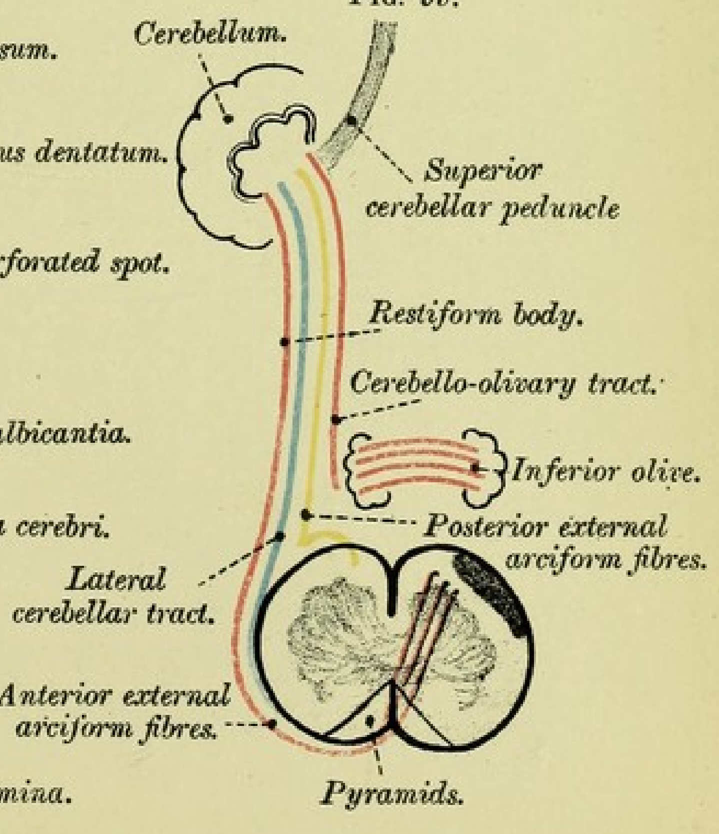


FIG. 99.



The relative positions of these tracts to each other will be understood by reference to fig. 61, page 84.

3. The **Substantia Nigra** is a semilunar band of grey matter placed between the two divisions of the crus. It is characterised by darkly pigmented cells—hence the name—and through it pass the roots of the 3rd nerve before they emerge at the oculomotor groove (fig. 61).

The two pedes are quite distinct from each other, whereas the two tegmenta are merely separated by the median raphé.

INTERNAL AND EXTERNAL CAPSULES.

(Plate 34, fig. 86, page 136).

In treating of the Basal Ganglia you will remember we referred to two strands of white fibres, the INNER and OUTER CAPSULES, the former lying internal to, the latter external to, the nucleus lenticularis. These so-called capsules are of the greatest importance clinically, for through them pass the chief motor and sensory tracts.

The **Internal Capsules** (fig. 86, plate 34, page 136).—Seen in horizontal section each internal capsule appears as a semi-lunar shaped band of white matter with its convexity directed towards the middle line. It can be divided into two portions—an *anterior* and a *posterior*. The ANTERIOR DIVISION lies between the nucleus caudatus and the nucleus lenticularis; the POSTERIOR DIVISION lies between the optic thalamus and the nucleus lenticularis, and forms with the anterior division a sharp angle, or knee-shaped bend—the GENU. The inner capsule therefore, may be said to consist of three parts—(1) A knee-shaped bend, the genu; (2) a part in front of the knee; and (3) a part behind the knee. This capsule contains all the fibres of the foot of the crus cerebri of the same side except those that go to the nucleus lenticularis. Emerging from between the nucleus lenticularis and the tail of the caudate nucleus and reinforced by fibres from the optic thalamus and the region below it, the fibres of the pes form a radiating, hollow fan-shaped mass of nerve fibres—the CORONA RADIATA—which spreads out into the cerebral cortex.

The tracts forming the knee, and the anterior two-thirds of the posterior division of the inner capsule are motor in function, and are in relation respectively, from before backwards, with the centres for the oro-lingual, facial, brachial, crural, and trunk muscles (Ferrier). Injury to this portion of the inner capsule results in loss of motion on the opposite side of the body.

The posterior third or more of the hinder division of the inner capsule, probably contains the sensory strands, for, when injured or diseased, there ensues loss of sensation, general and special, on the opposite side of the body, the motor powers not being affected, unless the lesion implicates the motor tracts also.

The anterior limb of the internal capsule—in front of the knee-shaped bend—carries fibres from the frontal lobes to the cerebellum—(fronto-pontine tract). They undergo descending degeneration, and are therefore an efferent tract.

FIG. 100.

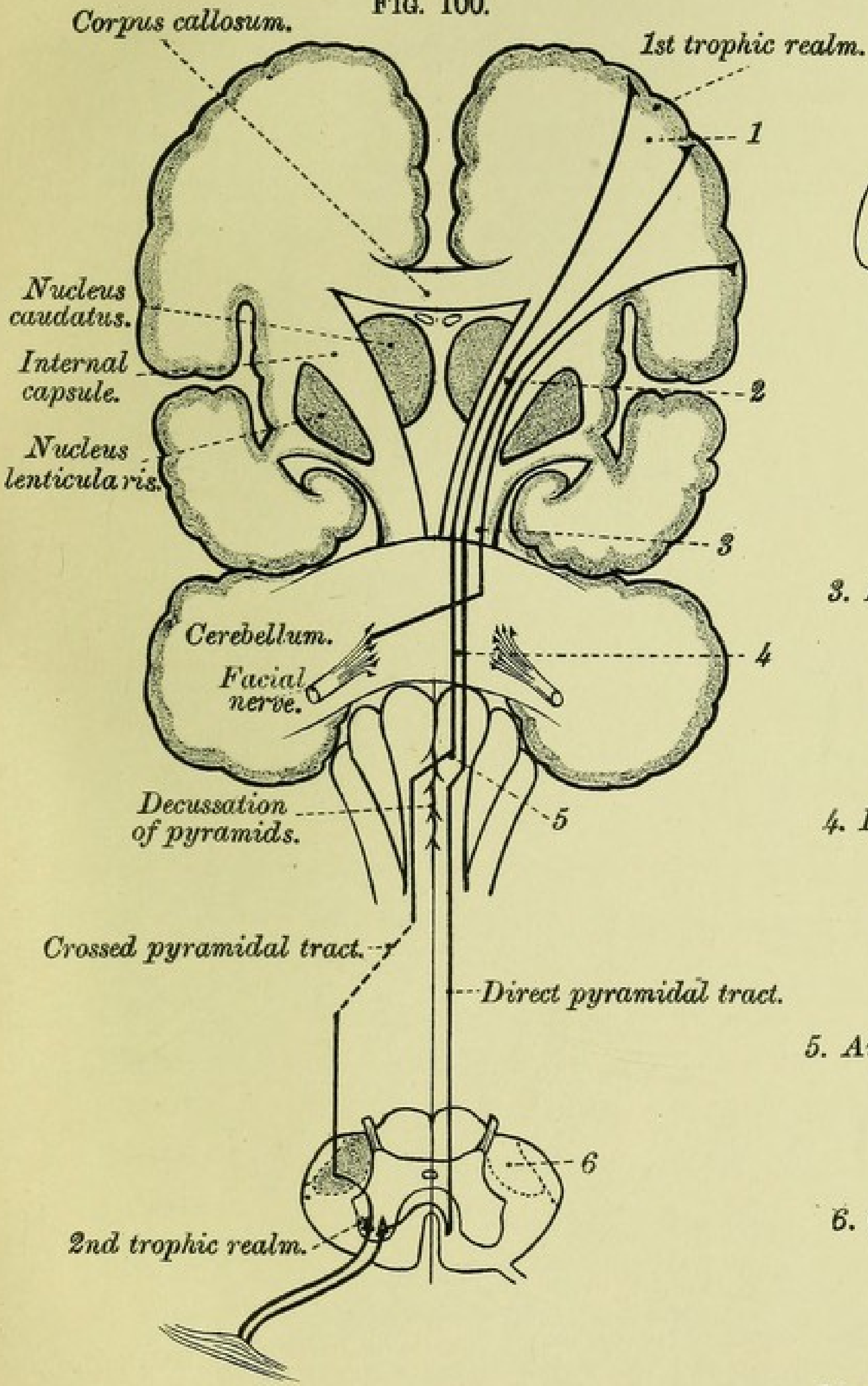


DIAGRAM OF MOTOR TRACTS.

FIG. 101.

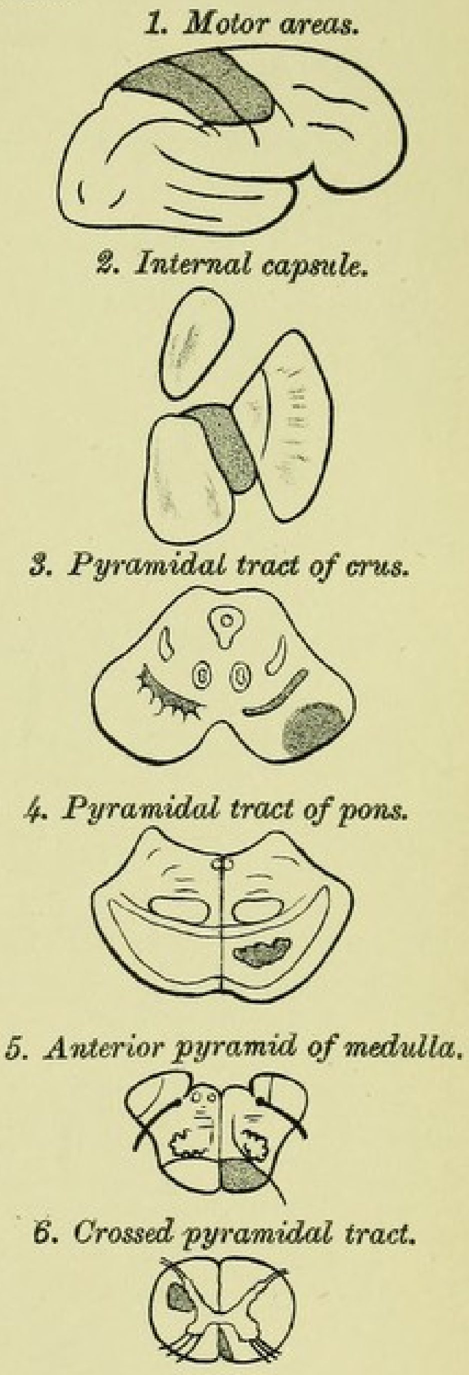


DIAGRAM OF A DESCENDING DEGENERATION.

The **External Capsule** lies between the nucleus lenticularis and the claustrum. The tracts which compose it, and their functions, are undecided.

Fig. 92, plate 36, page 144, will give you an idea of the relations of the Sylvian artery, and the distribution of its branches to the capsules, and to the contiguous nuclei. The lenticular-striate artery is called the artery of cerebral hæmorrhage.

Course of the Strands of Nerve Fibres.

(Fig. 50, page 70 ; fig. 37, page 146 ; fig. 39, page 150.)

Of the various strands of fibres described in the spinal cord, the course of the PYRAMIDAL TRACTS (crossed and direct) is alone known with any degree of certainty.

These tracts—*crossed pyramidal* and *direct pyramidal*—start from the motor areas in the brain—*ascending frontal* and *ascending parietal convolutions*—and thence pass down through the *corona radiata*, through the *knee-shaped bend* and *anterior two-thirds* of the *posterior limb* of the *internal capsule.* They then descend through the middle portion of the *crusta* of the *crura cerebri;* through the *pyramidal tracts of the pons,* thence to the *anterior pyramids of the medulla* where the crossed fibres decussate and travel down the *lateral column* of the opposite half of the cord. Finally, by means of collaterals, they come in relation to the nerve cells (root cells) of the anterior horn, whence pass the motor nerve fibres (fig 100, page 148).

The fibres of the *direct pyramidal tract* travel down the anterior columns of the same side, but ultimately decussate in the cord.

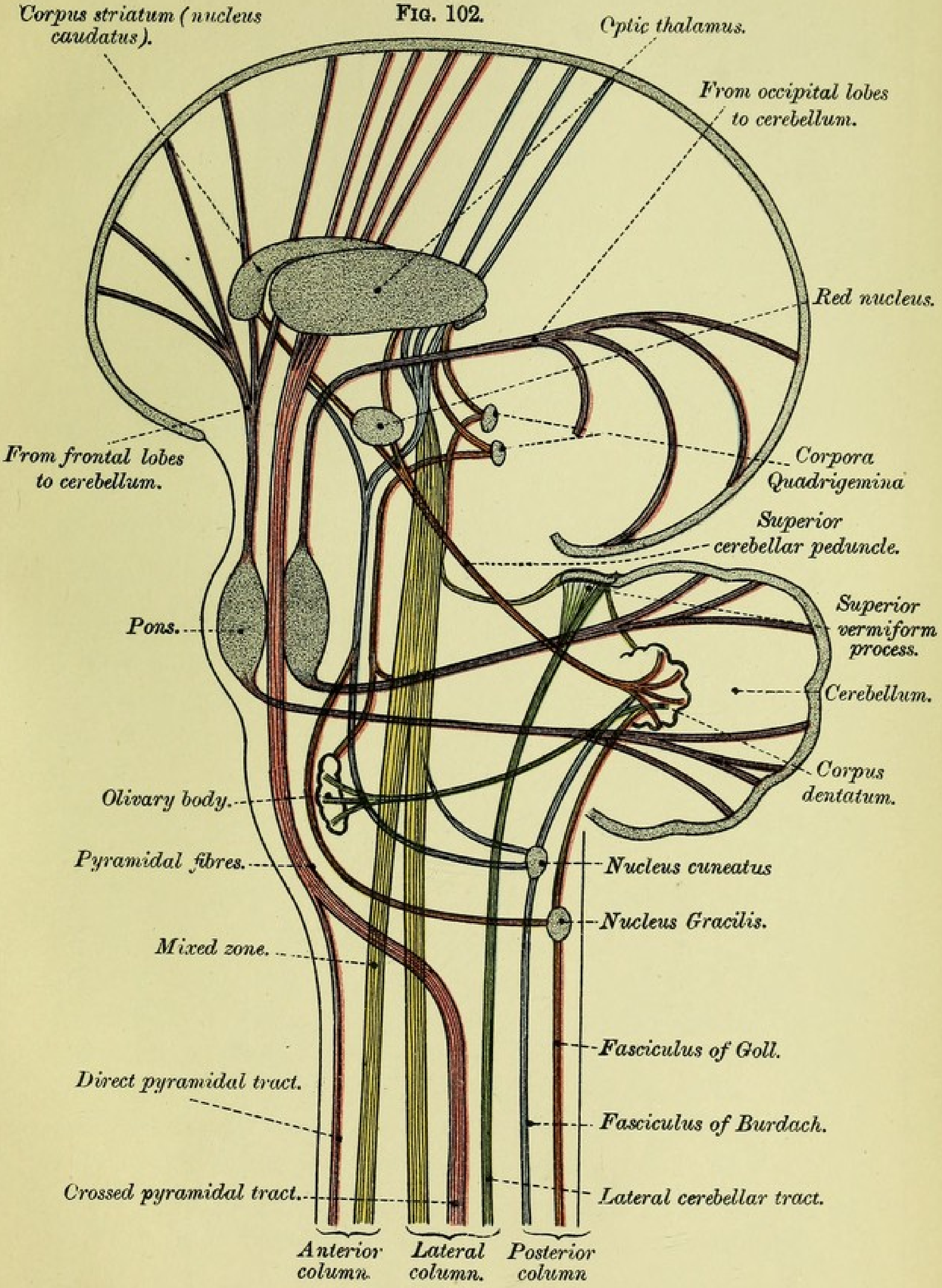
The DIRECT LATERAL CEREBELLAR TRACT of the spinal cord passes upwards to form part of the restiform body; and, judging from the degeneration which follows its section, is probably connected with the SUPERIOR VERMIFORM PROCESS of its own side (Ferrier).

The greater part of the fibres of the anterior and lateral columns of the cord enters the formatio reticularis of the medulla and pons. Some of the fibres there form distinct strands—viz., the *posterior longitudinal bundle* and the *fillet* (figs. 96, 97, page 146), which probably end in the region of the corpora quadrigemina and optic thalami, though some fibres can be traced to the cerebrum (plate 39).

The FUNICULUS GRACILIS and the FUNICULUS CUNEATUS first pass to their respective nuclei in the medulla, thence fibres can be traced through the restiform body to the cerebellum (see Restiform Body); and through the sensory decussation and tract of the fillet to the corpora quadrigemina, optic thalamus, and cerebral cortex of the opposite side, (plate 37, fig. 96, and plate 39).

The SUPERIOR CEREBELLAR PEDUNCLES (see page 90), pass upwards from the corpus dentatum and cerebellar cortex, and can be traced beneath the corpora quadrigemina, with which they are connected, and beneath which the fibres decussate in the middle line, and go to the red nucleus of the tegmentum, their primary

FIG. 102.


Corpus striatum (nucleus caudatus).
Optic thalamus.
From occipital lobes to cerebellum.
Red nucleus.
From frontal lobes to cerebellum.
Corpora Quadrigemina
Superior cerebellar peduncle.
Superior vermiform process.
Pons.
Cerebellum.
Corpus dentatum.
Olivary body.
Pyramidal fibres.
Nucleus cuneatus
Nucleus Gracilis.
Mixed zone.
Fasciculus of Goll.
Direct pyramidal tract.
Fasciculus of Burdach.
Crossed pyramidal tract.
Lateral cerebellar tract.
Anterior column.
Lateral column.
Posterior column

termination, though it may be that some of the fibres pass on to the lenticular nucleus, and through the optic thalamus to the corona radiata.

The transverse fibres of pons—MIDDLE PEDUNCLE of the CEREBELLUM—are partly commissural between the cerebellar hemisphere, but many of them, through the multipolar nerve cells of the pons (nucleus pontis), connect the cerebellar peduncles with the pyramidal strands of the opposite side (Ferrier).

The INFERIOR PEDUNCLES or restiform bodies have been sufficiently described at page 91.

SUPERFICIAL AND DEEP ORIGINS OF THE CRANIAL NERVES.

By the term *superficial origins* of the cranial nerves is meant the points at which they are attached to the surface of the brain. Their *deep origins* are the several deep-seated nuclei to which they can ultimately be traced.

1. The **Olfactory Nerves,** 1st pair, spring from the olfactory bulbs, and pass through the holes in the cribriform plate of the ethmoid, to be distributed to the upper part of the olfactory mucous membrane. The roots of the olfactory peduncles have already been noticed (page 107). Their deep origin is uncertain, but the outer root can be traced to the extremity of the temporo-sphenoidal lobe, where it blends with the anterior end of the gyrus hippocampi. It is worthy of note that in animals with well-developed organs of smell, the gyrus hippocampi, the striæ longitudinalis, and the fascia dentata are well marked; whereas in man,

with small olfactory lobes, they are relatively small. Injury to the olfactory bulb causes atrophy of the uncinate gyrus of the same side. There is, moreover, a connection of the olfactory bulb through the anterior commissure, some fibres of the olfactory peduncle passing into that commissure.

2. The **Optic Nerves,** 2nd pair, are given off from the sides of the optic commissure, and enter the eyeball through the optic foramen. Traced backwards they pass through the optic commissure, and then round the outer sides of the crura cerebri, as the optic tracts. The deep origin consists of a ganglionic and of a cortical set of centres.

(1) The *ganglionic centres* are the PULVINAR (posterior part of the optic thalamus), the CORPORA GENICULATA, and the ANTERIOR pair of the CORPORA QUADRIGEMINA (fig. 98, page 146).

(2) The *cortical centres.*—Many authors hold that the optic nerves are connected with all the lobes of the cerebrum, but there can be no doubt that, through the *optic radiation* they are connected with the occipital lobe, the region of the centre for sight (fig. 44, page 46).

In the optic tract there are three sets of fibres—(1) outer set, to eyeball of same side; (2) middle set, which decussate with the fibres of the opposite tract, and go to opposite eye—*e.g.*, those of the right tract to the left eye, and those of left tract to right eye; (3) an internal set, which pass from the one tract to the other, and back to the brain without entering the eye. (fig. 88, page 140).

"The roots of the optic tracts which spring from the corpora geniculata interna (the internal set of fibres named in the last paragraph) have no real connection with vision, as they do not undergo atrophy like the other roots when the eyes are destroyed" (Ferrier).

The **3rd Nerves** appear at the OCULOMOTOR GROOVE, on the inner side of the crura cerebri close to the pons Varolii (fig. 79, page 127; fig. 58, page 78). Traced backwards, they are found to pass through the tegmentum to a column of cells, on each side of the middle line, in the grey matter of the FLOOR of the AQUEDUCT OF SYLVIUS (fig. 87, page 140). This collection of cells is called the oculomotor nucleus, and is a continuation of the anterior horn of the spinal cord. It is closely connected with the nuclei of the 4th and 6th nerves. The nucleus of the 3rd nerve gives rise to three sets of fibres—

1. To the muscles of the eyeball.
2. To the sphincter pupillæ.
3. To the ciliary muscle.

The **4th Nerves** will be seen on the outside of the crura cerebri, between the cerebrum and cerebellum (fig. 79). They are small and slender, and after decussating in the superior medullary velum, run in the wall of the aqueduct of Sylvius to a nucleus below that of the 3rd nerve, and to the locus cæruleus. The 4th nerve is connected with the nucleus of the 6th nerve of the opposite side (fig. 87, page 140). It is noteworthy that the fibres of the 4th nerves decussate before passing back to their nuclei of origin.

The **5th Nerves** spring from the sides of the pons, near its upper margin, by two roots—a large one, *ganglionic*, and a small one, *aganglionic*. The smaller —MOTOR ROOT—is the higher of the two, and is separated from the larger root by some of the transverse fibres of the pons. Followed backwards, this smaller part is seen to arise from the motor nucleus lying just below the LATERAL ANGLE of the 4TH VENTRICLE (fig. 57, page 78). It is joined by the descending root of the 5th nerve, which comes from the grey matter at the sides of the aqueduct of Sylvius.

The nucleus of the larger part of the nerve—the SENSORY ROOT—lies close to but on the outer side of the motor nucleus. The sensory root receives the ascending root of the 5th nerve (fig. 57), which springs from the nerve cells of the posterior horn of the spinal cord as low as the second cervical nerve. Some fibres are derived from the cerebellum.

The **6th Nerves** take their superficial origin near the middle line from the groove between the anterior pyramids of the medulla and the lower border of the pons (fig. 79). Their deep origin is situated underneath the outer part of the FASCICULUS TERES in the fore part of the floor of the 4th ventricle, in front of the striæ acusticæ (fig. 57). The 6th nerve is connected with the nucleus of the third nerve of the opposite side.

The **7th Nerve** consists of two parts—the FACIAL PART (portio dura) and the AUDITORY PART (portio mollis).

The FACIAL PART (7th) springs from the groove between the olivary body and the restiform body, just below the pons (fig. 79). Its deep origin is the facial nucleus in the formatio reticularis of the dorsal aspect of the pons, above the nucleus of the 5th nerve, and near that of the 6th, round which latter the facial nerve makes a knee-shaped bend, on its way to the surface (fig. 57).

The *pars intermedia* is a small bundle of nerve fibres which lies between the facial and auditory nerve and is connected with both. Its fibres probably come from the glosso-pharyngeal, and carry sensory impulse —taste fibres—to the facial nerve, thence through the chorda tympani to the tongue.

The AUDITORY PORTION (8th nerve) takes its superficial origin from the same groove, but behind the facial and separated from it by the *pars intermedia.* It has two roots, an upper and a lower root. The *deep origin* of the *upper root*—VESTIBULAR DIVISION—is the outer auditory nucleus beneath the lateral angle of the 4th ventricle. Some fibres are connected with the cerebellum (vermis cerebelli); and with the inferior olivary body—*acustico-olivary tract* of Bruce.*

The *lower root*—COCHLEA DIVISION—can be traced partly to the inner auditory nucleus—tuberculum acusticum—in the floor of the 4th ventricle; a second portion can be followed as the auditory striæ round the outer side of the restiform body across the middle of the floor of the 4th ventricle to this same nucleus.

The **8th pair of Nerves** consist of three parts—GLOSSO-PHARYNGEAL (9th nerve), VAGUS (10th nerve), and SPINAL ACCESSORY (11th nerve). They take their superficial origin almost in a line with, but a little behind and below the 7th nerve (fig. 57). The spinal accessory has two portions—a *spinal part* which arises from the side of the spinal cord (the lateral horn), as low as the 5th or 6th cervical nerve; and an *accessory part*

* See papers by Dr Bruce, Lecturer on Pathology, School of Medicine, Edinburgh, whose magnificent work on the Brain is in course of publication.

which takes origin from the side of the medulla below the vagus. The GLOSSO-PHARYNGEAL, the VAGUS, and accessory part of the SPINAL ACCESSORY (figs. 57, 58), take their deep origins from a series of nuclei in a line with, but below that of the 7th nerve, and in the order from above downwards in which they are here enumerated. These nuclei lie beneath the ALA CINEREA and INFERIOR FOVEA of the 4th ventricle (fig. 57). Both vagus and glosso-pharyngeal are connected with the fasciculus solitarius or respiratory bundle (fig. 55, page 74).

The **9th Nerve** (12th)—HYPO-GLOSSAL—springs by several filaments from the groove between the anterior pyramids and the olives (fig. 79). Its fibres can be traced backwards through the formatio reticularis to its deep origin, a column of cells close to the surface and near the middle line of the floor of the 4th ventricle, beneath the lower part of the FASCICULUS TERES, called the trigonum hypo-glossi (figs. 57, 58).

FUNCTIONS OF THE BRAIN.

The chief functions of the several parts of the brain have been already mentioned, and are here merely summarised for the sake of easy reference.

I. FUNCTIONS OF THE MEDULLA OBLONGATA.

Besides being a conductor of impulses the medulla contains the following centres:—

1. Centres essential to life—
   - (1) Respiratory centres.
   - (2) Cardio-motor centre.
   - (3) Cardio-inhibitory centre.
   - (4) Vaso-motor centres.

2. Centres connected with the alimentary canal—
   (1) Centre for mastication.
   (2) Centre for deglutition.
   (3) Centre for vomiting.
   (4) Centre for sucking.

3. Centres connected with the eye—
   (1) Centre for winking.
   (2) Centre for dilator pupillæ.

4. Centres for secretion—
   (1) Salivary centre.
   (2) Lachrymal centre.
   (3) Sweat centres.

5. Centres for co-ordination of movement.

II. FUNCTIONS OF THE CEREBELLUM.

1. Probably contains psychical centres like the cerebrum.
2. Centres connected with the emotions.
3. Centres for co-ordination of movements.

III. FUNCTIONS OF THE CEREBRUM.

1. The HEMISPHERES are the centres for psychical processes.
   (1) The motor centres are located in the region of ascending frontal and ascending parietal convolutions (fig. 44, page 63).
   (2) The centre for speech is placed in the left inferior frontal convolution (fig. 44).
   (3) The centres for smell, taste, and hearing are in the temporo-sphenoidal lobe (fig. 45).
   (4) The centres for sight are the angular gyrus and the occipital lobes (figs. 44, 45).

2. Basil Ganglia.—We know little or nothing of the functions of the basal ganglia. The optic thalamus, however, is closely associated with sight (see page 138).

It is worthy of note that the motor faculties occupy the anterior part, the sensory the posterior part of the brain; just as in the spinal cord and medulla the motor tracts and nerves and their nuclei are anterior, the sensory posterior.

3. Corpora Quadrigemina.—They are connected with sight, but have other functions as yet not fully known (see page 140).

4. Internal and External Capsules. — The internal capsules are motor and sensory tracts. The functions of the external capsules are not known (see page 147).

Section 3.

OUTLINE OF THE DEVELOPMENT OF THE BRAIN AND SPINAL CORD.

AN outline of the development of the central nervous system will give us a better idea of the origin, relations, and connections of the several parts of the brain described in the preceding chapters. For it is only by the study of its development that we can thoroughly grasp and understand the complicated relations and mutual bearings of the several parts of the great central nervous system.

One of the earliest steps in the development of the human embryo is, you will remember, the formation of what is known as the BLASTODERM or GERMINAL MEMBRANE. This membrane is composed of three distinct super-imposed layers of cells, the *epiblast*, the *mesoblast*, and the *hypoblast*. The first of these, the EPIBLAST, is the one from which is developed, the central nervous system, the brain and spinal cord, as well as, in all probability, part of the peripheral nervous system.

On the dorsal aspect of the embryo, at a very early date, appear two ridges, separated from each other by an intervening furrow—the PRIMITIVE GROOVE. Gradually increasing in size, these two ridges grow upwards and ultimately meet in the middle line on dorsal aspect, and, blending together, form a cylindrical longitudinal tube—PRIMITIVE MEDULLARY TUBE — with walls of epiblastic cells. From this primitive tube the brain and spinal cord are developed; the walls giving rise to the *solid parts,* the cavity remaining as the central canal of the spinal cord and of the various *ventricles.*

I. The Spinal Cord.

(Fig. 103, etc., plate 40.)

The hinder part of the primitive medullary tube gives rise to the spinal marrow. The lateral walls of this part of the tube increases much in thickness, so that the cavity of the tube is reduced to a mere slit, but its roof and floor remain thin. These walls are at first composed of columnar epithelial cells, their free ends ciliated, their attached ends resting on a basement membrane. Soon, however, this layer of cells differentiates, and three different kinds of cells are formed.

1. SPONGIOBLASTS, consisting of branching cells, the processes of which anastomose with those of neighbouring cells and form a network called *myelospongium.* The inner part of the cells still retain their columnar character.

2. GERMINAL CELLS.—At the inner ends of the spongioblasts are many rounded nucleated cells with much clear protoplasm. Their nuclei are in some stage of division, and they give rise to the next group of cells, the neuroblasts; hence, they are called *germinal cells.*

3. NEUROBLASTS.—These cells have a large oval nucleus, and little protoplasm. They give rise to the grey matter of the spinal cord, to the *nerve cells*, and *grey crescents*. They have a distinct prolongation towards the surface of the embryonic cord, towards the point at which the future anterior nerve roots spring, and this prolongation is the commencement of the axis-cylinder processes of these nerve roots.

Externally, on the surface of the cord, are cells without nuclei, and in this region the *white matter* of the cord—the various columns, anterior, posterior, and lateral—are developed.

As we have already seen in the account of the spinal cord, these white strands acquire their medullary sheaths at different dates, thus enabling us to map out the course they take through the spinal marrow (page 21).

The posterior roots are a subsequent development from the spinal ganglia.

At first there are no indications of the anterior and posterior median fissures of the cord. The former, the anterior median fissure, is the cleft left between the enlarging lateral halves of the cord. The anterior commissure is developed at the bottom of the fissure, and separates it from the central canal of the cord.

The posterior fissure is probably the constricted dorsal part of the original canal. It gets filled up by a growth of pia mater and becomes a mere septum of connective tissue.

It is supposed that, at first, the spinal cord fills the entire length of the spinal canal, so that there is no cauda equina; but that by the rapid growth of the canal, as compared with the contained spinal marrow, the cord, at about the 9th month, reaches only as low as the 3rd lumbar vertebra. Symington, however, found that there was little or no difference in the child and in the adult.*

II. The Brain.

(Plate 40).

The brain is formed from the fore part of the primitive medullary tube. This tube dilates considerably, but at first remains single. Its walls thicken, and after a time, the contained cavity becomes subdivided by two constrictions into the three segments, known as the ANTERIOR, the MIDDLE, and the POSTERIOR CEREBRAL VESICLES. The anterior and posterior primary vesicles soon divide into two, one behind the other; the middle primary vesicle, on the other hand, remains single. Thus we get *five secondary vesicles* formed from the *three primary vesicles.* They are called from before backwards the 1st, 2nd, 3rd, 4th, and 5th secondary vesicles; being

Two from the anterior primary vesicle—

1. Prosencephalon.
2. Thalamencephalon.

The middle remains single, as the

3. Mesencephalon.

Two from the posterior—

4. Epencephalon.
5. Metencephalon.

It is by the subsequent changes in these vesicles that the brain and its subdivision and ventricles are formed.

1. The **Posterior Cerebral Vesicle.**—This vesicle gives rise to the medulla oblongata, to the pons Varolii,

* "Anatomy of Child," Edinburgh 1887.

Plate XL.

FIG. 103.

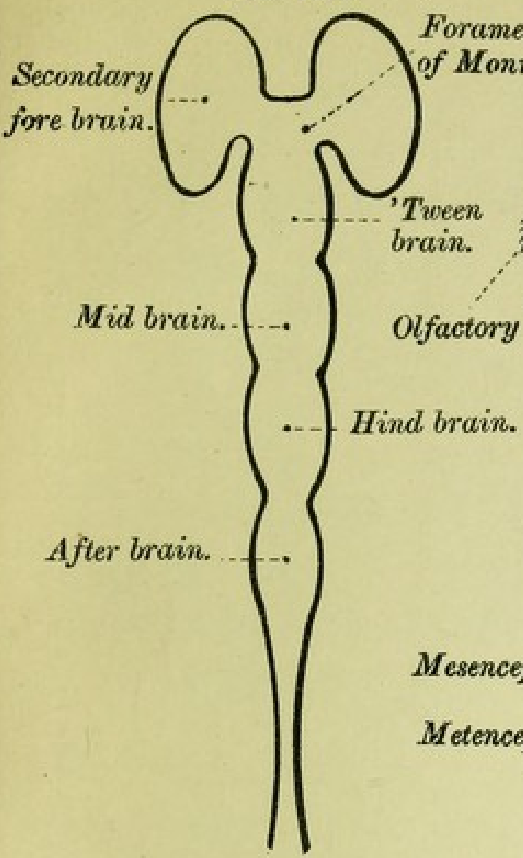


FIG. 104.

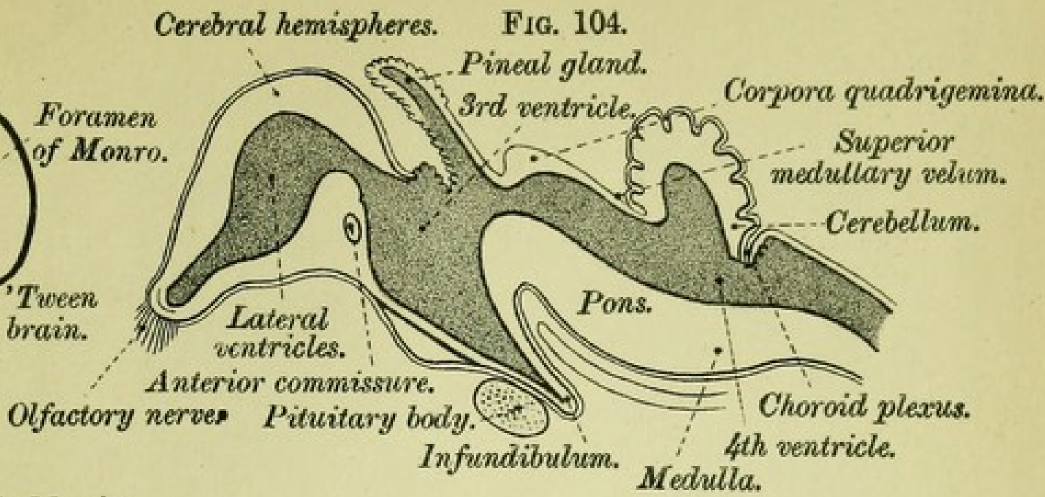


FIG. 105.

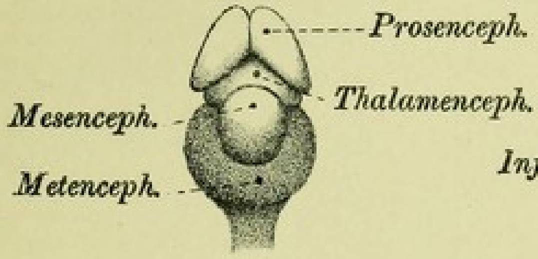


FIG. 106.

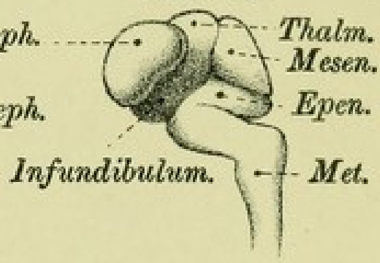


FIG. 107.

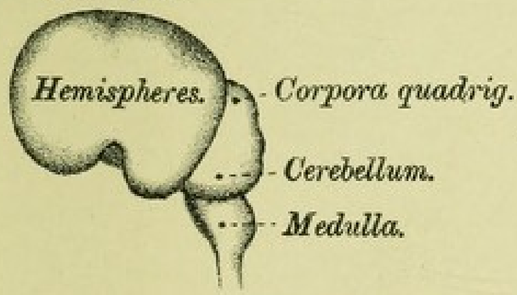


FIG. 108.

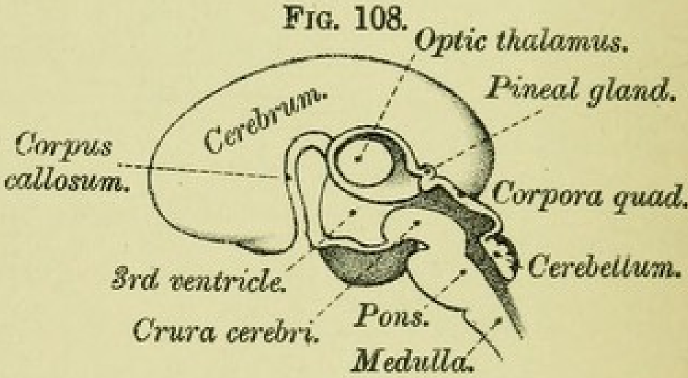
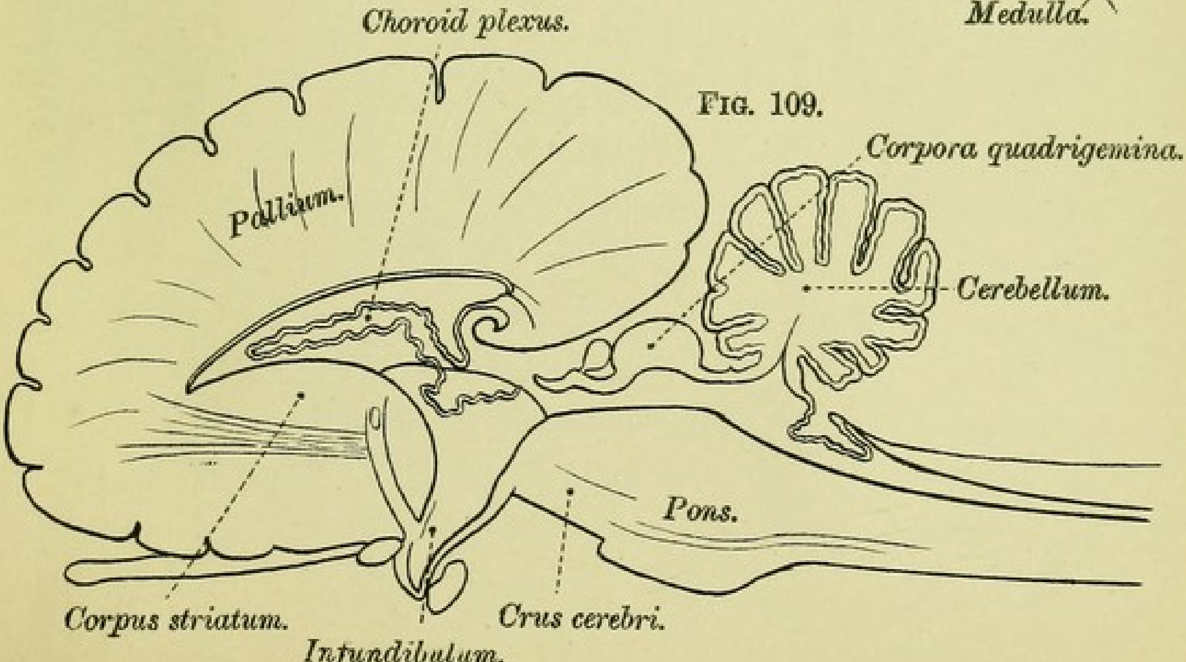


FIG. 109.



and to the cerebellum. It is, as we have seen, at first single, but soon becomes divided by a constriction into two parts, an *anterior division*—the EPENCEPHALON, and a *posterior division*—the METENCEPHALON. Bending forwards at the upper end of the primitive spinal cord (fig. 106), the posterior vesicle makes a second bend, a knee-shaped bend, backwards on itself (fig. 106). The hinder division of the vesicle—the *metencephalon* forming the forward bend, becomes developed into the MEDULLA, and the lower part of the 4TH VENTRICLE. The knee-shaped bend gives rise to the PONS VAROLII; hence, it is often called the pons curvature. The backward fold, forming the fore part of the original vesicle—the *epencephalon*—becomes the CEREBELLUM, of which the central lobe is first formed, the lateral lobes being a subsequent development.

2. The **Middle Cerebral Vesicle** likewise bends forwards from the posterior vesicle, but unlike the other primary vesicles does not divide, but remains single. Its *roof* becomes thickened, and in it are formed the CORPORA QUADRIGEMINA. Its *floor* and sides give rise to the CRURA CEREBRI, while the original CENTRAL CANAL, much narrowed by the growth of these parts, remains as the AQUEDUCT of SYLVIUS—iter a tertio ad quartum ventriculum.

3. The **Anterior Cerebral Vesicle** like the posterior becomes subdivided into two portions—an anterior, the *prosencephalon*, and a posterior, the *thalamencephalon*. The entire vesicle, at first straight, bends forwards on the middle vesicle, which now forms the most prominent part of the head. From each side of its *posterior segment* (thalamencephalon) are developed the OPTIC

VESICLES, which ultimately become the optic nerves and the retina. In its lateral walls are developed the two OPTIC THALAMI, separated from each other by a median cleft—the 3RD VENTRICLE—part of the original vesicle. Across this cavity, the middle or grey commissure is subsequently formed. Anteriorly, the floor of the ventricle is prolonged downwards as a funnel-shaped tube—the INFUNDIBULUM—connected with the PITUITARY BODY. Behind, on the other hand, the cavity communicates with the 4th ventricle through a narrow channel, the continuation backwards of the original cavity—AQUEDUCT of SYLVIUS. The roof of the vesicle rapidly becomes thinner and is reduced to a mere lamina, afterwards connected with the pia mater and choroid plexus of the 3rd ventricle.

The posterior part of the roof, however, has a transverse thickening—the posterior commissure; and in front of this the roof grows upwards and backwards as a hollow process—the PINEAL GLAND—epiphysis cerebri, —which is regarded as a rudimentary third eye.

The *fore* part—*prosencephalon*—of the original anterior cerebral vesicle bulges forward as a median mass, at first single, but which soon becomes divided by a longitudinal cleft into two lateral segments. These *lateral segments* become the CEREBRAL HEMISPHERES, and the *median cleft* forms the GREAT LONGITUDINAL FISSURE. The cavity within these lateral enlargements remains as LATERAL VENTRICLES, which are connected with each other by a constantly narrowing neck, the FORAMEN of MONRO (see fig. 103). In the *floor* of the ventricles appears a grey mass—the CORPUS STRIATUM —streaked with white matter, giving it the striated appearance from which it takes its name. Outside these we have the grey and white matter of the island of Reil.

The *roof* and *walls* of the cavity at first form an evenly expanded mass of grey matter, which, however, soon becomes convoluted and furrowed, giving rise to the FISSURES, LOBES, and GYRI of the cerebral hemispheres. Increasing rapidly in size these hemispheres grow backwards, and, finally, completely overlap and hide the other subdivisions of the brain.

In front and for some distance backwards the mesial surface of the cerebral hemispheres come in contact, and at certain portions partly grow together. The CORPUS CALLOSUM, the FORNIX, and the small commissures are developed from these united parts of the mesial aspect of the hemispherical vesicles. The anterior commissure is the first formed, then the fore part of the fornix, and afterwards its posterior pillars. Finally, the corpus callosum appears, the anterior part being first developed, and its growth extending backwards with the growth of the hemispheres. That portion of the wall of the vesicles which lies between the fore part of the corpus callosum and the fornix is left, as the mesial walls unite, as a triangular interval, bounded on each side by a layer of grey and white matter derived from the hemispheres. These lamina form the SEPTUM LUCIDUM, the vertical partition separating the lateral ventricles. Between them, is enclosed the cavity of the 5TH VENTRICLE, or ventricle of the septum, which you will readily understand is never connected with the rest of the ventricles, and is not, like them, part of the primitive medullary cavity, but is merely a portion of the great longitudinal fissure which has become enclosed in the process of development.

Table of the Cerebral Vesicles and the Parts Developed from Each.

PRIMARY VESICLES.	SECONDARY VESICLES.	PARTS DEVELOPED FROM THE VARIOUS VESICLES.
1. Anterior Vesicle divides into	1. Prosencephalon Fore-brain	Cerebral Hemispheres. Corpora Striata. Corpus Callosum. Fornix. Lateral Ventricles. Olfactory Lobe.
	2. Thalamencephalon Inter-brain	Optic Thalami. Pineal Body. Pituitary Body. 3rd Ventricle. Optic Nerve.
2. Middle Vesicle	3. Mesencephalon Mid-brain	Corpora Quadrigemina. Crura Cerebri. Aqueduct of Sylvius. Optic Nerve.
3. Posterior Vesicle divides into	4. Epencephalon Hind-brain	Cerebellum. Pons Varolii. Anterior part of the 4th Ventricle.
	5. Metencephalon After-brain	Medulla Oblongata. Posterior part of 4th Ventricle. Auditory Nerve.

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Opinions of the Press on the First Edition.

Anatomy of the Brain and Spinal Cord

By J. RYLAND WHITAKER,

Senior Demonstrator of Anatomy in the School of Medicine, Edinburgh.

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