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ANATOMY

OF THE

BRAIN AND SPINAL CORD

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TO

SIR JAMES ALEXANDER RUSSELL

LL.D., M.A., M.B., B.Sc., F.R.C.P.E., F.R.S.Ed.

This little Manual is respectfully Dedicated

IN TOKEN OF MANY KINDNESSES.

THE AUTHOR.

PREFACE.

SOMEWHAT reluctantly, at the urgent request of others, I have at length agreed to publish a 4th edition of this little book, which has now been out of print for several years. First written whilst I was a student it pretends to no originality. Its one aim has always been to present, in as simple and clear a manner as possible, an outline of the Central Nervous System, to the student who, for the first time, is brought face to face with this most intricate subject, and to furnish him with those facts which he will find most useful in his future work, and which, let us hope, he will not have soon to unlearn. This has been my endeavour: how far it has been attained it is for others to decide, but if the book finds the same favour in the future as it has done in the past, its reissue will be more than justified. The difficulties coincident with the introduction of a new nomenclature have been met by printing the newer names, and more important older ones, in dark type or in small capitals; other names are in italics. My gratitude is due to Messrs.

E. and S. Livingstone, the publishers; to Messrs. M'Lagan and Cumming, the lithographers; and to Mr. Cathie, the artist; but especially to Dr. A. Walker for the endless trouble he has taken in seeing the work through the press.

Surgeons' Hall,
Edinburgh, *March* 1911.

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ANATOMY

OF THE

CENTRAL NERVOUS SYSTEM.

BRAIN AND SPINAL CORD.

The Nervous System in man, as in all vertebrata, consists of two portions, the *Cerebro-spinal* and the *Sympathetic.* The latter comprises the scattered collections of nervous tissue called *ganglia,* chiefly made up of groups of nerve cells with their branches of communication and of distribution. The former—the *Cerebro-spinal nervous system*—includes the rest of the nervous elements of the body, and is subdivided into a *central part,* comprising the *Brain and Spinal Cord,* and a *peripheral part,* consisting of the several *Nerves*—Cranial and Spinal—which spring from the central portion.

TABLE.

Nervous System	1. Sympathetic	1. Ganglia and 2. Branches	
	2. Cerebro-spinal	1. Central Part	1. Brain and 2. Spinal Cord
		2. Peripheral Part	1. Cranial and 2. Spinal Nerves

The CENTRAL NERVOUS SYSTEM is then divided into two portions, the *Brain* and the *Spinal Cord*. The one is enclosed within the bony walls of the cranium, the other occupies the spinal canal. They form, however, one continuous whole, the line of demarcation between them being purely artificial, the part above the foramen magnum being called the *Brain*, the part below that foramen being called the *Spinal Cord*.

The Brain and Spinal Cord are, moreover, each invested by three distinct membranes—the *Meninges*—which form additional protective sheaths around them and help to support them in their respective cavities.

They are both composed of two kinds of nervous substance known from their colour as the *Grey* and the *White* matter, but with this difference in their arrangement, namely, that in the brain the grey matter is situated chiefly on the outside, forming the bark, or cortex, of the brain, while in the spinal cord the white matter is external, and the grey matter forms the central core or pith.

Two groups of nerves, called *Cranial* in the one case, *Spinal* in the other, spring respectively from the brain and spinal cord; the latter arise by two roots named from their positions the anterior and posterior roots.

We shall describe **1st** the *Spinal Cord* with its membranes and vessels, and **2nd** the *Brain* with its membranes and vessels.

SECTION I.

SPINAL CORD, MEMBRANES, AND VESSELS.

DISSECTION.—To see the spinal cord and its membranes it will be necessary to open the vertebral canal. To do this, remove 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. Carefully clear 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 in its entire length.

CHAPTER I.

MEMBRANES OF SPINAL CORD.

(Plate I. Page 4, and Plate II. Page 8.)

THESE membranes are, in many respects, identical 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 covering, 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 sub-dural and the sub-arachnoid. Thus we speak of the sub-dural space, meaning that between the dura mater and the arachnoid, and of the sub-arachnoid, 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. 2 and 3, Page 4; Figs. 4 and 7, Page 8.)

The Dura Mater is the most external and the strongest covering of the Spinal Cord. It is a firm fibrous membrane which is 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 pearly-white, shining appearance, and is separated from the walls of the spinal canal by 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, where it ends in a conical *cul-de-sac*. As you will see upon opening it, the cavity which it encloses is both much longer and much wider than the contained spinal cord, for this latter ends at the first or second lumbar vertebra, and there is a considerable interval between the dura mater and the surface of the cord. Below the pointed termination of the spinal marrow—*conus medullaris*—the cavity

PLATE I.

FIG. 1.

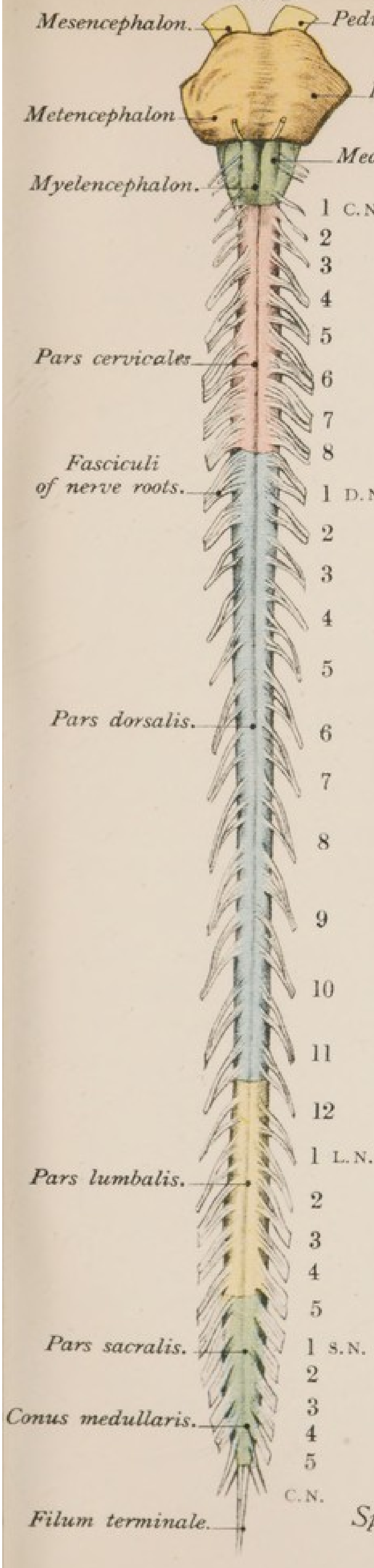


FIG. 2.

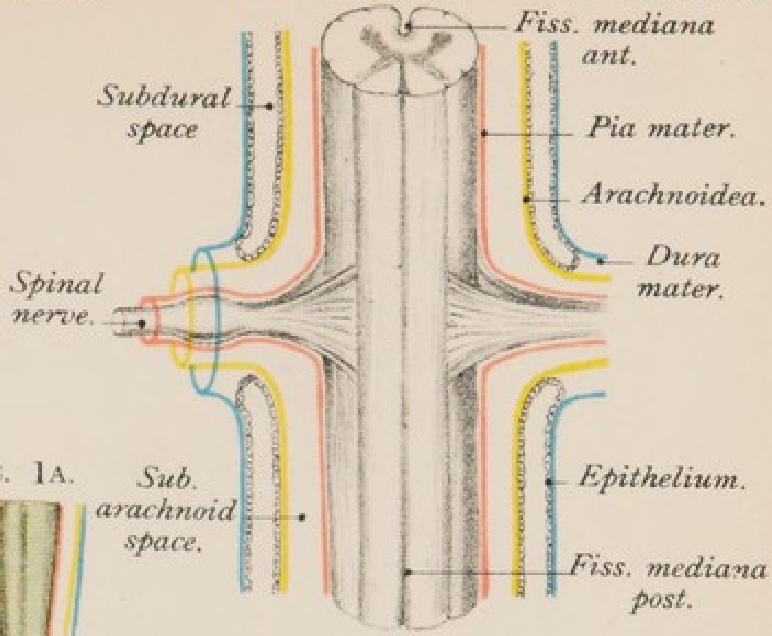


FIG. 1A.

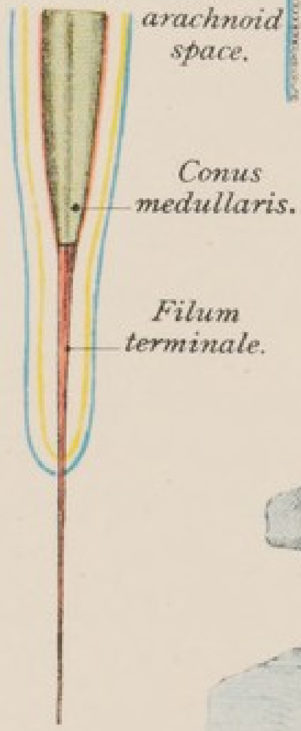
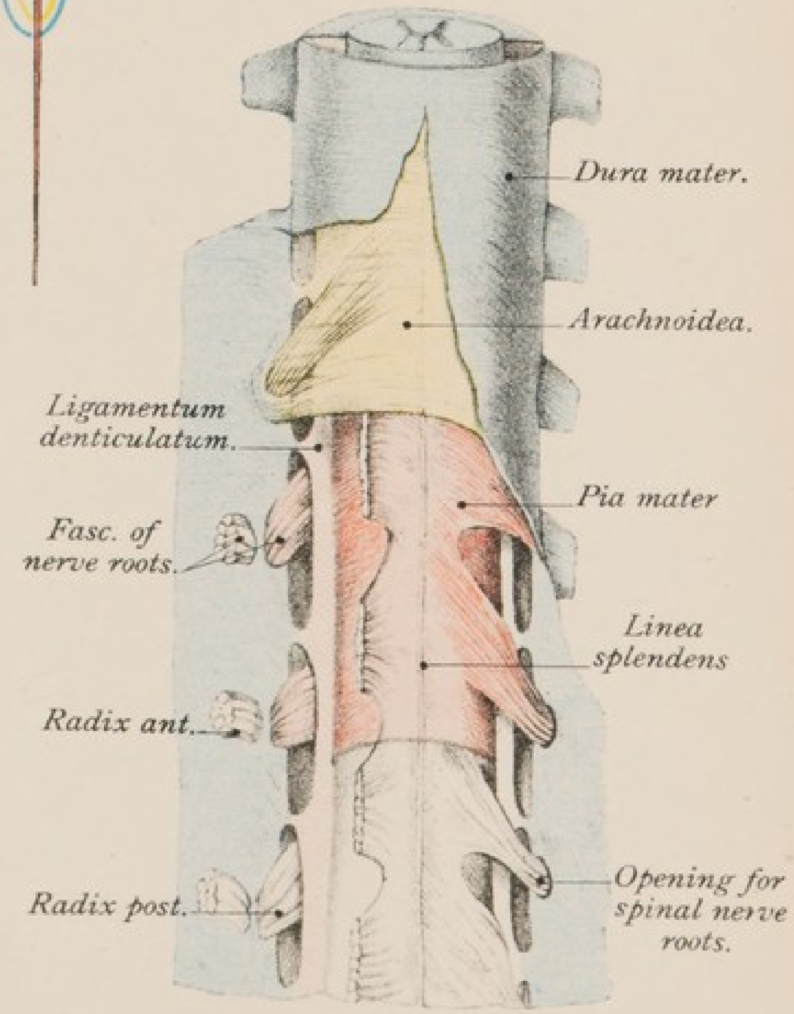


FIG. 3.



Spinal Cord.—Membranes.

Mc Lagan & Cumming, Edinr

of the dural sheath is occupied by bundles of nerve roots called the *cauda equina*, 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*a*, page 4). Continuous with 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. It there pierces the dural sheath, and receiving an investment from it, descends to be attached to the back of the 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 (fig. 3, page 4). These roots, as they pass out to the inter-vertebral foramina, carry with them a tubular prolongation of the dura mater which, in part, ensheaths the spinal nerves and their ganglia, and, in part, blends with the periosteum of the neighbouring bones (fig. 4, page 8).

It is important to recollect that, although the spinal cord itself ends at the spot indicated—viz. the first or second lumbar vertebra—the dura mater, the arachnoid, and the cerebro-spinal fluid, extend as far as the second piece of the 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 you will find that the dura mater consists of white fibrous and yellow elastic tissue 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 with epithelial plates. Many lymphatics and blood-vessels are furnished to its substance. It is supplied by slender nerve filaments derived from both the spinal and the sympathetic system.

II. THE PIA MATER.

(Figs. 2, 3, 4, 7, Pages 4 and 8.)

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 sub-arachnoid 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 the delicate, highly vascular, fibrous membrane which so closely surrounds the spinal cord that it cannot easily be stripped off. It, too, like the dura mater, furnishes sheaths to the roots of the spinal nerves. A distinct process or fold of it passes into the median fissure seen on the front of the cord, and other smaller septa penetrate the spinal marrow at various points, carrying with them blood-vessels and lymphatics for the nutrition of both its white and grey matter. The largest of these septa fills the fissure at the back of the cord called the posterior median fissure (figs. 4 and 5, plate II. page 8). It is not, however, a fold of pia mater like that in the anterior fissure, but consists of the supporting tissue of the spinal cord called neuroglia (see page 30). If afterwards 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.

The outer surface of the pia mater is comparatively rough, and has the three following structures connected with it: (1) the linea splendens; (2) the ligamentum denticulatum; and (3) the septum posticum.

1. The *linea splendens* (fig. 3, page 4) is the thickened vertical fibrous band seen along the anterior aspect of the pia mater. It is sometimes difficult to make out.

2. The *ligamentum denticulatum* is the well-defined structure (fig. 3, page 4, and fig. 7, page 8) which runs longitudinally on each side of the cord in the form of a toothed white band, with its serrated edge turned outwards. It helps to support the spinal marrow within its dural sheath. Internally, it is continuous with 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—*denticulations*—about twenty-one in number, which are fixed to the inner surface of the dura mater, in the intervals between the points of exit of successive nerve roots. The highest of these denticulations is attached opposite the margin of the foramen magnum, between the last cranial and first spinal nerve, and the lowest between the twelfth dorsal and first lumbar nerves. The ligamentum denticulatum thus partially divides the sub-arachnoid space into an anterior and a posterior compartment.

3. At the back of the cord is another process or partition—the *septum posticum* (fig. 4, page 8)—which crosses the sub-arachnoid 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 sheath to the delicate thread-like continuation of the spinal cord, the *filum terminale* or central ligament (fig. 1*a*, page 4). Its silvery hue distinguishes it amidst the surrounding bundles of nerve roots.

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, clothed with epithelial scales and arranged in the form of a spongy network, called the sub-arachnoid trabeculæ (fig. 4, page 8). The lacunæ or areolæ, thus formed, contain the greater part of the cerebro-spinal fluid.

MINUTE STRUCTURE OF THE PIA MATER.—The pia mater consists of a basis of white fibrous connective tissue, the fibres of which are arranged in interlacing bundles. Both its surfaces are covered with epithelial cells. It supports a fine plexus of blood-vessels, and possesses a complete network of lymphatics. Its nerve supply is derived from the sympathetic system.

III. THE ARACHNOID.

(Figs. 2 and 3, Page 4; Fig. 4, Page 8.)

The Arachnoid is an extremely fine and delicate membrane. It is non-vascular, and thus differs materially from the other two. Many authors deny that it is a special membrane, and consider it to be

PLATE II.

FIG. 4.

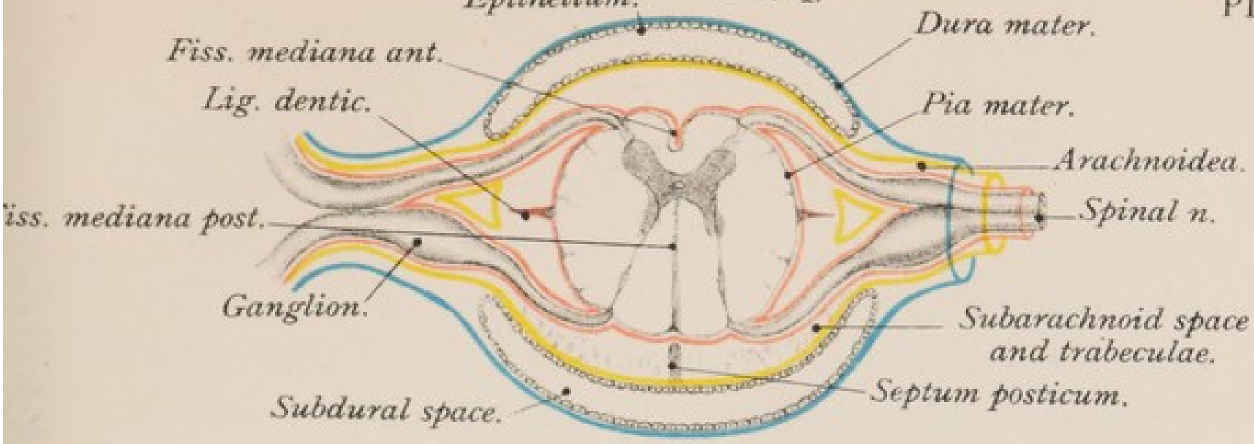


FIG. 5.

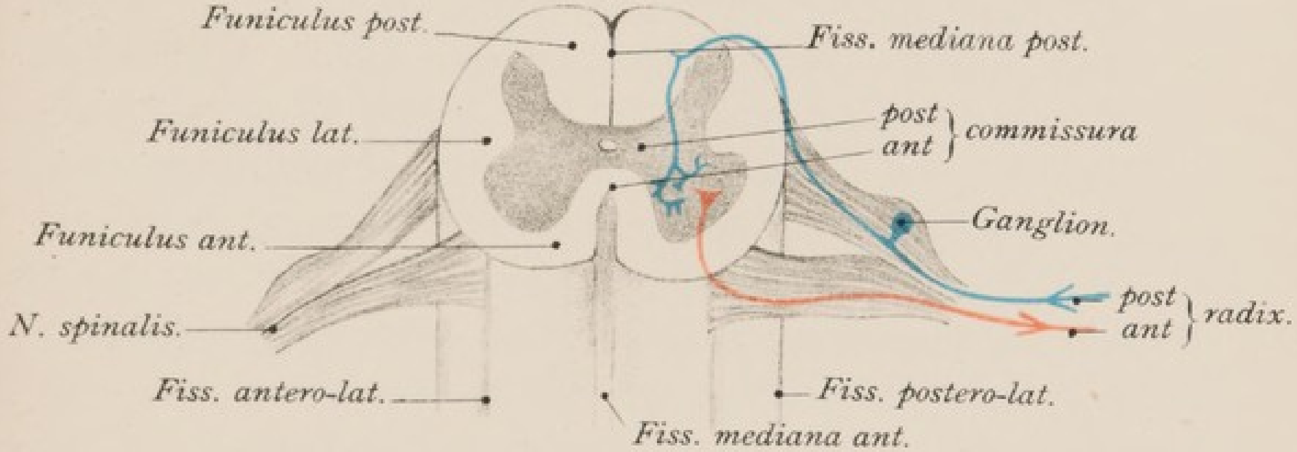


FIG. 6.

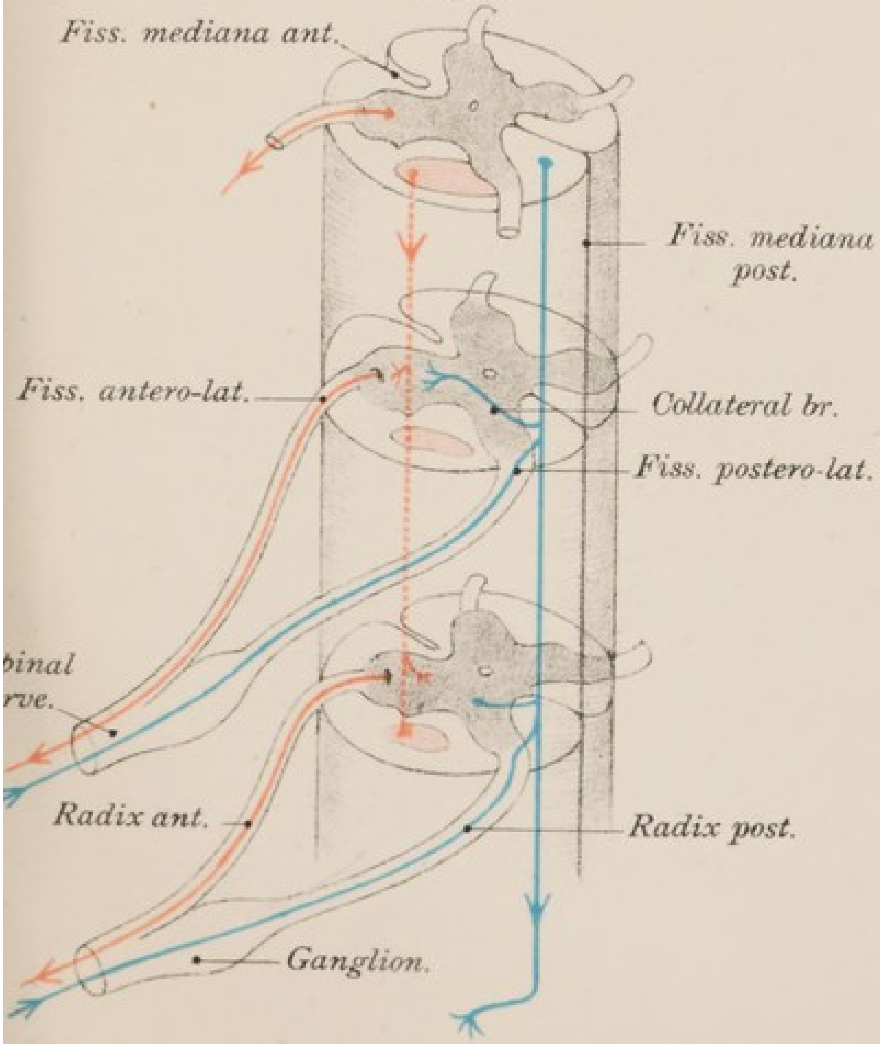
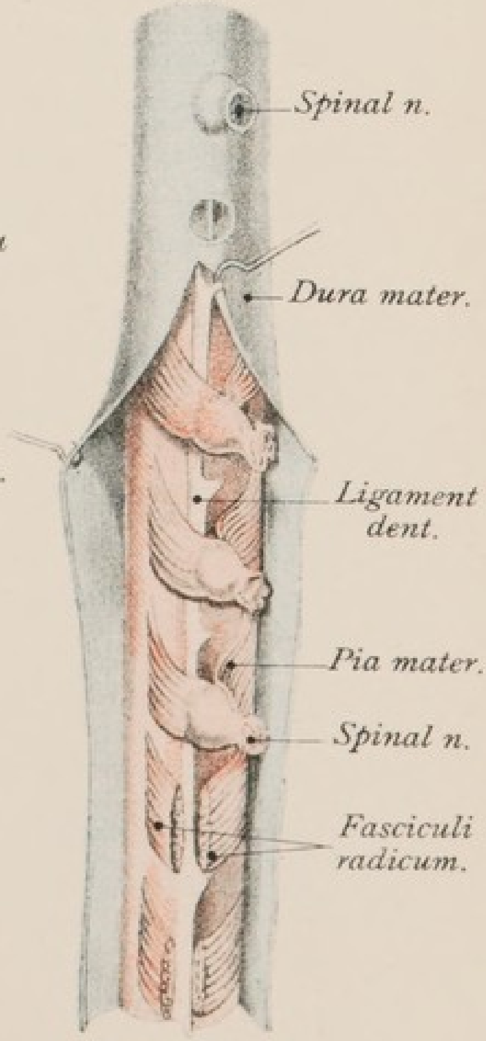


FIG. 7.



Membranes of Spinal Cord.

one of the layers of the pia mater, describing the two together under the name pia-arachnoid.

Forming a cylindrical partition between the dura mater and the pia mater, the arachnoid divides the space between them into two—the sub-dural and sub-arachnoid, previously referred to. The sub-dural space is very narrow, for the outer surface of the arachnoid is in more or less close contact with the dura mater. The sub-arachnoid space, on the other hand, is much larger and contains the chief part of the cerebro-spinal fluid. It is crossed by the sub-arachnoid trabeculæ which connect the arachnoid with the pia mater. The arachnoid, moreover, forms tubular prolongations around both the filum terminale and the teeth-like processes of the ligamentum denticulatum. Similar coverings are furnished to the roots of the spinal nerves as they pass outwards to the dura mater. When, however, the 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 (fig. 2, page 4, and fig. 4, page 8). Thus we see that each spinal nerve root receives a covering from all three membranes of the cord. It is stated, too, that the sub-dural and sub-arachnoid spaces, though they do not directly communicate with one another, are both continuous with the lymphatic plexuses which surround the spinal nerves.

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 epithelial cells. The source from which it derives its nerve-supply is still very doubtful, most probably it is sympathetic in origin. As before stated, many authors regard the arachnoid as one of the layers of the pia mater.

Cerebro-spinal Fluid.—The cerebro-spinal fluid, about 120 to 150 c.c. in quantity, is a clear-looking, alkaline liquid containing little or no albumen. It chiefly occupies the interstices of the sub-arachnoid trabeculæ. By its means, probably, an equality of pressure is maintained upon the brain and spinal 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 VESSELS.

(Fig. 18, Plate IV. Page 22.)

DISSECTION.—Remove the spinal cord with its sheaths from the spinal canal by cutting through the spinal nerves at their exit through the inter-vertebral foramina, and snipping the bands of connective tissue which attach it to the posterior common ligaments of the vertebræ.

1. **Arteries.**—The arteries on the surface of the spinal cord are the anterior and posterior spinal. They are derived from the vertebral, inter-costal, and lumbar arteries, and their branches form a network within the pia mater.

The ANTERIOR SPINAL ARTERY, formed above by the union of two branches arising one from each vertebral artery, runs, as a single trunk, along the front of the cord underneath the linea splendens. As it passes downwards, it is reinforced by a series of anastomotic branches from arteries in the neck and back, and it ends below upon the filum terminale.

It gives off branches to the pia mater, to the roots of the spinal nerves, and to the anterior median fissure—the cleft seen on the front of the cord. The branch to the anterior median fissure is called the *anterior median artery.* On entering the fissure, it gives off alternately right and left branches—*commissural arteries*—which are distributed to the corresponding right and left halves of the grey matter of the cord (fig. 18, page 22). They constitute a *central* or *centrifugal* set of vessels which supply all the grey matter, with the exception of the posterior horn and a small part of the anterior horn (fig. 18, page 22). The larger branches reach the adjacent white matter.

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 spinal arteries, and are joined by small branches which enter the intervertebral foramina along with the roots of the spinal nerves. They anastomose freely and send offsets into the vertical septum at the back of the cord. Together with the branches of the anterior spinal artery they form a *peripheral* or *centripetal* set of vessels, which enter the spinal cord at right angles to its surface. They are distributed to the white matter of the cord, though the larger branches also help to supply the grey matter (fig. 18, page 22).

Thus we see that there are three vascular areas in the spinal cord.

(1) A *superficial area*—composed of the chief part of the white matter—supplied by the *centripetal* group of vessels—coloured brown, fig. 18, page 22.

(2) A *central area*—comprising all the grey matter, except the surface of the anterior horn and part of the posterior horn,—supplied by the anterior median artery—*centrifugal set*—coloured red, fig. 18, page 22.

(3) An *intermediate area*—coloured green, fig. 18, page 22—formed in part by grey matter and in part by the adjacent white matter and supplied by both sets of vessels—*centripetal* and *centrifugal*.

The left-hand side of the same figure shows two areas, the one supplied by the anterior spinal artery—coloured yellow; the other by the posterior spinal vessels—coloured blue.

2. **Veins.**—The veins of the spinal cord lie within the pia mater, have an anterior, a posterior, and right and left lateral trunks, and form a fine plexus over the surface of the cord. They are larger on the back than on the front of the cord. Laterally, after being joined by veins from the bodies of the vertebræ, branches pass out with the spinal nerves through the inter-vertebral foramina, and open into either the vertebral, inter-costal, or lumbar veins, according to the regions in which they occur.

3. **Lymphatics.**—There are no lymphatic vessels, properly so-called, in the nervous system, but there are lymph spaces round the nerve cells—peri-cellular, and round the blood-vessels—peri-vascular.

CHAPTER III.

THE SPINAL CORD.

The Spinal Cord is the elongated cylindrical column of nervous substance contained in the vertebral canal. It is composed of two kinds of nervous matter—an outer cortical part, consisting principally of white nerve fibres, and an inner grey core or pith, consisting chiefly of nerve cells and their processes. Honeycombed throughout by a delicate supporting network of connective tissue, called neuroglia or nerve glue, it is invested by three membranes, the meninges; gives origin to thirty-one pairs of spinal nerves; and is partially divided by anterior and posterior median fissures into two lateral segments, which are united across the middle line by a band of grey and white matter called a commissure. 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 two-thirds only of the length of the spinal canal. About eighteen inches long, it reaches from the foramen magnum to the lower border of the first or second lumbar vertebra. Above, it is continuous with that part of the brain called the medulla oblongata (fig. 1, page 4); below, it ends in a pointed extremity, the conus medullaris, from the apex of which is prolonged downwards a delicate thread-like filament, the *filum terminale* (fig. 1*a*, page 4). According to the regions from which the several groups of spinal nerves take their origin, different portions of the cord have received special names, thus we speak of the cervical, dorsal, lumbar, and sacral portions, meaning thereby the parts of the spinal cord from which the cervical, dorsal, lumbar, and sacral nerves respectively take their origin.

The spinal cord, moreover, presents two swellings or enlargements—an upper one, the cervical enlargement—*intumescentia cervicalis*—extending from about the third cervical to the second dorsal vertebra; and a lower or lumbar enlargement—*intumescentia lumbalis*—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.

Filum Terminale.—This filament is the atrophied remnant of the embryonic spinal cord. In the upper part of its extent it consists of a central canal with walls of grey and white matter, but in its lower part it becomes solid, and is composed of cells (abortive caudal cells), of blood-vessels, and ultimately of mere prolongations of pia mater and of dura mater.

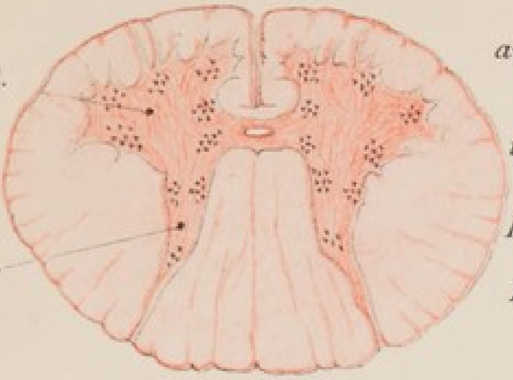
We shall now examine (1) the exterior of the cord with its spinal nerves; then (2) the interior.

I. FISSURES OF THE CORD.

(Figs. 4, etc., Plate II. Page 8.)

On both the anterior and posterior aspects of the spinal cord we see a median longitudinal cleft or depression, which penetrates some distance into the nervous substance, and partially divides it into two

FIG. 8.



CERVICAL. FIG. 12.

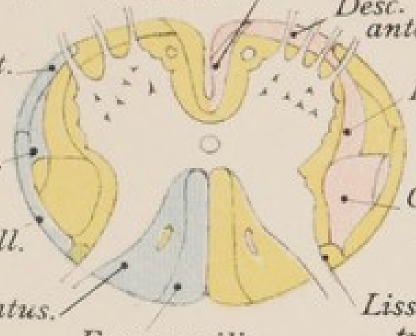
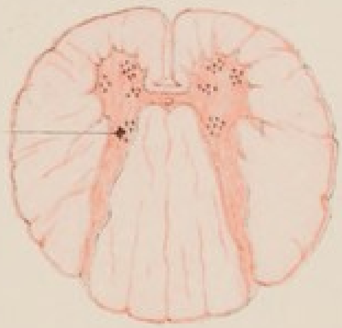


FIG. 9.



DORSAL. FIG. 13.

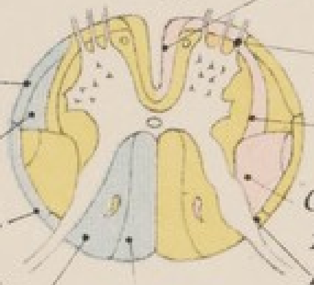


FIG. 10.

FIG. 14. LUMBAR.

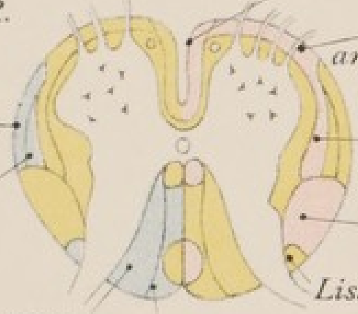


FIG. 11.

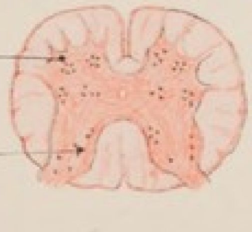


FIG. 15. SACRAL.

Columna or Cornua. *Fasciculi or Tracts.*

McLagan & Cumming, Edinburgh.

lateral halves. These clefts are called the *anterior* and the *posterior median fissures* or *sulci* (figs. 5 and 6, plate II. page 8), and the transverse band of white and grey matter, which connects the two halves of the spinal cord across the middle line at the bottom of these fissures, is called the *commissure* of the spinal cord.

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. 4, plate II. page 8). At the bottom of this fissure lies the transverse band of nerve fibres, the *anterior* or *white* part of the commissural band already referred to (fig. 5, plate II. page 8).

2. The POSTERIOR MEDIAN FISSURE, narrower but deeper than the anterior, is rather a septum than an actual fissure, for it does not, like the anterior, contain a fold of the pia mater, but is filled up by blood-vessels and by connective tissue—*neuroglia*—attached closely to the deeper layer of the pia mater. The *posterior* or *grey* commissure lies at the bottom of this septum (fig. 5, plate II. page 8). About the middle of this grey band you will find the central canal of the spinal cord.

3. In addition to these median fissures there are, on each side of the cord, two lateral longitudinal depressions, the positions of which are indicated by the lines of origin of the anterior and posterior nerve roots (figs. 5 and 6, plate II. page 8). 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 *funiculi* or columns—an anterior, a lateral, and a posterior. The *anterior column*—**funiculus anterior**—lies between the anterior median fissure and the anterior nerve roots; the *lateral column*—**funiculus lateralis**—between the anterior and posterior nerve roots; and the *posterior column*—**funiculus posterior**—between the posterior nerve roots and the posterior median fissure (fig. 5, plate II. page 8, and fig. 16, plate IV. page 22).

In the cervical region, close to the posterior median fissure, two additional slightly marked clefts can be made out, one on each side. They are the *paramedian* and *lateral dorsal sulci*, and will be noticed hereafter.

II. SPINAL NERVES.

(Figs. 5 and 6, Plate II. Page 8, and Fig. 16, Plate IV. Page 22.)

Along the sides of the spinal cord arise, as we have already seen, the several spinal nerves—thirty-one pairs—eight cervical, twelve dorsal, five lumbar, five sacral, and one coccygeal. Each nerve takes origin, called its superficial origin, by two roots—an anterior and a posterior—springing from the antero-lateral and postero-lateral grooves respectively. The roots, which arise from the spinal cord by many slender twigs or fasciculi (figs. 1 and 3, page 4), are enclosed in sheaths similar to those of the cord itself, and they pierce the dura mater by two separate openings, one for each root (fig. 3, plate I. page 4). Sometimes each root, especially the posterior, consists of two bundles, perforating the dura mater by separate openings. Except in the case of the first nerve, the posterior roots are the larger, and their fasciculi more numerous and thicker than those of the anterior roots. They, moreover, become connected with a ganglion, or collection of nerve cells (spinal ganglion), before they join the anterior roots to form a spinal nerve (figs. 5 and 6, page 8). The anterior roots are motor, the posterior sensory in function, whereas the spinal nerves themselves are called mixed nerves because they are composed of fibres some of which carry motor and other sensory impulses. With the exception of the first or highest, these nerve roots 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),[1] 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*. In the upper part of the cervical region of the cord, a little in front of the posterior roots of the first six nerves, we see a series of nerve filaments which are the twigs of origin of the spinal part of one of the cranial nerves, called the spinal accessory. They soon unite to form a single trunk, which ascends to the foramen magnum.

III. WHITE AND GREY MATTER OF THE SPINAL CORD.

Transverse sections of the spinal cord, similar to those represented in the figures on plate III. page 14, will demonstrate to you the interior of the cord and its subdivision into two lateral halves. They will

[1] See Hilton's *Rest and Pain*, 5th ed., 1892, page 86.

show you distinctly the existence (1) of the white cortex, (2) of the central grey core, and (3) of the commissural band, composed of white matter and grey matter, connecting together its lateral segments.

1. THE WHITE MATTER.

Taking up such a section of the spinal cord and examining it with the naked eye, you will see, as we have just said, that the white matter forms the outer or cortical part of the cord, and surrounds the grey centre. This white matter—arranged in a series of columns or **funiculi**—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 (figs. 8 to 11, page 14).

1. **Funiculi** and **Fasciculi.**—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*. Now each of these columns or *funiculi*, thus mapped out on the surface by the nerve roots and limited on their deep aspects by the central grey matter, can be further broken up into smaller tracts or **fasciculi** of ascending and descending nerve fibres, which have received special names and have special functions (figs. 12 to 15, plate III. page 14, and fig. 17, page 22).

Fasciculi—**Tracts** or **Strands.**—To determine by actual dissection these various tracts or strands would be impossible; the task has, however, been accomplished by the study of the development and of the degeneration of nerve fibres; for "we may learn as much of the course of nerve fibres in their birth as in their death, in their development as in their decay" (Gowers). Development teaches us that different tracts or bundles of nerve fibres acquire their white substance—medullary sheath—at different periods of their growth (see page 40), 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 study of physiology and the selective action exercised by disease (so analogous to that exercised by certain poisons) afford equally valuable information. For to physiology and pathology are we 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 staining reagents, behaves differently from the surrounding undegenerated nerves.

By the above and other means we can define with more or less certainty the following tracts or systems in the several white columns of the spinal cord (see Table, page 25).

(*a*) **Funiculus Anterior**—ANTERIOR COLUMN.—In this column have been mapped out a *median* and a *lateral* division.

(1) The median division—the DIRECT PYRAMIDAL TRACT—FASCICULUS CEREBRO-SPINALIS ANTERIOR—*fasciculus of Türck*—is a well-marked bundle of fibres, situated close to the anterior median fissure (fig. 17, page 22). It is a descending or motor tract, and 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 decreases in size from above downwards, and can be traced as a distinct fasciculus to the level of the first lumbar nerve, though isolated fibres have been followed as far as the fourth pair of sacral nerves. You must note, however, that its fibres, as they descend in the spinal cord, cross over at lower levels to the opposite side, and thence through the grey matter of the cord become connected with the anterior nerve roots of that side.

(2) The lateral division of the anterior column—FASCICULUS PROPRIUS ANTERIOR—forming by far the larger part of the column, has been also called the *anterior root zone, basis bundle,* or *anterior ground tract.* It is mostly made up of short fibres, called *association fibres,* which connect together different segments of the cord.

(*b*) **Funiculus Lateralis**—LATERAL COLUMN.—This well-defined column, marked off on the surface of the cord by the antero-lateral and postero-lateral grooves, and limited internally by the grey matter, is composed of the following seven distinct strands of fibres (fig. 12, page 14, and fig. 17, page 22).

(1) CROSSED PYRAMIDAL TRACT.—This tract—FASCICULUS CEREBRO-SPINALIS LATERALIS—occupies the posterior part of the lateral column, at a little distance from the surface of the cord. It is, as we shall afterwards see, the continuation downwards of the chief part of the anterior pyramid of the medulla oblongata of the *opposite* side; hence the name, *crossed pyramidal tract.* This crossed tract is the principal motor tract. It exists in all regions of the cord, though it decreases in sectional area as we descend the cord, for its fibres

constantly turn into the grey matter (figs. 12, etc., plate III. page 14, and plate XXXIII. page 182).

(2) The UNCROSSED LATERAL PYRAMIDAL TRACT (fig. 17, page 22), so called because it neither crosses in the medulla nor in the spinal cord, is composed of fibres which mingle with those of the crossed pyramidal tract. It is a direct motor strand from the brain of the same side (fig. 93, page 182).

(3) The PREPYRAMIDAL TRACT—rubo-spinal; Monakow's bundle—(fig. 17, page 22) lies immediately in front of the crossed pyramidal tract. It is a crossed motor strand, which starts in a collection of nerve cells—the red nucleus—seen in the crura cerebri (see page 170).

(4) The DIRECT CEREBELLAR TRACT, formerly so named from its connection with the cerebellum of the same side, is now known as the FASCICULUS CEREBELLO-SPINALIS POSTERIOR. Extending upwards from the level of the second lumbar nerve to the medulla (restiform body), it forms the thin lamina which separates the crossed pyramidal tract from the surface of the cord (fig. 17, page 22; fig. 93, page 182; fig. 96, page 186). It is an ascending tract, and its fibres are connected, through a group of nerve cells in the spinal cord, called Clarke's column, with the posterior nerve roots of the same side. It carries visceral sensations and sensations from tendons and from muscles, and is concerned in the maintenance of equilibrium.

(5) The ASCENDING ANTERO-LATERAL TRACT.—Gowers' tract (fig. 17, page 22) lies on the surface of the lateral column in front of the direct cerebellar tract. It is comma-shaped in section and extends forwards into the anterior column nearly as far as the anterior median fissure (fig. 17, page 22). Though formerly

regarded as a single strand, it is now known to consist of at least three bundles—(1) the *ventro-spino-cerebellar,* (2) the *spino-tectal,* and (3) the *spino-thalamic.* Gowers' tract most likely exists in all regions of the cord; its fibres can be traced to both the cerebrum and to the cerebellum. It is a sensory route from the spinal cord to the brain (fig. 79, page 168; fig. 96, page 186).

(6) The DESCENDING ANTERO-LATERAL TRACT, closely associated with Gowers' tract, occupies about two-thirds of the antero-lateral column (fig. 17, page 22). It is also called *Löwenthal's tract* or FASCICULUS DESCENDENS CEREBELLO-SPINALIS ANTERIOR. Its fibres, which mingle with those of Gowers' tract, come from the cerebellum of the same side—nucleus fastigii. It forms a connection between the auditory nerve—vestibular division—and the grey matter of the spinal cord (see Auditory Nerve, page 184).

(7) The rest of the lateral column—FASCICULUS PROPRIUS LATERALIS—also called the *mixed zone,* or *lateral ground bundle,* consists of fibres which have a short course and which connect together different segments of the cord (association fibres).

Thus we see that in the lateral column there are the following tracts, the crossed and uncrossed pyramidal, the prepyramidal, the three cerebellar tracts—two ascending and one descending—and the mixed zone.

(*c*) **Funiculus Posterior**—POSTERIOR COLUMN.—The arrangement of the strands in this column somewhat resembles that in the anterior (fig. 17, page 22). Thus, especially in the cervical region, we find, close to the posterior median fissure, (1) a narrow band called the FASCICULUS GRACILIS or *fasciculus of Goll,* and (2) an external division named the CUNEATE FASCICULUS,

PLATE IV.

FIG. 16.

Vesicular Columns.

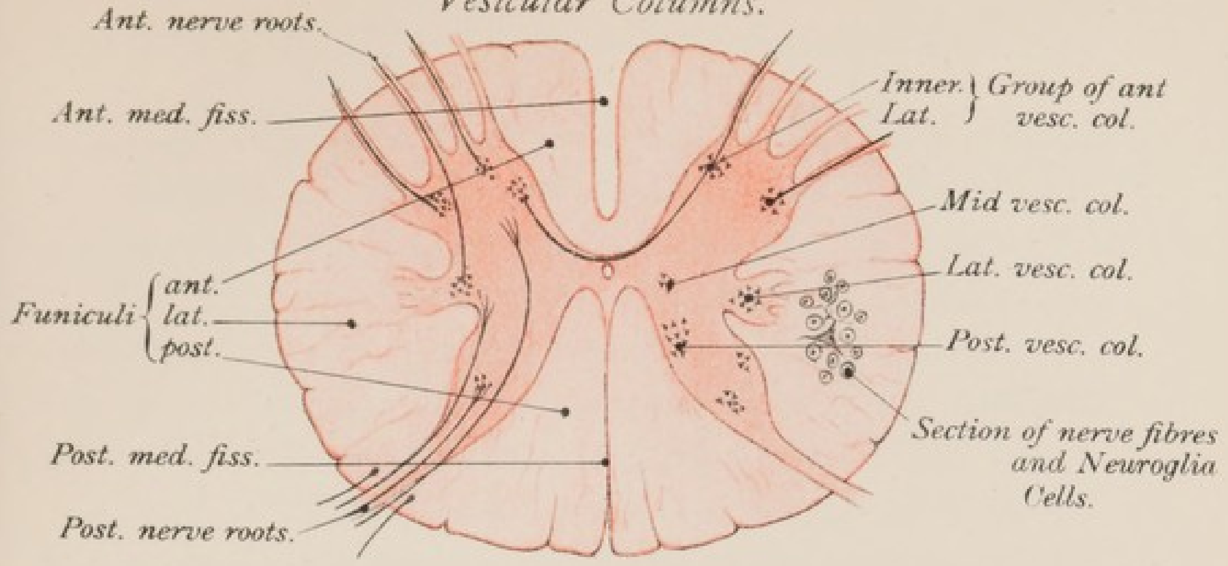


FIG. 17.

Fasciculi.

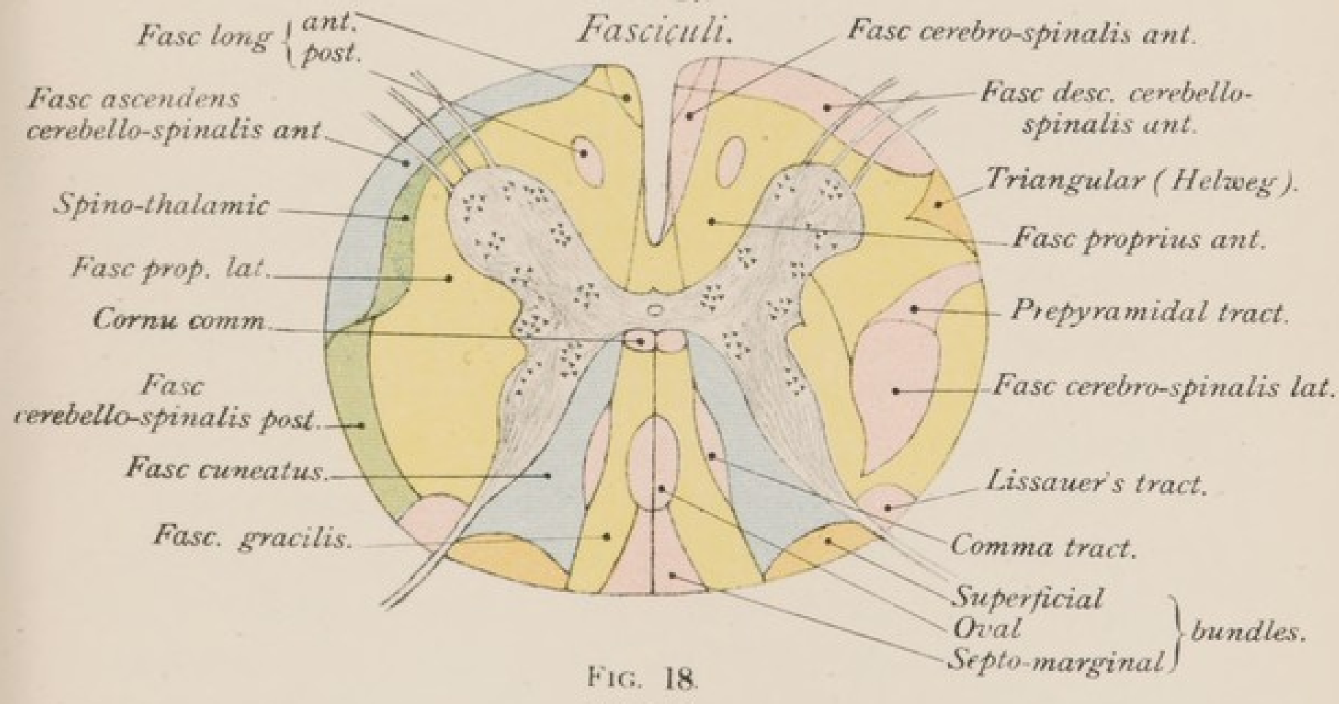
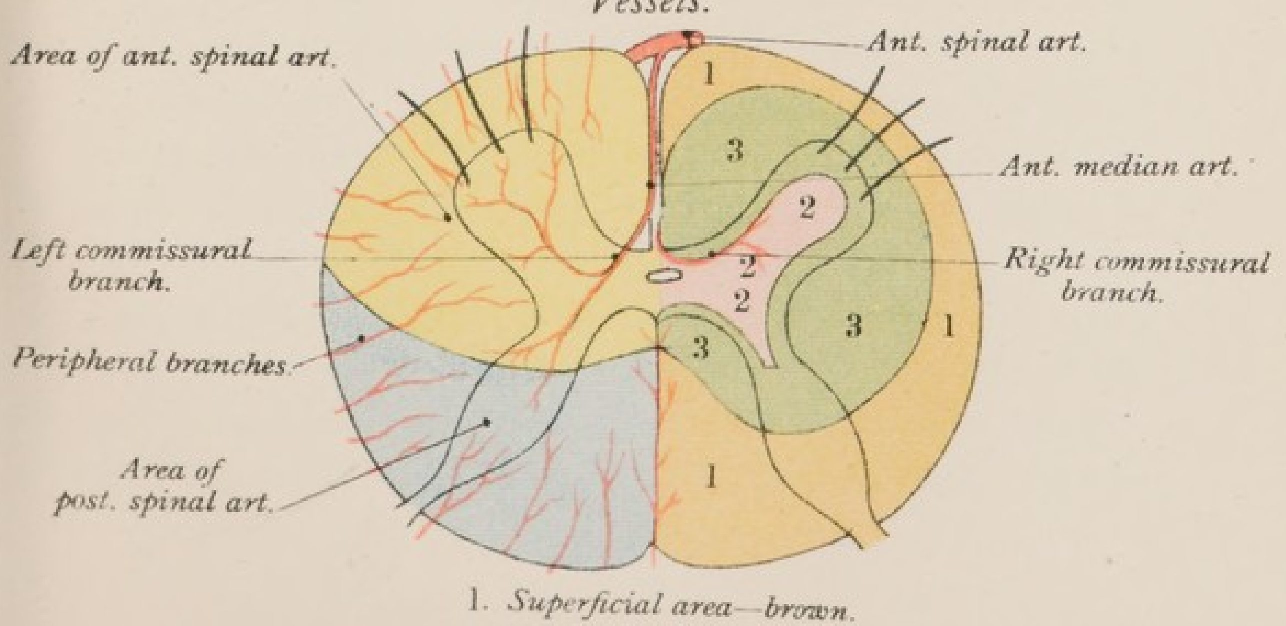


FIG. 18.

Vessels.



1. *Superficial area—brown.*
2. *Central ,, red.*
3. *Intermediate ,, green.*

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posterior root zone, or *fasciculus of Bürdach*. They are marked off on the surface of the cord by the paramedian and lateral dorsal sulci (fig. 44, page 66).

(1) The FASCICULUS GRACILIS—*Goll's tract*—increases in size from below upwards. It is best seen in the dorsal region, for at lower levels it is not distinct from the next bundle, the fibres of the two being intermingled. It is a direct tract from the muscles to the brain, its fibres being derived from the posterior roots of the *lower* spinal nerves.

(2) The FASCICULUS CUNEATUS—*fasciculus of Bürdach*—also increases in size as it ascends. Its fibres are derived from the posterior nerve roots of the *upper* spinal nerves. We shall presently trace them to their ultimate destination (see Posterior Nerve Roots, page 37).

These two parts of the posterior column (Goll and Bürdach) are of considerable importance in the pathology of locomotor ataxy, a disease of the posterior columns and of the posterior nerve roots, in which there is loss of muscular sense—sense of effort—and consequently of co-ordination of muscular movements, for in these tracts travel fibres which are closely connected with that sense and with the mechanism of co-ordination. That the columns of Goll and Bürdach conduct sensory impulses from the muscles is also proved by the fact that in whales, where the extremities are not developed, these columns—Goll and Bürdach—are rudimentary in comparison to what they are in animals with well-developed limbs.

(3) Another tract, the POSTERO-MARGINAL, is a small zone which lies in this column round the tip of the posterior horn, separating the horn from the surface. It is often called Lissauer's tract (fig. 17, page 22), and

its fibres, which come from the posterior roots, run for a short distance upwards and downwards in the tract, and then enter the grey matter. Lissauer's tract is sometimes described with the lateral column.

(4) The rest of the posterior column—FASCICULUS PROPRIUS POSTERIOR—consists of fibres which vary much in length; they are mostly association fibres between different segments of the cord.

Several other minor strands have been described in the different columns of the cord, but are not of sufficient importance to detain us here. Some of them are named in the table, page 25, and are figured in fig. 17, plate IV. page 22. It is well, however, to remember that the several tracts are not so definite as the figure would indicate, for with the ascending fibres we find descending intermingled, and *vice versa*.

To sum up then, the pyramidal tracts (direct, crossed, and uncrossed), the prepyramidal, and part of the antero-lateral tracts are descending or motor strands; on the other hand, the posterior column, the lateral cerebellar tract, and Gowers' tract are ascending or sensory strands. The rest of the white matter chiefly consists of inter-segmental fibres—often called endogenous—which connect together the cells of different segments of the cord.

Of sensory impulses, those of *muscular sense*, those from *bones* and from *joints*, and those of finer tactile nature, travel along the posterior columns of the *same* side as that at which they enter the spinal cord. They are therefore uncrossed.

Sensations of *touch*, of *temperature*, and of *pain* travel along the lateral columns of the *opposite* side to that at which they enter the cord; they therefore have a crossed course, the crossing taking place at various levels of the cord.

Vaso-motor impulses are conducted by the lateral columns.

TABLE OF WHITE TRACTS OF THE SPINAL CORD, WITH DUPLICATE NAMES.

Anterior column or Funiculus anterior.	1. **Fasciculus proprius anterior**; basis bundle; anterior root zone; antero-external tract; anterior root or ground bundle.	
	(a) *Dorsal* or *median* or *posterior* longitudinal bundle.	
	(b) *Ventral* or *anterior* longitudinal bundle or tecto-spinal.	
	2. **Fasciculus cerebro-spinalis anterior** or **ventralis**; *direct pyramidal tract*; fasciculus of Türck; anterior pyramidal tract; antero-internal tract.	Descending tracts.
Lateral column or Funiculus lateralis.	1. **Fasciculus cerebro-spinalis lateralis** or *crossed pyramidal tract.*	Descending tracts.
	2. *Uncrossed lateral pyramidal tract.*	Descending tracts.
	3. *Prepyramidal tract*; rubo-spinal; Monakow's bundle.	Descending tracts.
	4. **Fasciculus descendens cerebello-spinalis anterior**; antero-lateral descending; anterior marginal; Löwenthal's bundle; vestibulo-spinalis.	Descending tracts.
	5. Olivo-spinal; bulbo-spinal, triangular or Helweg's bundle.	Descending tracts.
	6. **Fasciculus cerebello-spinalis posterior**; *dorso-spino-cerebellar;* tract of Flechsig; lateral cerebellar; direct lateral cerebellar.	Ascending tracts.
	7. **Fasciculus ascendens cerebello-spinalis anterior**; antero-lateral ascending; Gowers' (1) *ventro-spino-cerebellar*, (2) *spino-tectal*, (3) *spino-thalamic.*	Ascending tracts.
	8. **Fasciculus proprius lateralis**; lateral ground bundle, mixed zone.	

Posterior column or Funiculus posterior.

1. **Fasciculus gracilis**; fasciculus of Goll; postero-internal or postero-median strand.
2. **Fasciculus cuneatus**; fasciculus of Bürdach; postero-external strand; posterior root zone; posterior ground fibres; ascending postero-lateral tract.
3. Marginal zone, Lissauer's tract.

(1–3: Ascending tracts.)

4. Cornu commissural; median triangular; septo-marginal, oval bundle. These are mostly association fibres.
5. Comma tract and superficial bundle. These are different names for groups of descending branches of the posterior roots in some cases mingled with endogenous fibres.
6. **Fasciculus proprius posterior.**

2. **White Commissure.**—The two anterior white columns of opposite sides of the cord are, as we already know, continuous with each other across the middle line through a band of white fibres, the *anterior* or *white commissure*, seen at the bottom of the anterior median fissure (figs. 8, etc., page 14). The constitution of this commissure is too complex for an elementary work of this kind. Suffice it to say that it consists (1) of *decussating* fibres, viz. axis-cylinder processes and protoplasmic processes of the nerve cells of the grey matter, (2) of *collaterals* from different sources, and (3) of *neuroglia* cells and their prolongations.

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 a supporting framework of connective tissue called *neuroglia* which will be fully described under the grey matter (page 30), (2) of *medullated* or *white nerve fibres* running for the most part longitudinally, and (3) of *non-medullated nerve* fibres which accompany the white nerve fibres.

The *white nerve fibres* of the spinal cord are the axis-cylinder processes of nerve cells, and have the same structure as peripheral nerves, consisting of a central core or axis-cylinder. In transverse section this core, though made up of a number of fibrillæ, appears as a dark spot, surrounded by a laminated white or medullary sheath (fig. 16, page 22). Usually, however, neither neurilemma nor nodes of Ranvier can be detected, though some hold that they are both present.

Collaterals.—In their course along the spinal cord, the axis-cylinder processes of the nerve cells turn in at right angles to their direction, and entering the grey matter, there break up into fine brushlets of branches which end free. Moreover, as they travel along the spinal cord they give off, at 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* of fine varicose fibrillæ. These brushlets ultimately end in little knobs, 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—synapses—around the body of the cells. Some authors hold that they do unite. At the point where the collaterals are given off, the fibres usually have a small triangular-shaped enlargement.

2. THE GREY MATTER.

(Figs. 8, etc., Plate III. Page 14.)

The grey matter occupies the interior of the spinal cord, and is completely surrounded by the white substance. It forms two columns—right and left—extending through the entire length of the cord, one in each half. These two columns are united across the middle line by a vertical, transverse grey band—the posterior or grey commissure. In transverse section, therefore, the grey matter presents more or less the appearance of the capital letter H, for it is arranged in two irregularly crescent-shaped masses, the down strokes of the H, one in each lateral half of the section (figs. 8, 9, plate III. page 14), and the transverse band of grey matter—the cross-bar of the H—which joins them together across the middle line, is the posterior or grey commissure previously mentioned. Each grey crescent is semi-lunar in shape, having its horns—cornua or columnæ—pointing, the one forwards and outwards, the other backwards and outwards, hence they are known as the *anterior* and *posterior cornua* or **columnæ.** The convexity of each crescent looks inwards towards the middle line, whereas the corresponding concavity is directed outwards.

1. **Cornua—Columnæ.**—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 from which the anterior nerve roots take their superficial origin. 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—*Columna*—on the other hand, is longer, narrower, and more 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. There it tapers to a point, called the *apex* cornu posterioris, which is capped by a stratum of rather clear-looking connective tissue and nerve cells, 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 the neck forms the *caput* cornu posterioris.

LATERAL HORN—*Columna.*—The outer concave side of each crescent, slightly behind its centre, assumes the form of a network, projecting outwards into the white substance (fig. 16, page 22). This network, called the *processus reticularis,* is best seen in the cervical region. Immediately in front of this process, and about midway between the anterior and posterior cornua, lies a collection of grey matter—the *inter-medio-lateral tract—lateral vesicular column*—which may be regarded as a lateral horn (fig. 16, page 22). Look for it especially in the dorsal region.

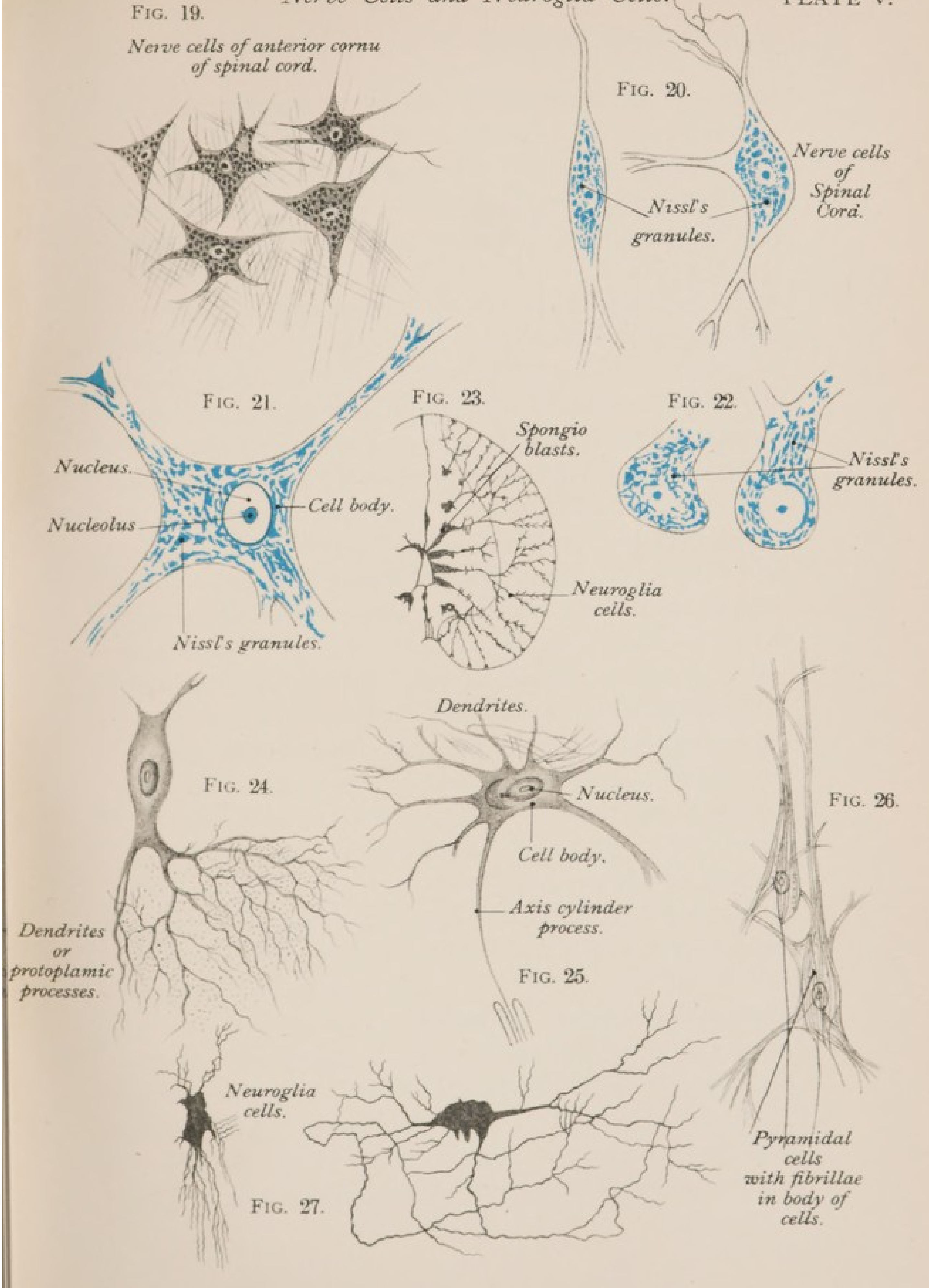
If, now, you take a series of tranverse sections from the different regions of the cord, and compare them together, you will find that the grey matter is relatively most abundant in the lumbar region, and least so in the cervical. Again, if you notice the respective sizes of the anterior and posterior 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 region of the cord (plate III. figs. 8, etc., page 14).

2. **Grey Commissure** (figs. 8, etc., plate III. page 14).—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 grey band, placed nearer to the anterior than to the posterior ends of the crescents, consists of nerve cells, of neuroglia cells, and of transverse nerve fibres. About its centre may be seen a small opening—the central canal 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 a wide, shallow, lozenge-shaped area—the fourth ventricle of the brain; whilst below it enlarges, becomes T-shaped in section, and is prolonged into the filum terminale. It is lined by a layer of columnar cells, ciliated in the child, though not so 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, viz. (1) a ground substance or stroma called *neuroglia* (nerve glue), and (2) *nervous elements*—nerve cells and their processes, embedded in this stroma.

1. **Neuroglia** (figs. 23 and 27, plate V. p. 30),

Nerve Cells and Neuroglia Cells. PLATE V.



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already referred to under the structure of the white matter, is a delicate and peculiar kind of connective tissue which pervades both the grey and white substance of the cord. It consists of cells, which are of two kinds—*ependyma cells* and *neuroglia cells* (fig. 27, page 30).

(1) The *Ependyma Cells* are epithelial cells which line both the central canal of the cord and the various spaces in the brain called ventricles. In the spinal cord the processes of these cells extend radially from the central canal to the deep aspect of the pia mater, and form, as we have seen, a distinct mesial septum on the posterior aspect of the cord (fig. 23, page 30).

(2) The *Neuroglia Cells*—Cells of Deiters—Spider cells—Astrocytes—are stellate nucleated cells which vary much in size. They have numberless slender processes, long and short, which usually do not bifurcate, but which, after extending a variable distance from the cell, end free without anastomosing.

The processes of neighbouring cells cross and recross each other, and form an intricate network throughout both the grey and white matter. Neuroglia is pretty evenly distributed through the grey and white substance of the spinal cord, but, upon the surface beneath the pia mater, and around the central canal, it forms distinct layers, the latter being called the central grey nucleus.

The substantia gelatinosa of Rolando, previously referred to, was formerly regarded as a similar accumulation of neuroglia, but it is now known to contain many nerve cells.

The function of neuroglia is to support and protect the delicate nerve tissues. It is of special interest, clinically, being the probable seat of many of the inflammatory processes which affect the central nervous system.

2. **The Nervous Constituents** of the grey matter are of two kinds: (1) *Multipolar nerve cells*—the cell bodies of the *neurones*—occurring either singly (figs. 19, etc., page 30), or collected into groups called *vesicular columns*; (2) *Non-medullated* and *medullated nerve fibres,* which are branched and unbranched processes of nerve cells, and which either form distinct strands or traverse the grey matter in all directions.

Vesicular Columns (figs. 8, etc., page 14).—We shall consider (1) the groups of nerve cells, and (2) their structure. 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. They are best marked in the cervical and lumbar regions.

(*a*) ANTERIOR VESICULAR COLUMN.—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. 16, page 22). This lateral group occurs only in the cervical and lumbar enlargements. In the lumbar region an additional posterior group, which lies behind the anterior, makes its appearance.

Since it is from these groups of cells of the anterior cornu that the anterior or motor nerve roots spring, the entire collection has been termed the *motor vesicular column.*

The cells of these columns exercise a trophic influence on motor nerves and on muscles, for, as we shall afterwards see, there are two strata of cells presiding over the muscles: (*a*) an upper stratum—*the first trophic realm*[1] or upper neurones—situated in certain regions of the brain surface; and (*b*) a lower stratum—*the second trophic realm* or lower neurones—the nerve cells of the anterior horn. Now, in any injury to the cells of the upper stratum—*first trophic realm*—the muscles are paralysed and rigid, and any atrophy which follows is by no means rapid, being due to disuse; whereas, if the cells of the anterior vesicular column, second stratum—*second trophic realm*—be injured, the paralysed muscles are flaccid and degenerate rapidly.

(*b*) POSTERIOR VESICULAR COLUMN.—The cells of the posterior horn are for the most part not arranged in distinct groups. At the base of the posterior horn, however, near its inner angle, is a well-marked collection of cells variously known as POSTERIOR VESICULAR COLUMN, *Clarke's column—dorsal nucleus* (fig. 16, page 22). Though it is found along only the middle region of the cord, from the level of the 7th cervical to that of the 2nd lumbar nerve, it probably has representations in all regions of the cord. As we have seen, its cells are, on the one hand, connected with the posterior or sensory nerve roots, and,

[1] These well-chosen terms we owe to John Wyllie, M.D., LL.D., Professor of Medicine, University of Edinburgh, late Lecturer on Medicine, School of Medicine, Edinburgh.

on the other, with the lateral cerebellar tracts, and through them with the cerebellum of the same side. It is also connected, through the spino-thalamic tract, with the cerebrum of the opposite side, and, through the ventro-spino-cerebellar, with the cerebellum.

Injury to the other cells of the posterior horn causes sensory and trophic disturbances of the skin.

(*c*) LATERAL VESICULAR COLUMN.—A third group of nerve cells, *the nucleus of the intermedio-lateral tract*, often called the *lateral horn* (fig. 16, page 22), lies at the base of the posterior cornu on its outer or concave side, within the column of grey matter, of the same name, and can, like it, be distinguished in the dorsal and upper lumbar regions of the cord. Its cells are the spinal centres for the white nerve fibres — rami communicantes — of the sympathetic, which pass out through the anterior nerve roots.

(*d*) MIDDLE VESICULAR COLUMN.—This group of nerve cells is placed near the centre of the *convex* side of each grey crescent.

TABLE OF VESICULAR COLUMNS.

(*a*) Anterior Vesicular Column	Internal Group. External Group. Posterior Group—found in lumbar region.
(*b*) Posterior Vesicular Column	Clarke's Column, dorsal nucleus —found from the 7th or 8th cervical to the 2nd lumbar nerve.
(*c*) Lateral Vesicular Column	Lateral Horn—found in the thoracic and lumbar regions.
(*d*) Middle Vesicular Column	

STRUCTURE OF THE NERVE CELLS.—The nerve cells of the grey matter of the spinal cord vary considerably, in size, in shape, and in structure. Firstly, as to the *shape* and *size.* Most of the cells are multipolar and stellate in transverse section, and have two sets of processes — protoplasmic and axis-cylinder processes. The largest cells are found in the anterior vesicular column, especially in its outer group, and similar cells occur in Clarke's Column. In the posterior horn most of the cells are small and spindle-shaped, others are larger with long curved processes.

Secondly, as to *structure.* Each cell has a distinct spherical or oval fibrillated nucleus, a single nucleolus, and a centrosome. It has, however, no distinct nucleated sheath, differing in this respect from the cells found in the various ganglia throughout the body, *e.g.* sympathetic and spinal ganglia, which have a distinct fibrous capsule, lined by epithelial cells.

The body of the cell—Cytoplasm—is permeated by a network of delicate fibrillæ—neuro-fibrillæ. These fibrillæ extend into the processes of the cell and carry impulses to and from the cell. Two chemically distinct substances, *chromatic* and *achromatic*, are found in the cells. The chromatic matter, when stained with methylene blue, appears as granules, stripes, cones, and blocks, called Nissl's granules (figs. 20, 21, 22, plate V. page 30). It is probably the nutritive material of the cell, for it is used up during its activity. The achromatic matter, on the other hand, is the essential protoplasmic constituent of the cell. On it the life and the activity of the cell depend.

Processes of Nerve Cells are, as we have said, of two kinds: (1) axis-cylinder processes—axons or axones; (2) protoplasmic processes — dendrons or dendrites.

(1) The AXIS-CYLINDER PROCESSES are branched or unbranched processes of the nerve cells, and are connected to the nerve cell either directly, as seen in the motor type of cell, or indirectly through a plexus of fibres, as seen in the sensory type. Composed of many primitive fibrillæ they, in many cases, soon acquire a medullary sheath, and become the axis-cylinders of nerve fibres, which, after a longer or shorter course, end in the grey matter in fine brush-lets of branches. They are centrifugal processes, carrying impulses away from the cell.

(2) The PROTOPLASMIC or GREY PROCESSES are a series of delicate ramifying branches which cross and recross each other in all directions (figs. 24 and 25, plate V. page 30). They are centripetal processes, carrying impulses to the cell, and may, through their relation to neuroglia and to blood-vessels, subserve the nutrition of the nerve elements.

In the cells, the protoplasmic and axis-cylinder processes are in most cases continuous with each other, traversing the cells without interruption: their terminal processes, however, do not anastomose with the processes of other nerve cells, but are merely in contact with the nerve elements. Hence it follows (1) that though nerve cells can receive and transmit nerve motion, they do not generate nerve motion, but are nutritive only; and (2) that contact, and not actual continuity, is sufficient for the conduction of motor, sensory, and reflex impulses along the spinal cord.

IV. ORIGINS OF SPINAL NERVES.

(Fig. 16, Plate IV. Page 22.)

The several spinal nerves are, as you know, mixed nerves, for they contain both motor and sensory fibres. They spring from the spinal cord by two roots, an *anterior*—motor, coming from the antero-lateral groove, and a *posterior*—sensory, from the postero-lateral groove. These attachments to the cord are called the *superficial origins* of the nerves, as distinct from the *deep origins* —the nerve cells in the grey matter, to or from which the nerve roots can be traced.

(1) The ANTERIOR NERVE ROOTS—*Motor Roots.*— Most of the fibres of these roots can be traced from the nerve cells of the anterior and lateral horns—deep origins—of the same side (fig. 16, page 22). The cells from which they spring are called root cells, and the several bundles of white fibres, which, in sections of the cord, can be seen passing through the peripheral white substance to the antero-lateral grooves—their superficial origin—are the axis-cylinder processes of these cells. Other fibres of the anterior roots come from cells in the opposite anterior horn, and are, by means of dendrons and collaterals, brought into relation with the cells of the posterior horns.

(2) The POSTERIOR NERVE ROOTS—*Sensory Roots*— before reaching the spinal cord, pass through the spinal ganglion—deep origin—in which there are unipolar nerve cells. At a little distance from these cells, the pole, or axis-cylinder process, bifurcates in a T-shaped manner, one limb of the T becoming the distal, the other the central end of a nerve fibre of the posterior root (fig. 5, page 8). The central

processes enter the cord in two sets, a mesial set, which forms the chief part of the posterior column, and a *lateral* set, which forms the marginal zone—Lissauer's tract. On entering the spinal cord all the fibres, mesial and lateral, at once divide into ascending and descending branches, which give off collaterals to different parts of the grey matter (fig. 6, page 8, and fig. 96, page 186). The *descending branches* after a short course turn at right angles into the grey matter, and there end free in little tufts of fine filaments. Some of them form special tracts, for which see table, page 25. Of the *ascending branches* those of Lissauer's tract lose themselves in the substantia gelatinosa of Rolando, those of the rest of the column, after a long, short, or intermediate course, enter the grey matter.

At first, *i.e.* in the lower part of the cord, the ascending branches constitute the fasciculus of Goll, which alone exists in this part of the cord. They are derived from the sacral, lumbar, and lower dorsal nerve roots. At higher levels, however, the column of Goll is pushed towards the mesial plane by the entrance into the cord of the fibres of the upper dorsal and cervical nerve roots, which now constitute the fasciculus of Bürdach. Hence it follows that there is no real distinction between these two parts of the posterior column—Goll and Bürdach,—they are one in function and in constitution, differing merely in the length of their fibres, the column of Goll being composed of fibres which enter the cord below the level of the 8th dorsal nerve, the column of Bürdach of those which enter above that level. The tracts of Goll, therefore, convey impulses from the lower limbs, the tracts of Bürdach from the upper limbs and from the neck. The fibres of the columns of Goll and Bürdach ultimately end in two nuclei (nucleus gracilis and cuneatus) in the medulla. From the cells of these nuclei new fibres can be traced to the opposite side of the brain, in what is known as the *superior pyramidal* or *sensory decussation.*

Besides the fibres of the posterior roots, which are thus connected with the nerve cells of the ganglia, there are others having no such connection, but which merely pass through the ganglia on their way to nerve cells in the spinal cord. On entering the cord these fibres pass at once into the grey matter, through which they can be followed in various directions, even as far as the cells of the anterior horn (fig. 16, plate IV. page 22).

Summary.—To sum up, then, we have the spinal 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 mesial fissures or sulci into two lateral segments, each with three subdivisions—funiculi or columns—which can again be mapped out into numerous fasciculi—tracts or systems of varying significance.

We see, moreover, 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 it consists of one nerve element only—*the neurone*—the nerve cell with its protoplasmic and axis-cylinder prolongations. These neurones are arranged in tiers or columns, one above the other, and are connected together by their protoplasmic and axis-cylinder processes and collaterals. These facts have important bearings on the physiology of the spinal cord.

The following Tables will be found useful for reference :—

Table of the Order in which the Several Tracts of White Matter receive their Medullary Sheaths.

1. Anterior and posterior nerve roots and commissural fibres of the grey matter.
2. Fasciculus proprius of the anterior, of the lateral, and of the posterior columns.
3. Bürdach's column and Lissauer's tract.
4 Goll's tract
5. Lateral cerebellar tract.
6. Gowers' tract.
7. Crossed and direct pyramidal tracts, which in man get their medullary sheath at birth.
8. Helweg's tract.

[Table

GOWERS' TABLE.

SHOWING THE APPROXIMATE LOCALISATION OF THE VARIOUS MOTOR, SENSORY, AND REFLEX FUNCTIONS IN THE SEGMENTS 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	4	Shoulder	4	
	5	Scalene, Rhomboids, Serratus, Flex. of elbow, Supinators (Shoulder muscles)	5	Arm, outer side	5	Scapular
	6	Ext. wrist and fingers	6	Radial side, forearm and hand; thumb	6	
Lower neck muscles, Middle part of Trapezius	7	Ext. elbow; Flex. wrist and fingers	7	Arm, inner side; ulnar side of forearm and hand; tips of fingers	7	
	8	Pronators	8		8	
	D 1	Muscles of hand	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
Lumbar muscles	2	Cremaster	2		2	*Knee-jerk*
	3	Flexors of hip	3	Thigh: outer side, front, inner side	3	
	4	Extensors of knee; Abductors of hip	4		4	Gluteal
Peroneus, l. Flex. of ankle, Ext. of ankle	5	Ext. and abduct. of hip	5	Leg, inner side	5	*Foot-clonus*
	S 1	Flexors of knee	1	Buttock, lower part; Back of thigh	1	Plantar
	2	Intrinsic muscles of foot	2	Leg & foot except inner part	2	
	3	Perineal and anal muscles	3		3	
	4		4	Perinæum and anus	4	
	5		5	Skin from coccyx to anus	5	
	Co.		CO		CO	

SECTION II.

BRAIN, ITS MEMBRANES AND ITS VESSELS.

THE term BRAIN, or Encephalon, includes all that part of the great central nervous system which is enclosed within the cavity of the cranium. On an average it weighs from 40 to 50 ozs.[1] Invested by three membranes or meninges, it presents, as you will afterwards see, four distinct subdivisions: (1) the CEREBRUM, a large convoluted mass, or big brain; (2) the CEREBELLUM, or little brain; (3) the PONS VAROLII, a white traverse band uniting the two halves of the little brain; and (4) the MEDULLA OBLONGATA, or bulb, the enlarged upper end of the spinal cord (figs. 28 and 29, page 44; fig. 66, page 134).

From a developmental point of view, the brain is divided into six parts, which, named from before backwards, are the Telencephalon (end-brain), Diencephalon (inter-brain), Mesencephalon (mid-brain), Isthmus Rhombencephali (lozenge-shaped brain), Metencephalon (hind-brain), Myelencephalon (after-brain) (see Development, page 209).

We shall describe (1) the membranes and vessels of the brain, (2) the several parts of the brain, and (3) the cranial nerves; but before doing so we shall,

[1] Male 1360 gms.; female 1235 gms.; children at seven years 1305 gms.

for convenience, give *seriatim* the following dissections:—

DISSECTION.—1. *To expose the Membranes of the Brain.*—Make an incision across the vertex of the head from ear to ear. Turn back the scalp to the level of the external occipital protuberance behind, and to the root of the nose in front. 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. This dissection will expose the outer surface of the dura mater. 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 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 forepart 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 attached margin of the tentorium on each side, just behind and parallel to the upper border of the petrous part of the temporal bone, carrying the incision as far back 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 the other. 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* are the *7th* or *facial*, and *8th* or *auditory nerves*, and the auditory artery ; immediately below the *8th* are the *9th*, *10th*, and *11th nerves*. Cut the *9th*, or *glosso-pharyngeal*, and the *10th*, the *vagus*, but leave intact the spinal part of the *11th nerve*, the *spinal accessory* ; lower down near the middle line is the *12th* or *hypoglossal 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. Snip through the vein of Galen, and the brain can now be easily removed from its bed, and should be at once placed in spirit or in a solution of formalin. Leave it there for a few days ; then examine it and carefully remove the pia mater, except at the back of the brain between the cerebrum and cerebellum, in order not to disturb a process of pia mater—the velum interpositum—which passes into the brain at this point.

CHAPTER I.

MEMBRANES OF THE BRAIN.

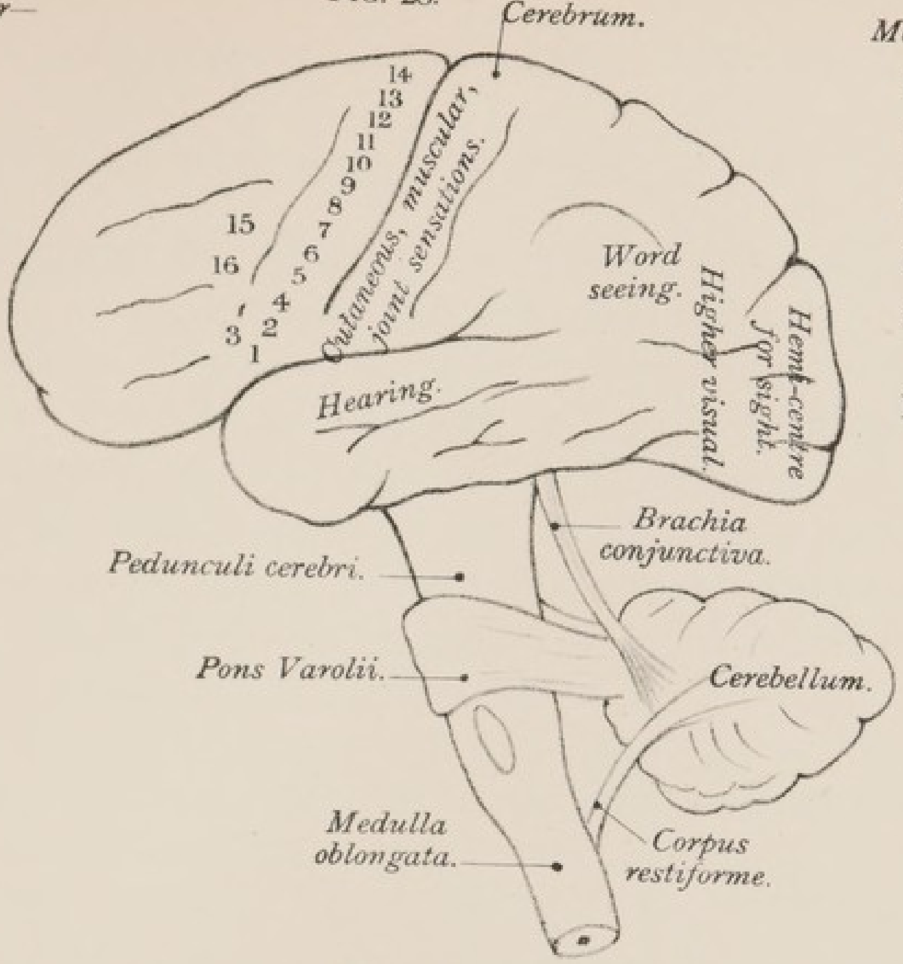
(Plate VII. Page 50 ; Plate VIII. Page 54.)

To examine the first of these membranes—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.

Fig. 28.

Motor Areas for—

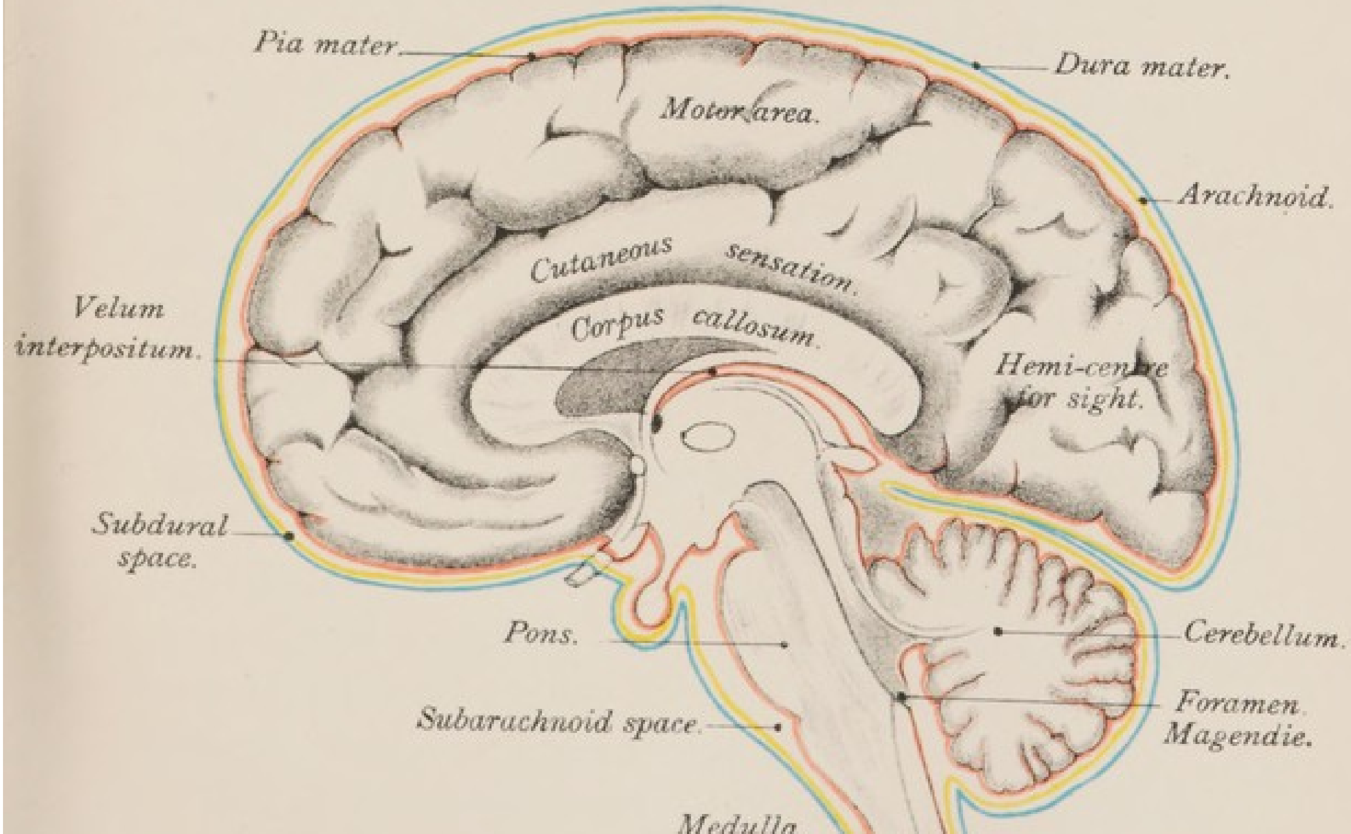
1. *Tongue.*
2. *Lips.*
3. *Larynx.*
4. *Face.*
5. *Neck.*
6. *Digits.*
7. *Wrist.*
8. *Elbow.*
9. *Shoulder.*
10. *Trunk.*



Motor Areas for—

11. *Hips.*
12. *Knee.*
13. *Ankle.*
14. *Toes.*
15. *Head and Eyes.*
16. *Writing.*

Fig. 29.



McLagan & Cumming, Edinburgh.

I. THE DURA MATER.

The Cranial Dura Mater is a dense white fibrous membrane, rough externally, but smooth and polished within, where it is lined by a layer of epithelial cells similar to that which lines the spinal dura mater. It is composed of two layers—though in the greater part of their extent these are not distinct from each other—an inner, which sends processes or partitions between certain parts of the brain, and an outer, which adheres to and forms the endosteum of the inner table of the cranium. In two places especially is this attachment well marked, (1) along the lines of the cranial sutures, and (2) 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 between the dura mater and the bone. The dura mater, moreover, sends a tubular process round each of the several cranial nerves as they leave the skull through their various foramina; part of this tubular process forms a sheath to the nerve, part of it becomes attached to the pericranium. Similar processes also extend into the orbital cavities, and there blend with the periosteum. At the lower margin of the foramen magnum the dura mater is closely adherent 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 between them 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 between the cerebrum and the cerebellum.

1. **The Falx Cerebri**—so called from its sickle-shaped form (fig. 32, page 54)—is the vertical mesial process of dura mater which is lodged in the great longitudinal fissure of the cerebrum, and 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, forms the base of the sickle, and is fixed along the middle line of the upper surface of the tentorium cerebelli. Its upper convex margin contains the superior longitudinal sinus, and adheres to the ridges seen on each side of the median depression on the deep aspect of the vault of the skull. The lower margin contains the inferior longitudinal sinus. It is concave and free, and is in contact with the upper surface of the corpus callosum behind, though some distance from it in front.

2. **The Falx Cerebelli** (fig. 32, page 54) is the small, median, vertical, triangular partition, attached behind by a convex border to the internal occipital crest, and above, at its widest part, to the mid-line of the under surface of the tentorium cerebelli. Its free concave anterior margin projects forward, and fits into the notch between the two halves of the cerebellum. Its posterior attached margin contains the occipital sinus. This sinus is single above, but bifid below.

3. **The Tentorium Cerebelli** (fig. 32, page 54), supporting the posterior part of the cerebrum, slopes

forwards and upwards, somewhat horizontally, as an arched, tent-like partition between the big and the little brain. The posterior convex margin is attached behind to the transverse ridges on each side of the grooves on the inner aspects of the occipital and parietal bones. Further forwards it is fixed to the upper margins 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 V-shaped margin is free in the greater part of its extent, but, in front, it is attached on each side by two narrow slips—the ends of the V—to the anterior clinoid processes. Between this margin and the dorsum sellæ of the sphenoid is an oval opening—tentorial notch—for the passage of the crura cerebri, of the superior peduncles of the cerebellum, and of the posterior cerebral arteries. Along the middle line of the upper surface of the tentorium runs the straight sinus, which receives the vein of Galen—vena cerebri magna—from the interior of the brain (fig. 32, page 54).

The MINUTE STRUCTURE of the dura mater of the brain is similar to that of the spinal cord. It consists of layers of fibrous tissue. The larger arteries lie near the outer surface of the membrane, whereas the veins are embedded in its midst or lie between its layers. There are few capillaries in its substance, but on its inner aspect is a rich network of vessels covered by epithelial cells and surrounded by perivascular spaces which, by means of stomata, communicate with the sub-dural space (Robertson).

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

Pacchionian Bodies (fig. 34, page 54) are small white elevations of lymphoid tissue which indent the inner surface of the vertex of the skull, mostly along each side of the middle line, near the superior longitudinal sinus. Others are found near the lateral, cavernous, petrosal, and straight sinuses. They are said to be outgrowths of the villi, which normally exist in the arachnoid; their exact nature and use is, however, unknown. Some hold that they are mere excretions, others that they are communications between the sub-arachnoid space and the venous sinuses of the dura mater, and others that they are ligaments which fix the pia mater to the dura mater and help to suspend the brain.

II. THE PIA MATER.

(Fig. 29, Page 44, and Fig. 30, Page 50.)

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. 30, page 50). It is practically one layer with the arachnoid. Covering the surface of the brain, it dips into the various fissures between the convolutions; and from its inner surface numberless blood-vessels emerge for the nourishment of the substance of the brain. Besides the septa between the convolutions, the pia mater also sends into the brain 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 called the *choroid plexus*. A similar vascular process of pia mater, known as the *tela choroidea inferior,* or choroid plexus of the 4th ventricle, lies in the roof of that cavity (see Ventricles, page 143).

In STRUCTURE the pia mater of the brain corresponds to the inner of the two layers of the pia-arachnoid described on the following page. It receives its nerve supply from the 3rd, 5th, 6th, 7th, and 8th cranial 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. 30, page 50). Its outer surfaces is covered by minute reddish-grey villi (see Pacchionian Bodies, page 48). Formed of a single layer, it is, on the one hand, separated from the dura mater by veins, and, on the other, envelops the brain, but does not pass into the fissures between the convolutions, though it dips into the superior longitudinal fissure and into the fissure between the cerebrum and the cerebellum. It is closely connected with the pia mater beneath by the sub-arachnoid 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 more widely separated from each other, forming the SUB-ARACHNOID SPACE, which contains most of the cerebro-spinal fluid.

MINUTE STRUCTURE.—The arachnoid is not a distinct membrane from the pia mater, and the two are often described together under the name pia-arachnoid. This consists of two layers of epithelium—a superficial and a deep—the latter being in contact with the brain. The two layers are united by numberless delicate threads of fibrous tissue, clothed with epithelial cells, and called sub-arachnoid trabeculæ. The nerve supply to the arachnoid is probably derived from the 5th, the facial, and the spinal accessory nerves.

Sub-dural and Sub-arachnoid Spaces (fig. 29, page 44).—The space between the dura mater and the arachnoid is called the sub-dural space, and is lined by epithelial cells. The space between the arachnoid and pia mater is the sub-arachnoid space, and is crossed by the sub-arachnoid trabeculæ. It contains cerebro-spinal fluid. Both its inner and outer walls are lined by epithelial cells, which also cover the surfaces of the trabeculæ. The sub-arachnoid space is most distinct in the following situations—(1) at the great longitudinal fissure; (2) at the base of the brain, in the triangular interval called the inter-peduncular space; and (3) posteriorly, between the cerebellum and the medulla oblongata.

Cerebro-spinal Fluid.—Most of this fluid is contained in the meshes of the sub-arachnoid trabeculæ, though a small quantity is found in the sub-dural space. Through an opening—the *foramen of Majendie*—in the roof of the 4th ventricle (fig. 29, page 44), and through two similar lateral openings in the ventricular roof between the medulla and cerebellum, the cerebro-spinal fluid of the sub-arachnoid space is continuous with the fluid in the central canal of the spinal cord and in the ventricles of the brain.

Fig. 30.

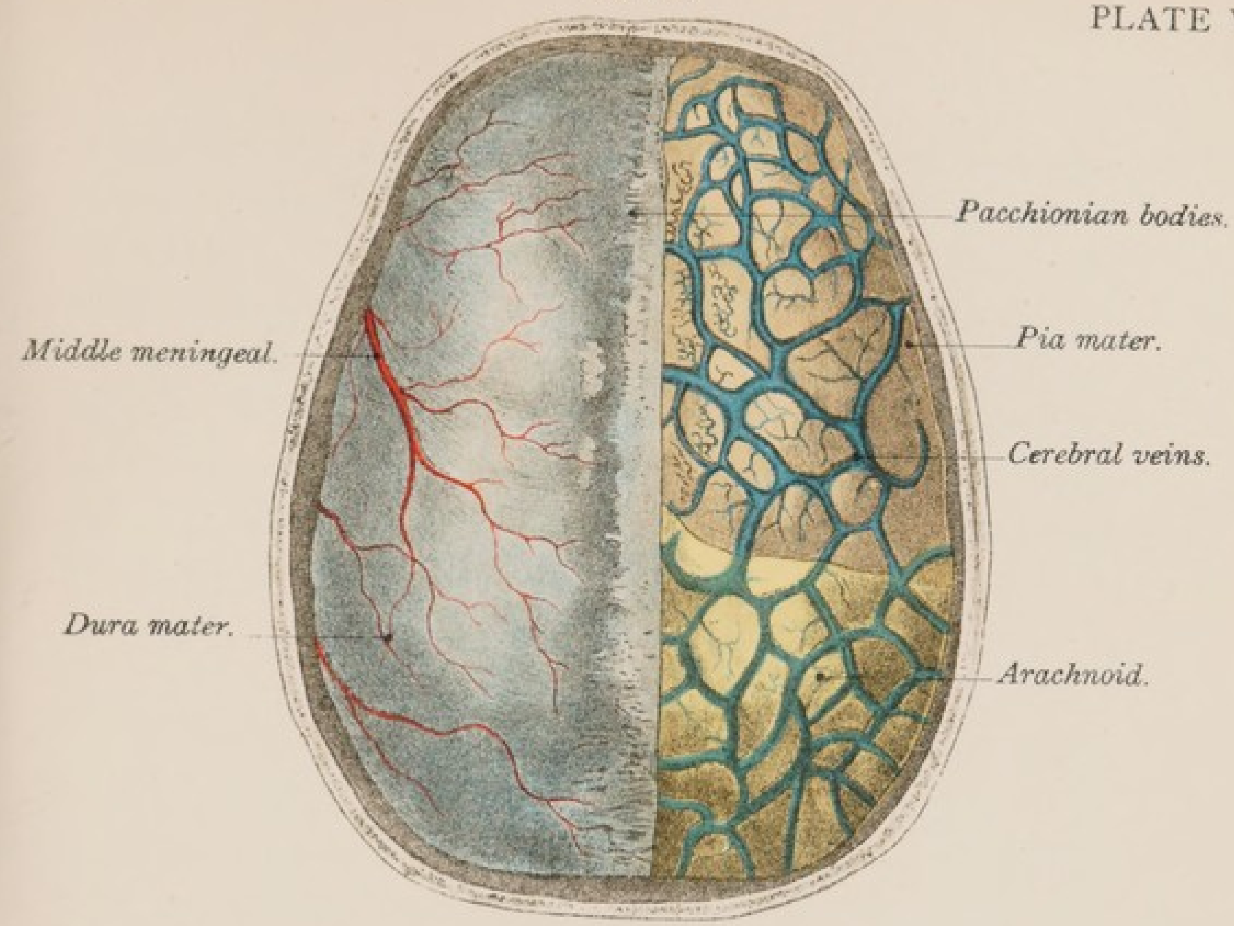
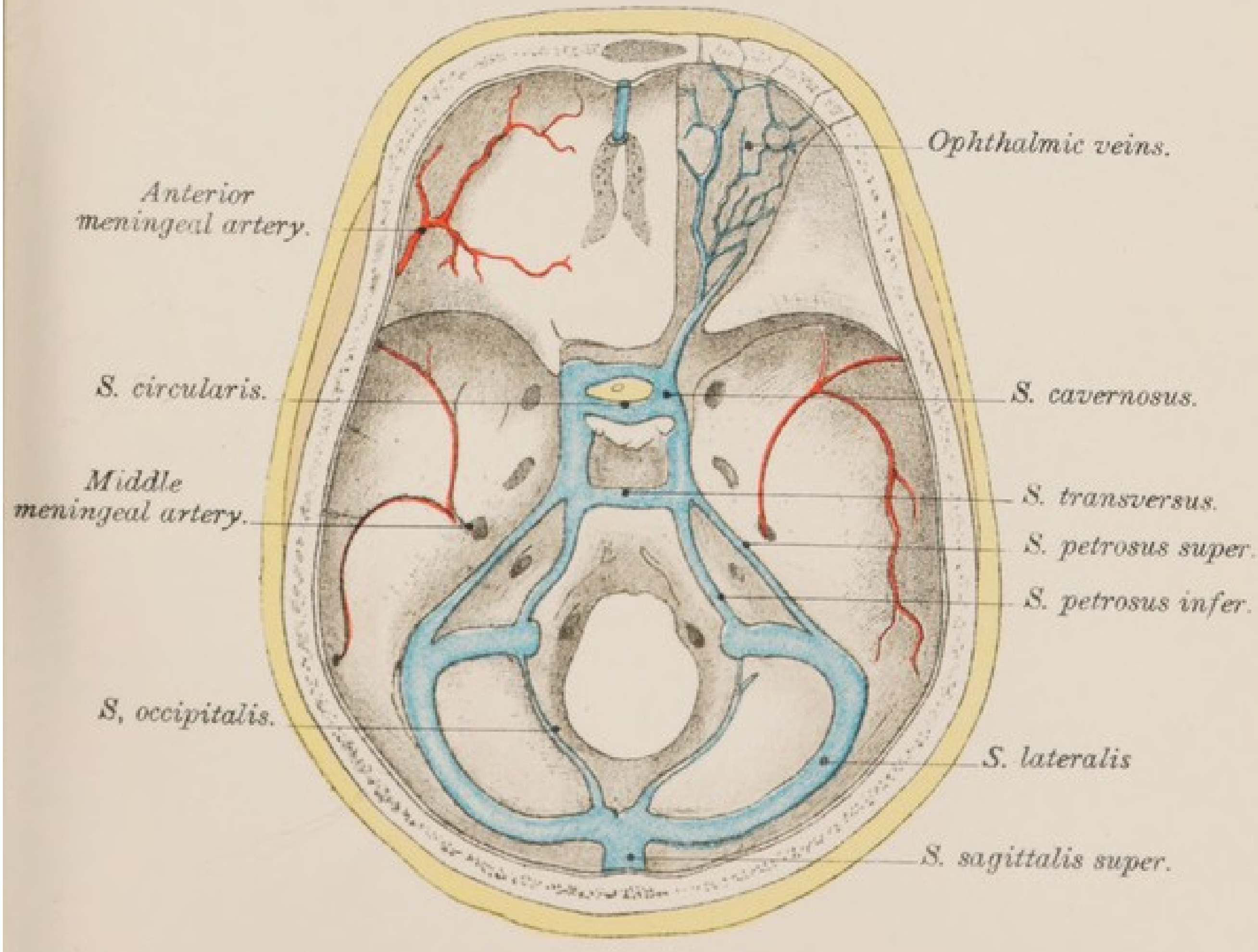


Fig. 31.



Venous Sinuses.

Mc Lagan & Cumming, Edinburgh.

Corresponding communications also exist at the inferior horns of the lateral ventricles. The cerebro-spinal fluid is not merely intended to fill the sub-arachnoid space, but to help to protect the nerve centres from sudden shocks, acting, in fact, as a water-bed, on which the brain rests (Hilton). According to Foster, it is probable that the cerebro-spinal fluid, being of the nature of lymph, may also subserve the nutrition of the brain.

IV. VENOUS SINUSES.

(Fig. 31, Plate VII. Page 50 ; Figs. 32, etc., Plate VIII. Page 54.)

The sinuses of the dura mater are formed by the separation of its two layers, and are lined by epithelial cells continuous with the cells lining the interior of the veins. These sinuses are seventeen in number—six paired and five single. The single sinuses are the superior and the inferior longitudinal, the straight, the circular, and the transverse or basilar. The paired set includes the two lateral, the two superior and the two inferior petrosal, the two cavernous, the two occipital, and the two spheno-parietal.

1. **The Superior Longitudinal Sinus**—*S. Sagittalis Superior*—(figs. 32 and 33, page 54) begins in front at the foramen cæcum as a small vein, which often communicates with the veins of the nose. Arching upwards and backwards in the convex margin of the falx cerebri, it reaches the internal occipital protuberance, where it is joined by several other sinuses at the triangular dilatation, called the torcular Herophili,[1] or the meeting of the sinuses—*confluens*

[1] As Holden points out, the term torcular (a wine-press) is a mistranslation of the original word, σωλήν—a canal or gutter.

sinuum. 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 is 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 within the sinus. 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 para-sinoidal spaces, which lie on each side of the superior longitudinal sinus (fig. 34, page 54). Other smaller veins enter this sinus from the diploë of the surrounding bones, and it receives a large emissary vein through the parietal foramen.

2. **The Inferior Longitudinal Sinus**—*S. Sagittalis Inferior*—(figs. 32, 33, page 54) 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 major and it ends behind in the straight sinus.

3. **The Lateral Sinuses**—*S. Transversi*—(fig. 31, page 50) are two in number, right and left, the right being usually the larger. 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 in the attached margin of the tentorium cerebelli, in the grooves on the inner surface of the occipital and parietal bones, finally turn downwards and forwards in the groove on the mastoid part of the temporal bone and on the

jugular process of the occipital bone, to end in the bulb of the internal jugular veins. Blood enters these sinuses from the superior and inferior petrosal sinuses, from the inferior cerebral and cerebellar veins, and from the diploë of the bones. By means of emissary veins, which pass through the mastoid and anterior condyloid foramina, they communicate with the veins of the scalp.

4. **The Straight Sinus**—*S. Rectus*—(fig. 32, page 54) 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 vena cerebri magna or vein of Galen, the latter bringing blood from the third and the lateral ventricles of the brain. Some cerebral and cerebellar veins also open into this sinus.

5. **The Cavernous Sinuses**—*S. Cavernosi*—(fig. 31, page 50), 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 vertical transverse section, and contain, in their thickened outer wall, the third, the fourth, and the ophthalmic and superior maxillary divisions of the fifth nerves; while internally, and separated from the blood of the sinus by a thin lining membrane, is the internal carotid artery, with the sixth nerve on its outer side. These sinuses communicate with the circular sinus, and with the superior and inferior petrosal sinuses. They receive small cerebral veins, the veins from the orbits (fig. 31, page 50), and from the pterygoid plexus of veins.

6. **The Circular Sinus**—*S. Circularis*—(fig. 31,

page 50) surrounds the pituitary body in the sella turcica. At each side it communicates with the cavernous sinuses.

7. **The Petrosal Sinuses** (fig. 31, page 50) are two on each side—the superior and the inferior. The *Superior Petrosal Sinus—S. petrosus superior*—lies along the upper border of the petrous part of the temporal bone, and connects the cavernous sinus with the lateral sinus at its highest point. The *Inferior Petrosal Sinus—S. petrosus inferior*—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 after the latter has passed out of the skull to become the internal jugular vein. Cerebral, cerebellar, tympanic, and auditory veins pour their blood into one or other of these sinuses.

8. **The Transverse or Basilar Sinus**—*S. Basilaris*—(fig. 31, page 50), sometimes double, is placed across the basilar process of the occipital bone, and connects together the inferior petrosal sinuses. It is in reality a plexus of veins and not a mere sinus. It communicates below with the anterior spinal veins.

9. **The Occipital Sinuses**—*S. Occipitales*—(fig. 31, page 50) commence 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.

10. **The Spheno-parietal Sinuses** are two small venous channels which are found along the posterior margin of the lesser wing of the sphenoid. They open into the cavernous sinus of the corresponding side.

Emissary Veins are small vessels which pass

FIG. 32.

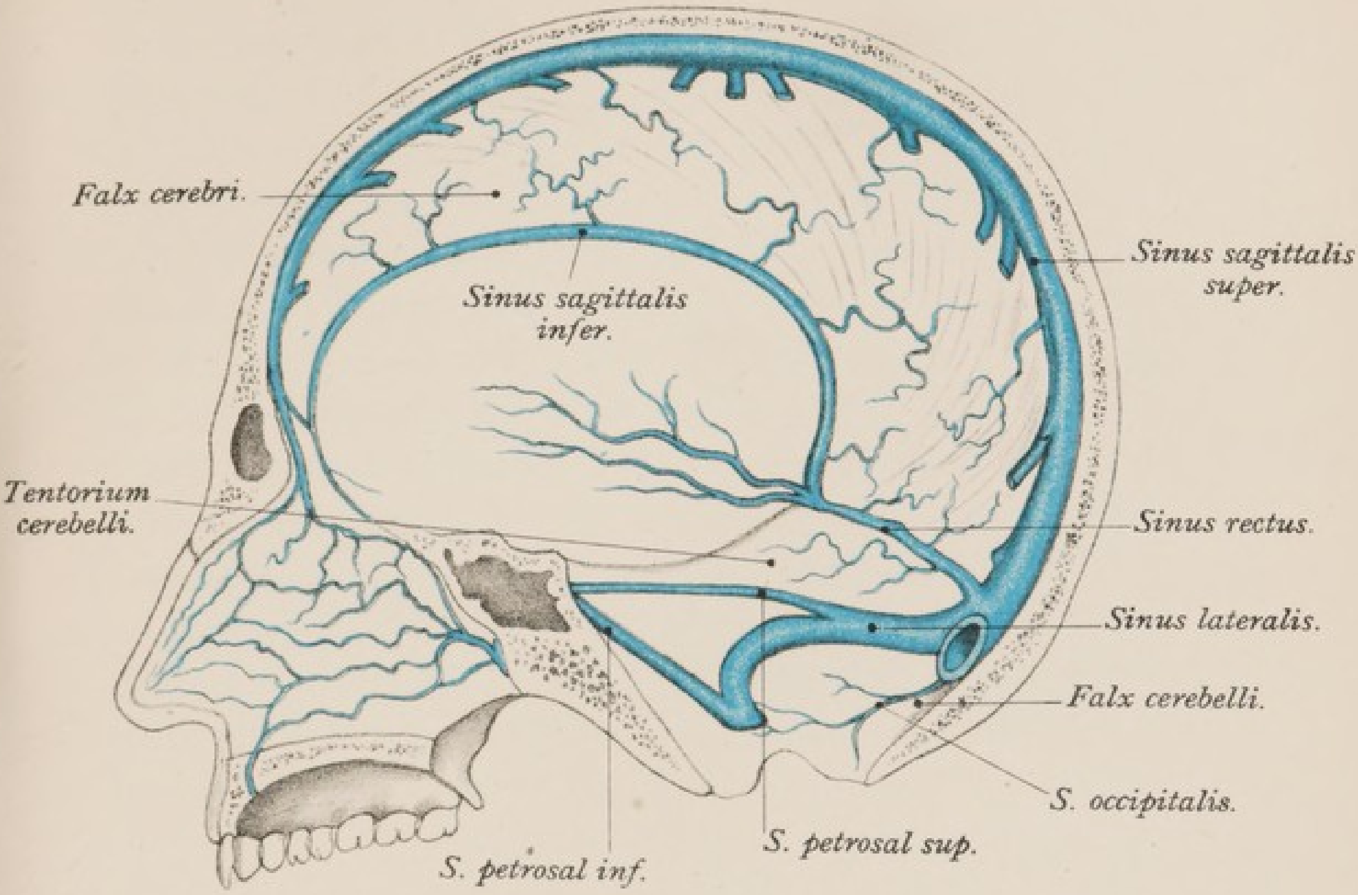


FIG. 33.

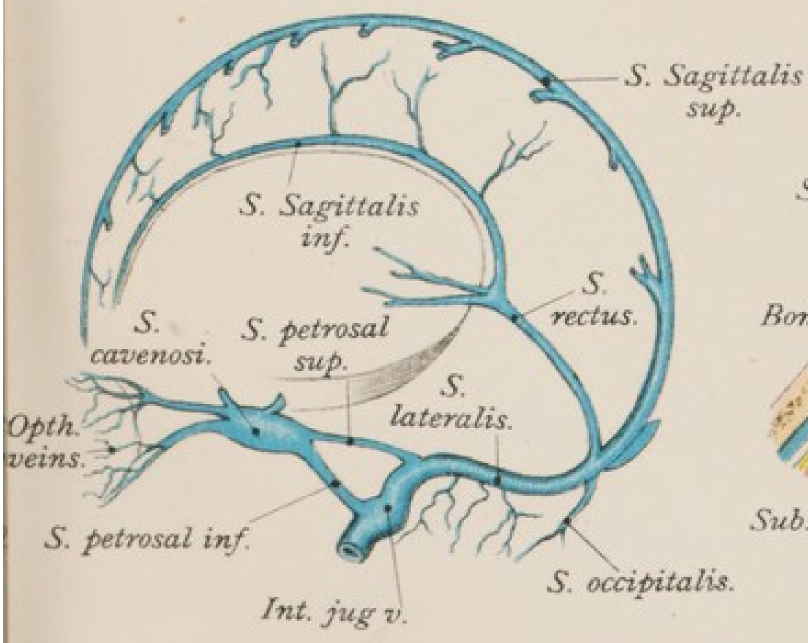
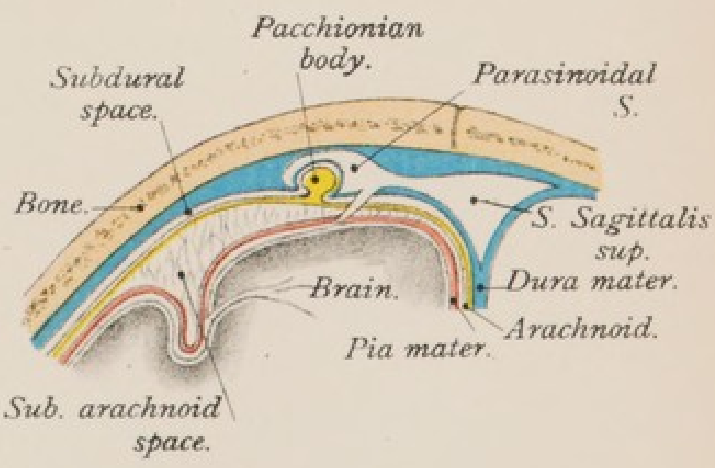


FIG. 34.



Sinuses.

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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).

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. 31, page 50). From the cranial fossæ in which they ramify they are called the anterior, the middle, and the posterior meningeal arteries, and they arise from the ethmoidal, ascending pharyngeal, internal maxillary, occipital, and vertebral arteries. For the description of these vessels see your dissecting manual. We shall now pass on to examine the vessels of the brain.

CHAPTER II.

VESSELS OF THE BRAIN.

(Figs. 35 and 38, Plate IX. Page 58, and Fig. 39, Plate X. Page 60.)

DISSECTION.—Remove the pia mater with great care, and in doing so, at the under surface of the brain, dissect out the vessels and the cranial nerves.

Note.—Those who have no previous knowledge of the brain might do well to read Chapter III. first, page 63, and then turn to the perusal of this chapter.

I. ARTERIES.

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

The anterior cerebral arteries give off two sets of branches—(*a*) a cortical set, and (*b*) a basal set.

(*a*) The *cortical* set, after ramifying and anastomosing within the pia mater, perforate the convex aspect of the brain at right angles to the surface, and supply the fore and upper parts of the inner surface of the hemispheres as far back as the parieto-occipital fissure. They also supply the inner part of the outer and lower aspects of the frontal lobes (figs. 39, etc., plate X. page 60).

(*b*) The *basal* set enter the anterior perforated space and are distributed to the front part of the corpus callosum and to the interior of the cerebrum, viz. to part of the caudate nucleus and of the internal capsule (see Table, page 61).

2. The MIDDLE CEREBRAL or SYLVIAN ARTERIES are the largest branches of the internal carotid. They run upwards and outwards in the fissure of Sylvius till they reach the island of Reil, when they ramify in the pia mater, and anastomose with the anterior and posterior cerebral arteries (plate IX. page 58, and plate X. page 60).

Like the anterior cerebrals, they give off cortical and basal branches.

The *cortical branches*, four in number, are distributed to the outer surface of the parietal lobe and to the adjacent parts of the frontal and temporal lobes (figs. 38, plate IX. page 58, and plate X. page 60).

The *basal branches* are furnished through the anterior perforated space to the corpus callosum and to part of the internal capsule and of the corpus striatum. They are all terminal arteries, by which we mean that they do not anastomose with each other. They are sometimes called the *ganglionic system* of arteries, and are named the lenticular, lenticular-striate, and the lenticular-optic. They will be again referred to in describing the central grey matter 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 temporal lobe and the crus cerebri (figs. 35 and 38, page 58), they reach the descending cornu of the lateral ventricle, and there form the vascular fringe called the choroid plexus. They also supply the uncinate gyrus of the temporal lobe, and part of the posterior limb of the internal capsule.

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 (see Table, page 61).

II. The Vertebral Arteries—branches of the subclavian—enter the foramen magnum by perforating the posterior occipito-atlantal ligament and the dura mater. They then curve round to the anterior surface of the medulla between the 12th cranial nerve and the anterior roots of the 1st cervical nerve. At the lower border of the pons they unite to form a single trunk—the *basilar artery*—which runs in the groove on the front of the pons, till it reaches the upper margin, when it divides into the two *posterior cerebral arteries* (fig. 38, page 58).

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 chiefly supplies the under surface of the cerebellum.

2. BRANCHES OF THE BASILAR (fig. 38, page 58):

(1) *Transverse branches,* three or four in number, run transversely outwards on the pons and supply it. One branch—the internal auditory—enters the internal auditory meatus.

(2) 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.

(3) 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.

(4) The *posterior cerebral arteries*—the terminal branches of the basilar—curve outwards and backwards, round the outer side of the crura cerebri, to the under

PLATE IX.

FIG. 35.

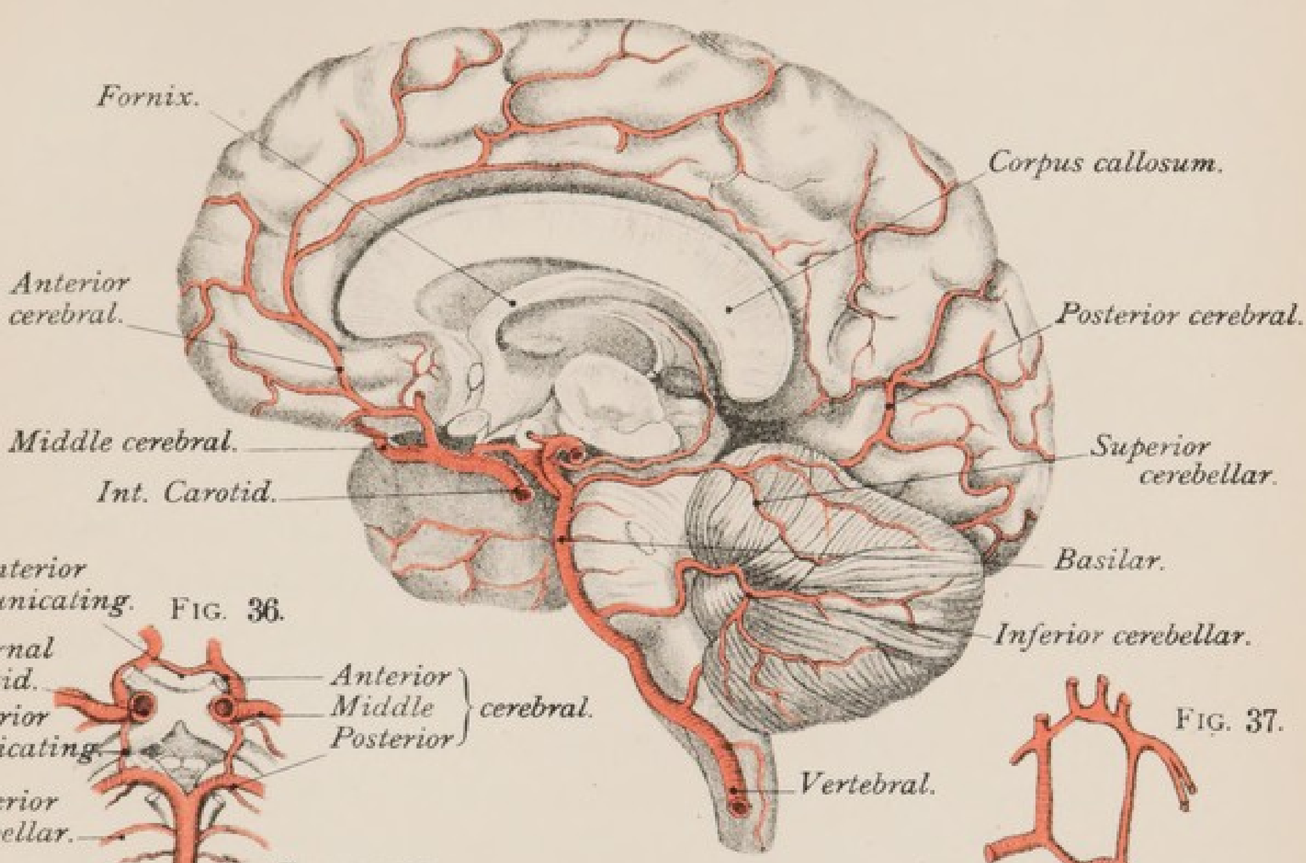


FIG. 36.

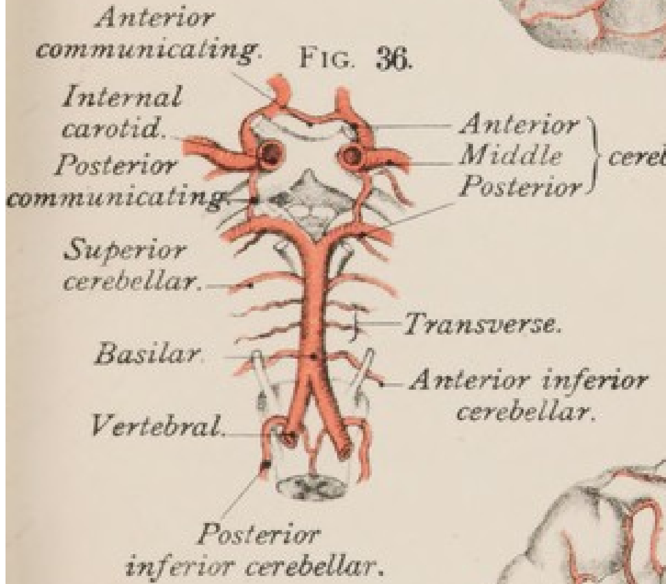
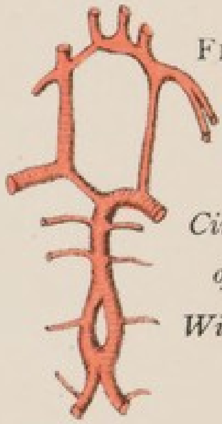
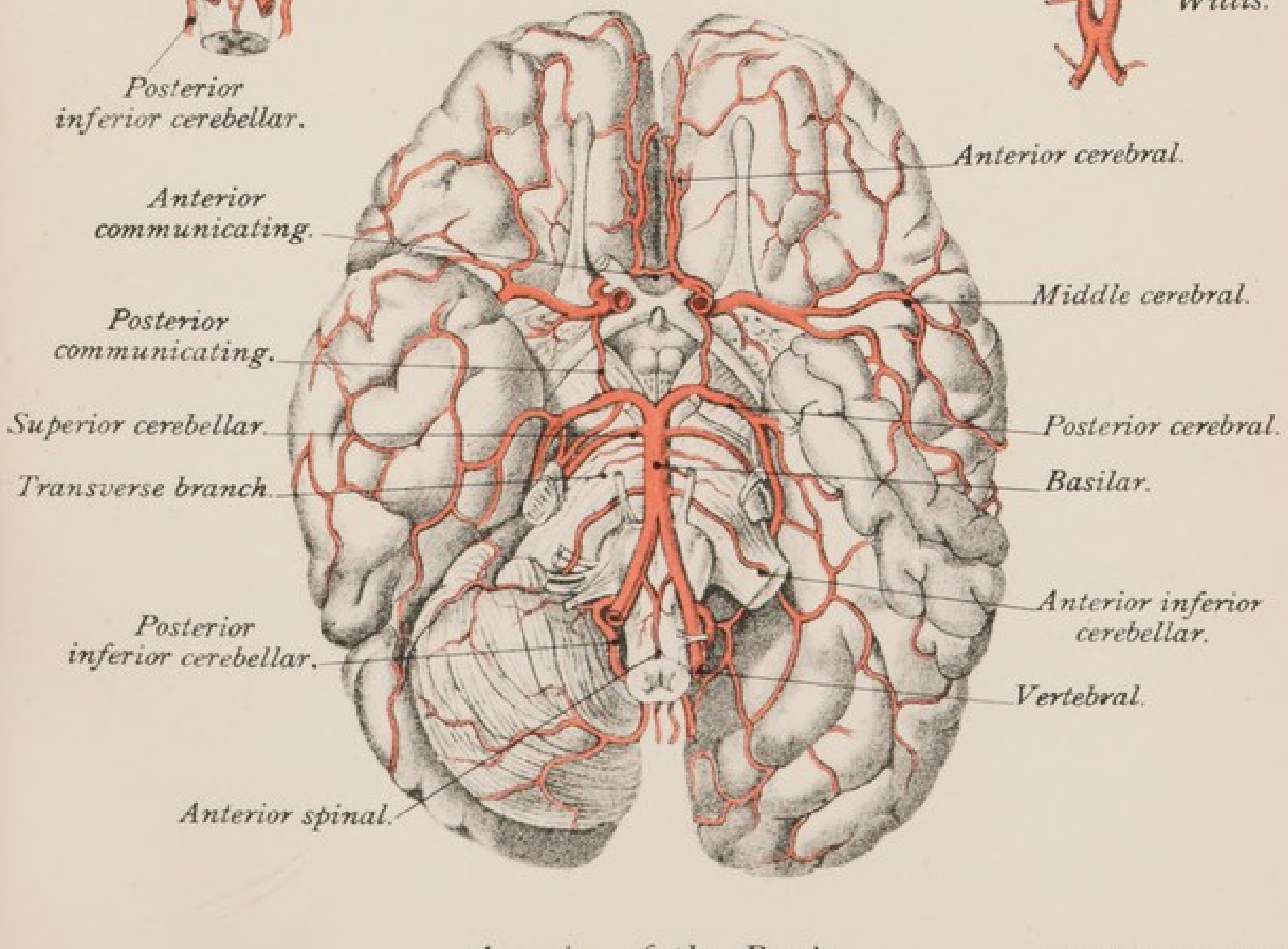


FIG. 37.



Circle of Willis.

FIG. 38.



Arteries of the Brain.

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surface of the posterior cerebral lobes, supplying them and anastomosing with the anterior and the middle cerebral arteries. They send *basal* branches to the posterior perforated spot and to the velum interpositum (posterior choroidal), and give off three *cortical* branches (fig. 38, page 58), which supply the occipital lobe, part of the quadrate lobe, and the mesial and contiguous parts of the outer surface of the temporal lobe (figs. 39 and 42, page 60).

Circle of Willis (figs. 36, 37, 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 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.

CIRCLE OF WILLIS.

In front:
Anterior Communicating.

On each side:

Left side.	Right side.
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, the cavernous and the superior petrosal sinuses. The deep set of veins, gathering the blood from the interior of the brain, enters the vein of Galen, and thus pours its blood into the straight sinus.

Cerebellar Veins.—The veins on the upper surface of the cerebellum enter the vein 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, and at their terminations by capillary vessels, there is little communication between the branches of the cerebral arteries, so that if any artery be obstructed, the nutrition of the area to which it is supplied becomes impaired.

FIG. 39.

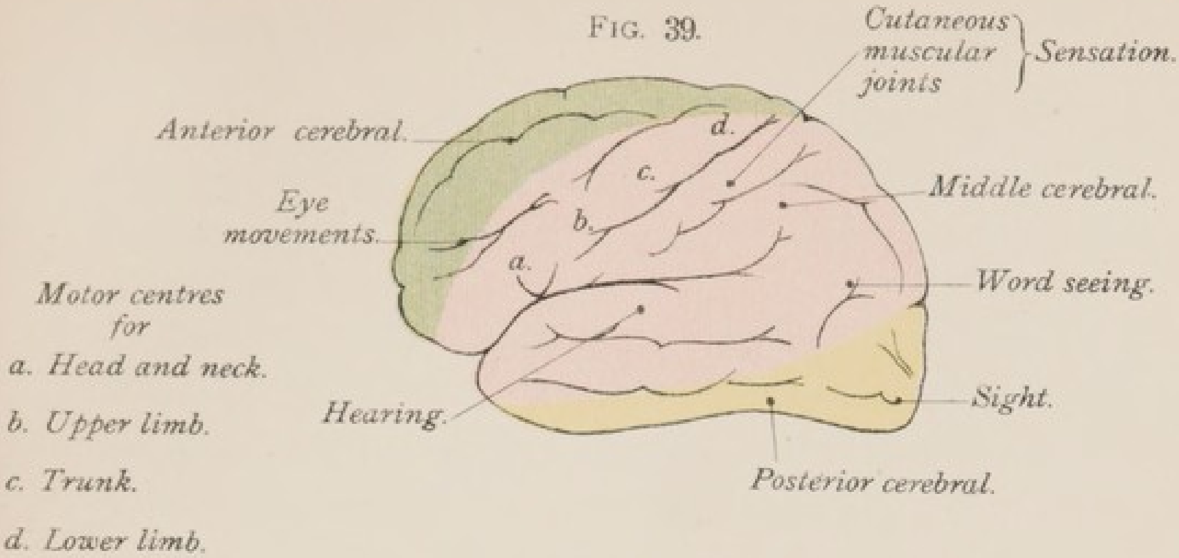


FIG. 40.

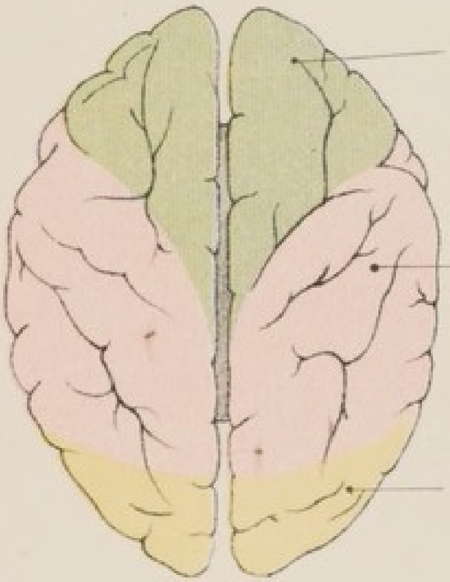


FIG. 41

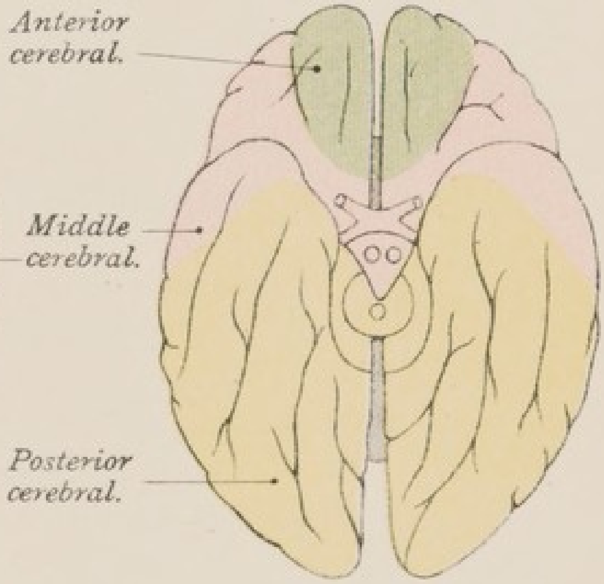
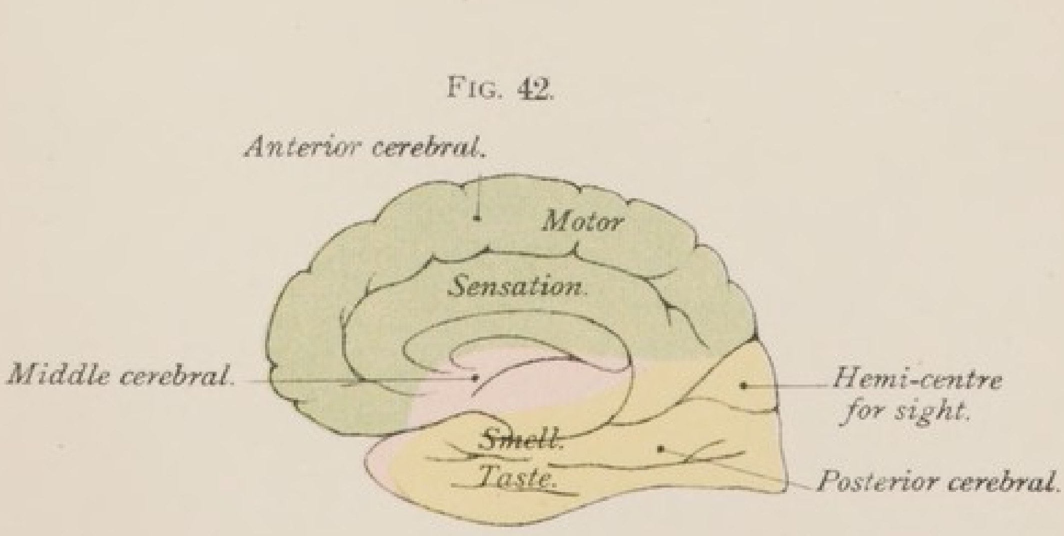


FIG. 42.



Vascular Areas of Brain.

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

The figs., plate X. page 60, will give you an idea of the distribution of the chief arterial branches to the cerebral cortex, and on this page you will find a useful table for reference.

III. LYMPHATICS.

In the brain there are no lymphatics properly so called; they are represented by spaces either round the nerve cells—pericellular spaces, or round the blood-vessels—perivascular spaces, and, leaving the brain with the blood-vessels, end in the lymphatics in the neck.

Table of the Distribution of Cerebral Arteries for Reference.

Anterior Cerebral.	1. Convolutions.	Superior frontal.	Cortical set.
		Anterior two-third middle frontal.	
		Upper end of ascending frontal.	
		Inner surface of frontal lobe (marginal convolution).	
		Mesial surface (quadrate lobe) and inner part of external surface of parietal lobe.	
		Gyrus fornicatus.	
		Olfactory bulb.	
		Orbital surface of frontal lobe internal to olfactory groove.	
	2. Other parts.	Fore part of the corpus callosum.	Basal set.
		Septum lucidum.	
		Anterior part of the caudate nucleus.	
		Lower half of anterior limb of internal capsule.	

- Middle Cerebral.
  - 1. Convolutions.
    - Cortical set.
      - Inferior frontal.
      - Middle frontal.
      - Great part of ascending frontal.
      - Orbital surface of frontal lobe outside olfactory groove.
      - Outer surfaces of the parietal lobe.
      - Superior and middle temporal.
      - Insula.
  - 2. Other parts.
    - Basal set.
      - Corpus striatum except head of caudate nucleus. Optic thalamus.
      - Upper half anterior limb of internal capsule.
      - Posterior limb of internal capsule.
- Posterior Cerebral.
  - 1. Convolutions.
    - Cortical set.
      - The occipital lobe.
      - Under or mesial aspect of temporal lobe except its anterior pole.
      - The cuneate lobe, the posterior part of quadrate lobe and part of the outer aspect of the parietal lobes.
  - 2. Other parts.
    - Basal set.
      - Caudate nucleus (lateral choroidal).
      - Posterior limb of internal capsule (slightly). Optic thalamus.
      - Velum interpositum and choroid plexus of lateral ventricle.
- Anterior communicating to anterior perforated spot.
- Posterior communicating.
  - Crura cerebri.
  - Anterior and inner part of optic thalamus.
  - Posterior limb of internal capsule.
- Anterior choroidal (from internal carotid).
  - Choroid plexus of lateral ventricle and part of posterior limb of internal capsule.
- Circle of Willis.
  - Interpeduncular space.
    - Optic chiasma.
    - Infundibulum.
    - Corpora mammillaria.
- Anterior cerebellar. Fore part of cerebellum.
- Superior cerebellar .
  - Superior medullary velum.
  - Superior peduncle of cerebellum.
  - Upper surface of cerebellum.

Inferior cerebellar	Choroid plexus of 4th ventricle. Under surface and back part of upper surface of cerebellum. Inferior corpora quadrigemina.
Basilar	Posterior perforated spot. Medulla. Pons. Anterior aspect of cerebellum (anterior inferior cerebellar).
Vertebral	Cerebellum. Medulla. Pons.

CHAPTER III.

BRAIN AND ITS SUBDIVISIONS.

(Figs. 28, 29, Page 44.)]

General Outline of the Brain.—On 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; for "one cannot but be forcibly struck with the resemblance between the human head and a walnut. There is, first, the pericranium and the skin, then the bone and the shell; within, the dura mater and a thick membrane lining the shell of the fruit; then the pia mater and the delicate membrane covering the kernel, which is again made up of convolutions into two masses joined together by a commissure or corpus callosum" (Wilks).

Viewed from above, the surface of the brain is seen to be 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 organ a most characteristic appearance. Along the middle line of this aspect of the brain runs a deep longitudinal cleft, which, when the brain is *in situ*, lodges the falx cerebri and divides the mass into two similar halves. This cleft is the great longitudinal fissure and the two symmetrical halves are called the CEREBRAL HEMISPHERES. They together form the first great division of the brain—the CEREBRUM—which is united to the rest of the brain and to the spinal cord by a mass of nerve substance known as the CEREBRAL PEDUNCLES or CRURA CEREBRI. On separating the walls of this median longitudinal fissure you will find that, in front and behind, the cleft extends right through to the base of the cerebrum, 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 or BASE of the brain, convoluted like 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 (figs. 28, 29, page 44; fig. 66, page 134), viz. (1) the CEREBELLUM or little brain, lying behind and below the posterior part of the cerebral hemispheres; (2) the PONS VAROLII, which, when viewed from the front, appears as a broad white band, crossing transversely between the two halves of the cerebellum; (3) the MEDULLA OBLONGATA or bulb, placed between the pons above and in front, the cerebellum behind, and the spinal marrow below. The subdivisions of the brain, from a developmental point of view, are given on page 209.

We shall describe (1) the MEDULLA, (2) the PONS, (3) the CEREBELLUM, (4) the CEREBRUM, and (5) the CEREBRAL PEDUNCLES.

I. MEDULLA OBLONGATA.

(Figs. 43 to 46, Plate XI. Page 66.)

DISSECTION.—If you have only one brain to work upon it will be best to pass on at once to the study of the cerebrum (page 114) and afterwards to return to the medulla. If you have more than one brain, then cut through the crura cerebri, and begin the examination of the medulla.

The Medulla Oblongata—Myelencephalon—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 two lateral aspects. The anterior surface rests upon the basilar process of the occipital bone; the posterior 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, the medulla measures about one and a quarter inches; in breadth, at its widest part, about one inch; in thickness about half-an-inch. Its ventral or anterior aspect is convex, and is limited above by the lower border of the pons; below, by what is known as the decussation of the pyramids—several bands of nerve fibres crossing, at the bottom of the anterior median fissure, from one side of the medulla to the other. Behind, that is, on its dorsal aspect, the medulla, in its lower half, is convex, and resembles the spinal cord, but, in its upper half, it expands laterally and becomes flattened from before backwards, forming part of the rhomboidal depression called the floor of the 4th ventricle. On this aspect, the upper boundary of the medulla is marked by several transverse lines — the *striæ medullares* or *acusticæ*—which run across the widest part of the ventricular floor (fig. 44, page 66); the lower boundary is purely artificial, corresponding with the lower margin of the foramen magnum. Each lateral aspect of the medulla supports an oval eminence, the olivary body, which is marked in the lower part of its extent, as well as the surface of the medulla just below it, by several transverse streaks, the external arciform fibres (fig. 46, page 66), the significance of which you will understand hereafter.

1. FISSURES OF THE MEDULLA.

The medulla, like the spinal cord, is a symmetrical organ, being divided by superficial median longitudinal 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 the origin of the anterior and posterior spinal nerve roots (fig. 46, page 66).

1. The ANTERIOR MEDIAN FISSURE of the medulla is a direct continuation upwards of the anterior median fissure of the spinal cord. Above, at the lower margin of the pons, it ends in a slight recess, need-

FIG. 43.

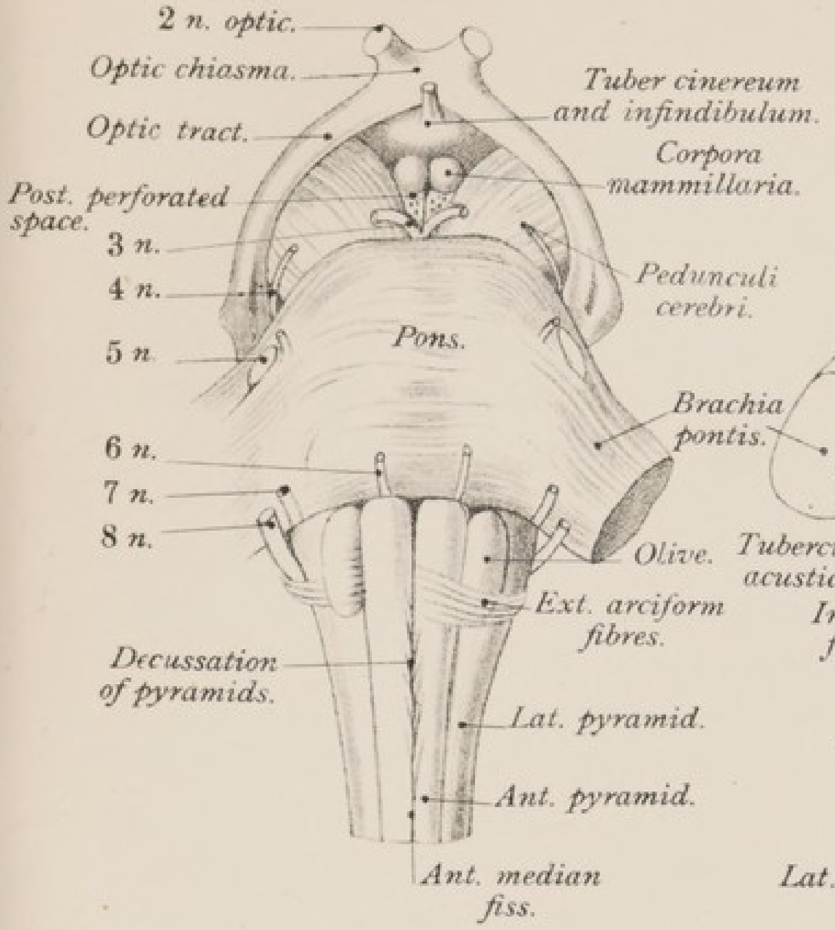


FIG. 44.

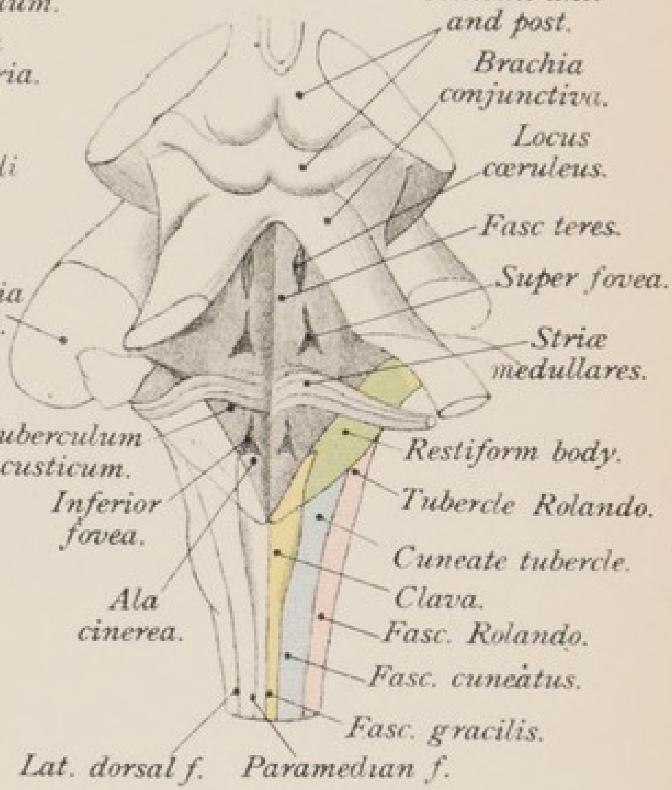


FIG. 45.

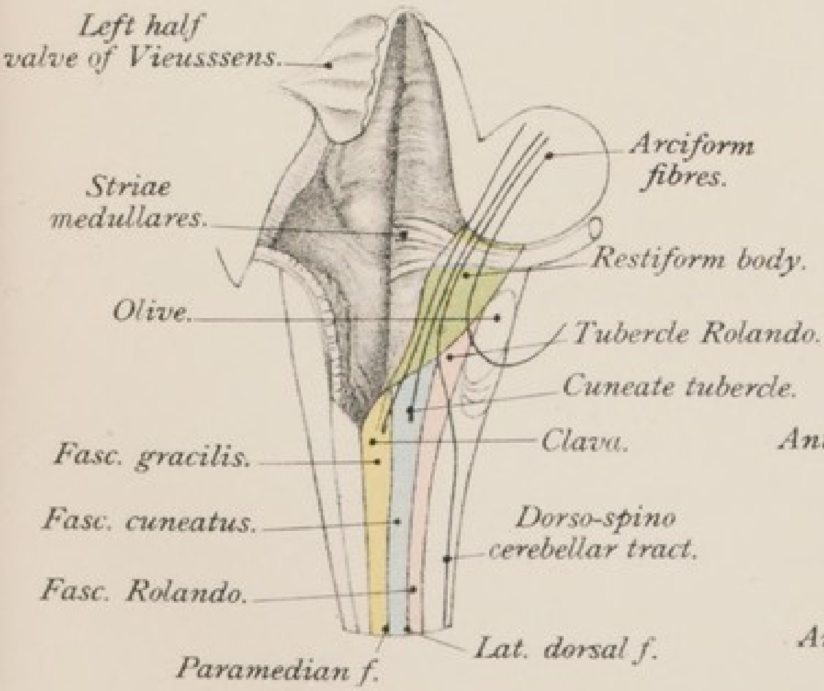
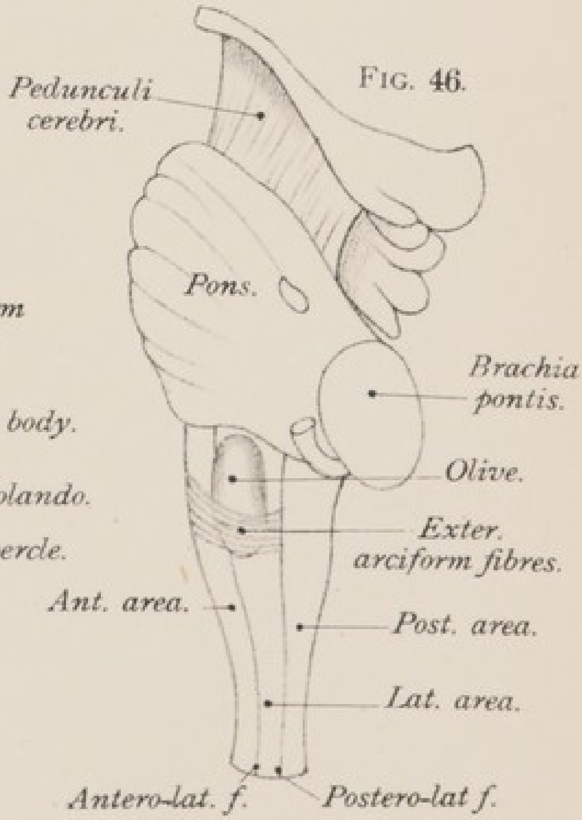


FIG. 46.



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lessly named the foramen cæcum. Below, at the lower limit of the medulla, it is interrupted by the bands of nerve fibres known as the decussation of the pyramids already referred to (fig. 43, page 66).

2. The POSTERIOR MEDIAN FISSURE, continuous with the posterior median fissure of the spinal cord, expands above into the shallow rhomboidal space called the floor of the 4th ventricle, along the centre of which runs a mesial groove, in a line with, though not a direct continuation of, the median fissure of the cord. External to the posterior median fissure of the medulla are two minor sulci—the paramedian and lateral dorsal sulci (figs. 44, 45, page 66).

3. The LATERAL FISSURES—antero-lateral and postero-lateral—are continuous with the lateral fissures of the cord. They give origin to the roots of the 9th, 10th, 11th, and 12th pairs of cranial nerves—the 9th, 10th, and 11th pairs springing from the continuation of the postero-lateral groove, and the 12th pair from the continuation of the antero-lateral groove.

2. WHITE MATTER OF THE MEDULLA.

(Areas or Pyramids of the Medulla.)

By means of the above fissures the surface of each half of the medulla is marked out into three areas, viz. an *anterior area* or *pyramid*, between the anterior median fissure and the line of origin of the 12th nerve; a *lateral area* or *pyramid*, between the 12th nerve in front and the 9th, 10th, and 11th nerves behind; and a *posterior area* or *pyramid*, between the posterior median fissure and the 9th, 10th, and 11th pairs of nerve roots. We shall begin with the description of the anterior area (figs. 43 to 46, page 66).

1. **The Anterior Area,** also called the *anterior pyramid* of the medulla (fig. 43, page 66), lies between the anterior median fissure and the roots of the hypoglossal nerve, which serve to separate it from the olivary body. It is a pear-shaped prominence, which is broader above than below, though it becomes slightly constricted before disappearing beneath the transverse fibres of the pons. It is streaked transversely by the external arciform fibres. To its constitution you will require to give your closest attention, for it is somewhat complicated, and of the greatest importance (fig. 93, page 182). Note that although we are tracing these pyramidal tracts *upwards,* they are in reality *descending* or *motor* strands.

The anterior column of the spinal cord, you will remember, had (1) a median division, *direct pyramidal tract,* and (2) a lateral division—*fasciculus proprius anterior.*

(1) Now the anterior 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 belong to the *opposite lateral* column of the spinal cord. This crossed tract, after leaving the opposite lateral column, can be traced upwards and inwards through the anterior commissure, across the bottom of 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, this crossed tract now lies internal to the direct pyramidal tract and forms the inner and by far the larger part of the opposite anterior pyramid; the outer and smaller part of the same pyramid being formed by the continuation upwards of the direct and uncrossed pyramidal tracts of the same side. Thus, for example, the LEFT ANTERIOR PYRAMID of the medulla is chiefly made up of the *crossed pyramidal tract* of the RIGHT LATERAL COLUMN, and, to a much smaller extent, by the *direct pyramidal* and *uncrossed lateral pyramidal tracts* 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, through the nerve cells of the base of the posterior horn, become connected, like the crossed tracts, with the anterior nerve roots of the opposite side to that at which they left the brain. The pyramidal tracts are the chief motor strands, and their decussation explains the phenomena of certain forms of paralysis, in which when one side of the brain, say the left, is injured, loss of motion ensues, not on that side, but on the opposite side of the body. "In cases, then, in which we find total or partial paralysis of the muscles on one side, with increased excitability to mechanical stimuli and a tendency to contracture, we can justly conclude that the opposite pyramidal tracts are affected" (Edinger).

(2) The lateral division of the anterior column of the spinal cord—*fasciculus proprius anterior*—consists of (1) endogenous fibres, and (2) of fibres which, on reaching the medulla, are either connected with the formatio reticularis or with the anterior and posterior

longitudinal bundles. For these bundles see Pons and Crura, and fig. 49, page 78, and figs. 52, 53, 54, plate XIV. page 90.

2. **The Posterior Area.**—This area, lying between the posterior median fissure and the line of origin of the 9th, 10th, and 11th 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, a cavity which should naturally be described at this stage, but owing to the fact that many of its parts are connected with the pons and with the cerebellum, its description must be deferred until we have treated of that portion of the brain (page 107).

The *lower portion* of the posterior area, very similar in appearance to the spinal cord, 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 position, their arrangement, and their names. These changes we shall now describe. There are, however, on this aspect of the medulla, two other strands, known respectively as the FASCICULUS of ROLANDO and the RESTIFORM BODY. They 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.

(1) FASCICULUS GRACILIS.—In dealing with the white substance of the posterior 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 *fasciculus of Goll.* Now, traced into the medulla, this strand, which lies between the posterior median and the paramedian fissures, becomes more prominent, and at the point where the central canal of the cord becomes the cavity of the 4th ventricle, the fasciculus enlarges, and is removed a little to one side. It is called the FASCICULUS GRACILIS—slender, and its enlarged upper end is known as the CLAVA—a club (figs. 44, 45, page 66). When followed upwards it tapers to a point and becomes gradually lost, though we shall afterwards be able to trace its fibres along with those of the next bundle, first, to collections of grey matter—nucleus gracilis and nucleus cuneatus—in the medulla, and thence to the cerebrum and cerebellum (see Sensory Decussation and Fillet, page 82).

(2) FASCICULUS CUNEATUS.—The outer division of the posterior column of the spinal cord—the *cuneate fasciculus* or *fasciculus of Bürdach*—passes into the medulla under the former name. It lies between the paramedian and the lateral dorsal sulci, and expanding above into a tubercle—the CUNEATE TUBERCLE—reaches upwards beyond the clava, and forms one of the lateral boundaries of the lower part of the 4th ventricle (fig. 45, page 66).

(3) FASCICULUS OF ROLANDO.—This tract—greyish in colour, for there is little or no white matter on its surface—lies outside the fasciculus cuneatus, between it and the line of origin of the roots of the 9th, 10th, and 11th cranial nerves. Like the two tracts previously mentioned, it expands above into a tubercle—the TUBERCLE of ROLANDO (fig. 45, page 66). It is the continuation upwards of the substantia gelatinosa

of Rolando of the spinal cord, and the white matter on its surface is the spinal root of the 5th cranial nerve. The fasciculus of Rolando, though often very poorly developed in the adult brain, is always well marked in the medulla of the child.

(4) The RESTIFORM BODY.—The remaining prominence, the largest and most conspicuous on this surface of the medulla, is called the INFERIOR CEREBELLAR PEDUNCLE or RESTIFORM BODY—*restis*, a rope (figs. 44, 45, page 66). Placed behind, and to the outer side of the lateral column of the cord, it lies above the level of the clava, of the cuneate tubercle, and of 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 presently see, it is composed of fibres derived, for the most part, from the lateral column of the spinal cord (fig. 45, page 66).

On this area of the medulla, then, we note four strands—(1) the fasciculus gracilis and its clava, (2) the fasciculus cuneatus and its tubercle, (3) the fasciculus of Rolando, and (4) the restiform body.

3. **The Lateral Area** or *Pyramid* of the medulla, continuous with the lateral column of the cord, lies between the roots of the hypoglossal nerve in front and those of the 9th, 10th, and 11th nerves 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 seven tracts —the crossed and uncrossed pyramidal, the pre-

pyramidal, the dorso-spino-cerebellar (lateral cerebellar), the ascending and descending antero-lateral tracts, and the fasciculus proprius lateralis (mixed zone). Of these strands (1) the *crossed* and (2) the *uncrossed pyramidal* have already been traced; the one to the *anterior pyramid* of the *opposite* side, the other to the *anterior pyramid* of its *own* side; (3) the *dorso-spino-cerebellar* (lateral cerebellar) tract reaches the *posterior* area of the medulla. Commencing in the lateral column of the spinal cord, it forms a superficial band of fibres (fig. 45, page 66), which runs upwards and backwards across the line of origin of the 9th, 10th, and 11th nerves, over the fasciculus of Rolando, and above its tubercle. It then crosses the cuneate fasciculus, and turning sharply upwards, is joined by a set of fibres—the external arciform fibres—which, together with it, constitute the main mass of the *restiform body* or inferior peduncle of the cerebellum, seen on the posterior area of the medulla (fig. 45, page 66). The four remaining tracts of the *lateral column* of the spinal cord enter the *lateral pyramid* of the medulla—thus, (4) the *fasciculus proprius lateralis* (mixed zone) goes to the formatio reticularis, some of its fibres passing on the superficial, some on the deep surface of the olivary body; (5) the *ascending antero-lateral* (ventro-spino-cerebellar and spino-thalamic) and (6) the *prepyramidal* (rubospinal) tracts lie in the groove behind the olive (fig. 49, page 78); whereas (7) the *descending antero-lateral tract* (Löwenthal) is found in the corresponding groove in front of the olive (fig. 49, page 78).

Thus, then, the fibres of the lateral column of the spinal cord, on reaching the medulla, are disposed of in three ways: (1) Some—the crossed and uncrossed pyramidal tracts—go to the anterior pyramid of the same or of the opposite side (fig. 93, page 182); (2) others—dorso-spino-cerebellar tract—to the restiform body, and thence to the cerebellum of the same side; (3) others—the antero-lateral and the prepyramidal tracts—reach the lateral area of the medulla, passing partly behind, partly in front, partly superficial to, and partly beneath the olive to the formatio reticularis (fig. 49, page 78). The constitution and ultimate destination of these strands of fibres will be seen hereafter.

Olivary Body.—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 12th nerve, but is separated behind from those of the 9th, 10th, and 11th nerves by a narrow white tract, which, as we have just seen, is part of the lateral column of the cord. Above, the olive almost touches the lower border of the pons; below, it is crossed transversely by delicate fibres—the external arciform fibres, which, at the present stage of their course, can be seen to 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 to turn upwards, along with the lateral cerebellar tract, to form, with it, part of the restiform body (figs. 43, 45, 46, page 66). They will be again referred to in treating of the grey matter of the medulla. If you cut into the olive you will find that it contains a grey core, called the *corpus dentatum* or inferior olivary nucleus (see page 80).

Cranial Nerves.—Besides the various longitudinal tracts which have been engaging our attention, there are, in this part of the medulla, several strands of nerve fibres which traverse the medulla from behind forwards. They are the fibres of the 8th to the 12th cranial nerves, which are on their way from their deep to their superficial origins, or *vice versa* (fig. 49, plate XII. page 78). See also Cranial Nerves, page 176.

Table of Objects seen on Surface of Medulla.

Sulci or Fissures.	Anterior median, with decussation of the pyramids.		
	Posterior median, which widens out into the 4th ventricle.		
	Two lateral, with nerve roots—the 12th from antero-lateral, the 9th, 10th, and 11th from postero-lateral groove.		
Areas or Pyramids.	1. Anterior area or Pyramid.		Anterior pyramids.
			Decussation of pyramids.
			External arcuate fibres.
	2. Lateral area or Pyramid.		Olive.
			External arciform fibres.
			Tract of white matter in relation to the olive.
	3. Posterior area or Pyramid.	Lower part.	Restiform body.
			Fasciculus of Rolando and its tubercle.
			Fasciculus cuneatus and its tubercle.
			Fasciculus gracilis and its clava.
		Upper part.	Lower half of the floor of 4th ventricle.

Summary.—Thus, then, we see that the surface of the medulla oblongata presents four fissures—an anterior, a posterior, and two lateral with their nerve roots: three areas—an anterior, with its pyramids and their decussation; a lateral, with its olive; a posterior, with its fasciculus gracilis, fasciculus cuneatus, and fasciculus of Rolando, and their respective enlargements; and, finally, the restiform body, or inferior cerebellar peduncle.

TABLE OF RELATIONS BETWEEN WHITE TRACTS OF CORD AND THEIR REPRESENTATIVES IN THE MEDULLA.

	Cord.	*Medulla.*
Anterior column.	1. Direct pyramidal tract	from outer part of the anterior pyramid of the medulla of the same side.
	2. Fasciculus proprius anterior	to anterior and posterior longitudinal bundles. to formatio reticularis.
Lateral column.	1. Crossed pyramidal tract	from the inner part of the anterior pyramid of the opposite side.
	2. Uncrossed lateral pyramidal tract	from anterior pyramid of its own side.
	3. Dorso-spino-cerebellar (lateral cerebellar) tract	to restiform body and thence to the cerebellum of same side.
	4. Antero-lateral ascending tract (Gowers), or ventro-spino-cerebellar	to the cerebrum and cerebellum—probably crossed sensory tract.
	5. Prepyramidal tract	to lateral pyramid.
	6. Antero-lateral descending tract (Löwenthal)	from nucleus of the vestibular division of the auditory nerve, through the cerebellum.
	7. Fasciculus proprius lateralis	to formatio reticularis.
Posterior column.	1. Fasciculus gracilis (Goll)	to fasciculus gracilis and its nucleus.
	2. Fasciculus cuneatus (Bürdach)	to fasciculus cuneatus and to its nucleus.
	3. Lissauer's tract	to the grey matter of the posterior horn.
	4. Fasciculus proprius posterior	to formatio reticularis.

3. 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 the accompanying figures—plate XII. page 78—will no doubt give you material assistance.

The grey matter of the medulla oblongata may be described under two heads—(1) that represented in the spinal cord, and derived from or replacing 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 replacing the Grey Crescents.**— Transverse sections of the lower part of the medulla will show you that its grey matter has an arrangement very similar to that of the grey matter of the spinal cord; but that higher up in the medulla the appearance of the grey crescents becomes much changed (compare fig. 47, plate XII. page 78, with figs. 8, etc., plate III. page 14).

(*a*) The *anterior cornu* of the spinal cord, as we trace it upwards, loses its characteristic shape, for, owing to the fact that the fibres of the crossed pyramidal tract, in their course from the medulla to the lateral column of the cord, cut their way through the neck of the anterior horn, the head becomes severed from the base. The *head* of the horn, thus detached, enlarges, and is pushed, by the interposition of the anterior pyramids between it and the anterior median fissure, 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. 48, page 78).

Again, when the central canal of the spinal 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 (figs. 47, 48, and 49, page 78). It is now 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 anterior surface of the medulla (fig. 49, page 78). Close to this nucleus is another small collection of nerve cells—the nucleus of the fasciculus teres (fig. 49, page 78).

The greater part of the anterior horn—the *neck*—is replaced 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* (figs. 48 and 49, page 78).

(*b*) The grey matter of the *posterior horn*, on reaching the medulla, also takes up a lateral position and increases in amount. The *head* of the horn, severed from the base by the sensory decussation, as the head of the anterior horn was severed by the motor decussation, is now much enlarged, and comes nearer to the surface. At about the middle of the medulla it appears as a well-marked grey nucleus, the NUCLEUS

FIG. 47

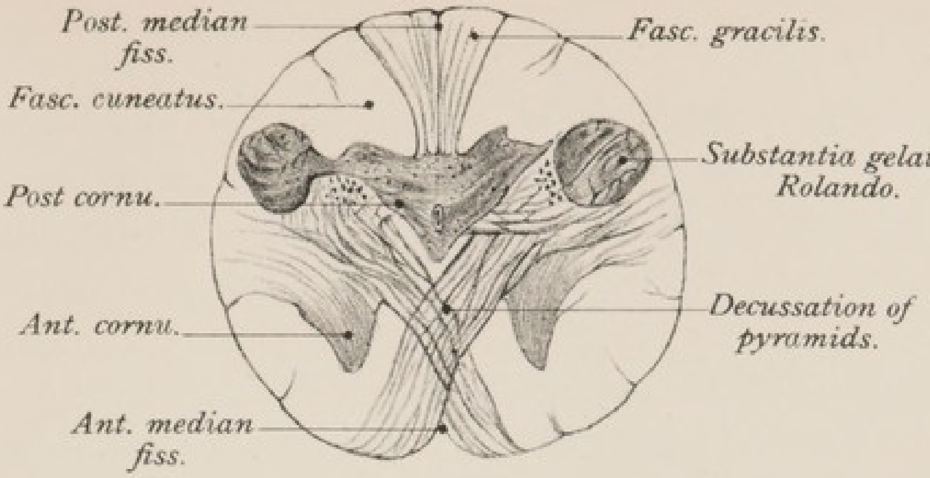


FIG. 48.

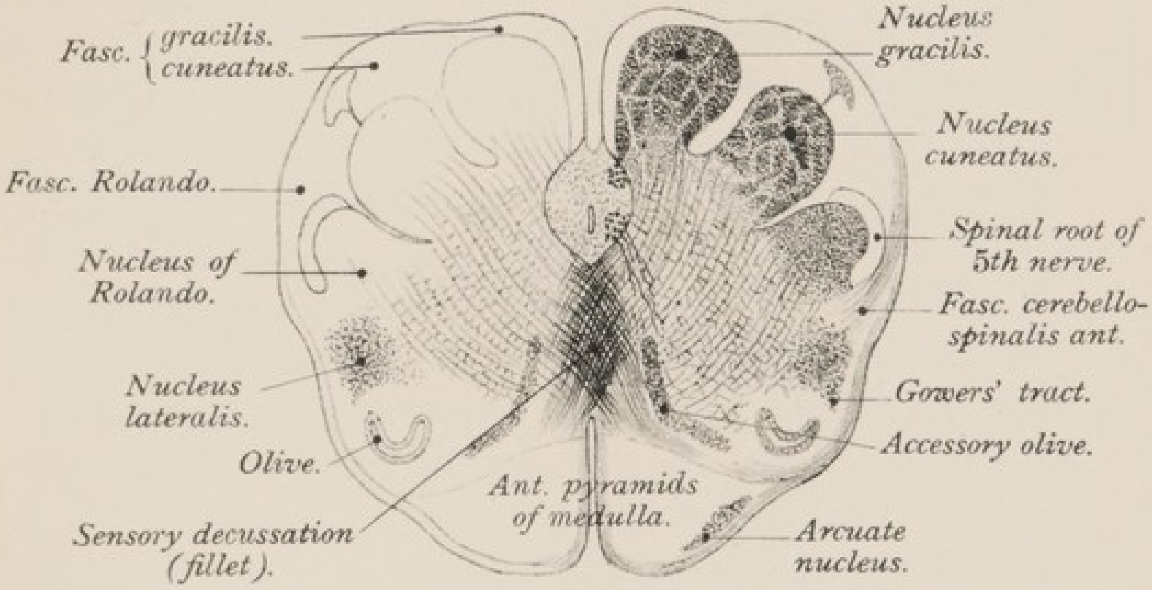
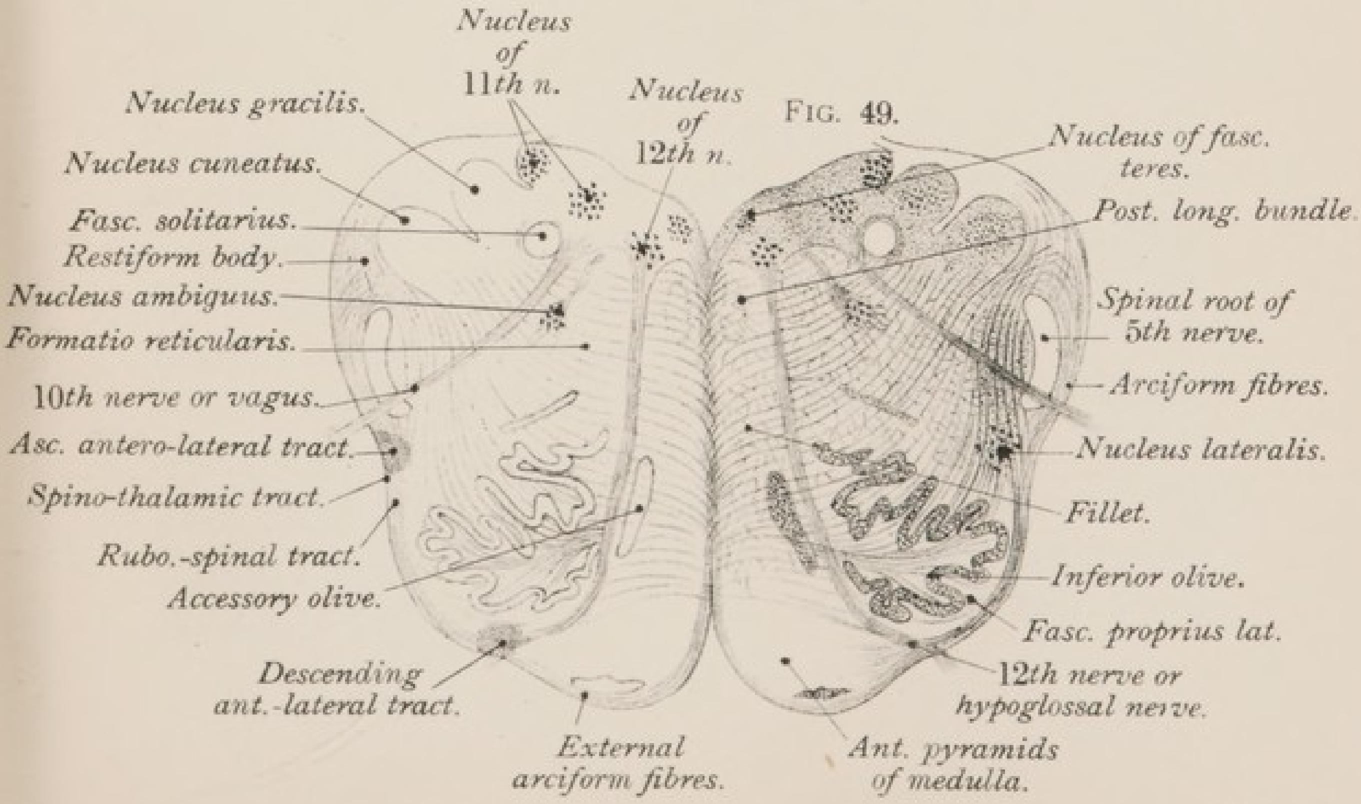


FIG. 49.



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of ROLANDO (fig. 48, page 78), beneath the surface prominence called the tubercle of Rolando. To its outer side will be seen a band of white fibres, the SPINAL ROOT of the FIFTH CRANIAL NERVE (fig. 48, page 78).

The grey matter of the *base* of this horn is also much increased in amount, and, between the median line and the grey nucleus of Rolando, is replaced by two superficial aggregations—the inner one, beneath the fasciculus gracilis, forming the NUCLEUS of the FASCICULUS GRACILIS; the outer, which is in part an outgrowth of the posterior horn, beneath the fasciculus cuneatus, forming the NUCLEUS CUNEATUS (fig. 48, page 78). Each nucleus thus lies beneath the corresponding white tract on the surface, and causes the elevations called the clava and the cuneate tubercle. To these nuclei, as we have seen, can be traced most of the fibres of the posterior column of the spinal cord. The nuclei themselves may be followed as far as the pons. From them start a secondary set of fibres (internal arciform fibres) which cross the middle line and go to form the sensory decussation or the decussation of the fillet.

The *neck* of the posterior cornu, like that of the anterior, is replaced by a network of fibres, the white reticulum, which becomes continuous with the grey reticulum, constituting together the FORMATIO RETICULARIS, a network of longitudinal, oblique, and transverse fibres (arciform fibres) with nerve cells and neuroglia cells embedded therein (figs. 47, 48, 49, page 78). The fibres of this reticulum are chiefly commissural in nature, though there are reasons for thinking that sensory impulses, and impulses which inhibit spinal reflexes, travel through this reticulum to the cerebrum. Some of its longitudinal fibres are derived from the mixed zones—fasciculi proprii—of the anterior and lateral columns of the spinal cord.

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

1. The corpus dentatum or olivary nucleus.
2. The accessory olives.
3. The arciform nucleus.
4. Nuclei of cranial nerves.

(*a*) The CORPUS DENTATUM or olivary nucleus is contained in the centre of the olivary body, which must be cut into in order to see it. It is covered superficially by the external arciform fibres (fig. 46, page 66). 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 on its inner aspect (fig. 49, page 78). Through this opening, called the hilum, enters the olivary peduncle, a bundle of nerve fibres, which passes into the centre of the olivary nucleus, to be there distributed in different directions.

The corpus dentatum or olivary ganglion is closely connected with a grey mass in the cerebellum—the corpus dentatum of the cerebellum—for any injury to this latter nucleus causes atrophy of the opposite olivary ganglion (fig. 79, No. 6, page 168).

(*b*) Two other isolated nuclei—the ACCESSORY OLIVES (fig. 49, page 78)—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. 48, page 78)—is placed amongst these fibres as they cross over the anterior pyramids of the medulla. It is continuous above with the nucleus pontis.

(*d*) NUCLEI OF CRANIAL NERVES.—The remainder of the grey matter of the medulla consists of the nuclei of the several cranial nerves. It will be studied in relation to the floor of the 4th ventricle (page 108).

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 hypoglossal 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.	
		Nuclei of cranial nerves.	

Raphé.—A transverse section of the medulla will show you that, 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 septum 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.

Sensory Decussation.—The SUPERIOR PYRAMIDAL DECUSSATION, which has so often been referred to (page 71), must not be confused with the inferior or motor decussation (page 68). You will remember that fibres could be traced from the posterior spinal nerve roots through the posterior columns of the spinal cord to their primary stations, the nuclei gracilis and cuneatus of the medulla. From the cells of these nuclei new fibres take their origin and travel towards the anterior aspect of the medulla until they come to lie in front of the central canal, thus pushing that canal towards the dorsal aspect of the medulla. Decussating in the raphé, above and behind the pyramidal decussation, the sensory fibres now cross to the opposite side of the bulb, and becoming longitudinal, form a considerable bundle of fibres just behind the pyramids (motor fibres). They finally ascend to the cerebrum in what is known as the tract of the fillet or lemniscus. They are therefore crossed sensory tracts to the cerebrum.

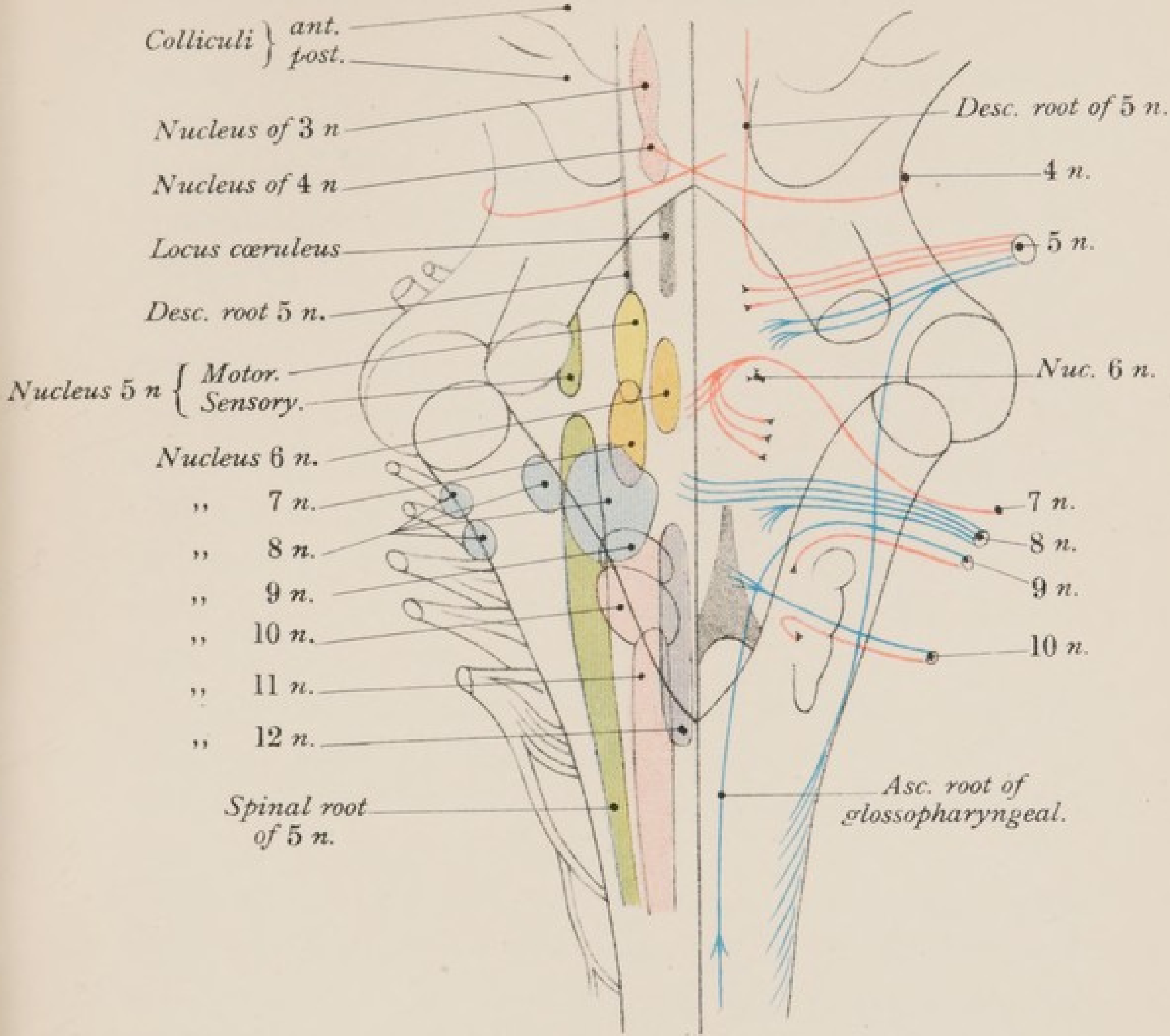
Thus we see that we have in the medulla two important sets of decussating fibres—the *inferior pyramidal* or *motor* decussation ; and, behind and above this, the *superior pyramidal* or *sensory* decussation.

The Arciform Fibres have already been several times alluded to, so that we shall now 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—

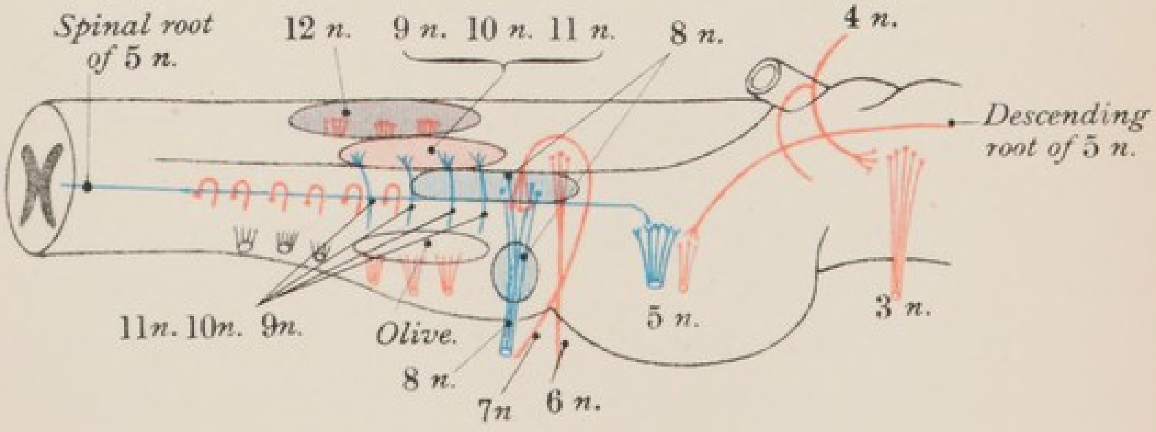
(*a*) The *anterior external arciform fibres,* which

FIG. 50.



Nuclei of Floor of 4th Ventricle.

FIG. 51.



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spring from the cells of the nuclei gracilis and cuneatus of the posterior area of the medulla. From these nuclei the fibres sweep forward towards the ventral aspect of the medulla and cross, in the mesial raphé, to the opposite side. Emerging from the anterior median fissure, they now, as we know, wind round the anterior pyramids, below and over the outer surface of the olives, across the line of origin of the 9th, 10th, and 11th nerves. Turning upwards, they then blend with the fibres of the dorso-spino-cerebellar (lateral cerebellar) tract, and with them form the chief part of the restiform body (fig. 79, No. 5, page 168).

(*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. 79, No. 4, page 168).

2. The DEEP ARCIFORM FIBRES are a delicate network of fibres found between the olives and behind the pyramids. Their exact course and origin are not yet known with certainty. Many of them are derived from the nuclei of the posterior columns before mentioned (superior pyramidal decussation). Others enter the centre of the olivary nucleus through its hilum; others join the cells of that nucleus, or pass through the nucleus to the restiform body directly, or first make for the surface, and then, along with the external arciform fibres, go to the restiform body; others are connected with the nuclei of the sensory cranial nerves, and others with the cells of the formatio reticularis.

Recapitulation.—Since the constitution of the medulla is so complicated, it will be well to summarise the above facts in a somewhat different order. If you will examine a section of the medulla such as that shown in fig. 49, plate XII. page 78, you will find that the strands of fibres which constitute the 9th, 10th, 11th, and 12th cranial nerves, as they traverse the medulla from their deep to their superficial origins, divide the medulla into three triangular areas—(1) one between the anterior mesial fissure and the fasciculi of the 12th nerve; (2) one between the fasciculi of the 12th nerve and those of the 9th, 10th, and 11th nerves; and (3) one between the fasciculi of the last-named nerves and the posterior mesial fissure. Commencing, then, at the anterior median fissure, we meet on each side of that fissure the—

1. **Anterior Area.**—In this area are (*a*) the ANTERIOR PYRAMIDS of the medulla (fig. 49, page 78), composed of longitudinal fibres, derived chiefly from the crossed pyramidal tracts of the opposite lateral columns, and to a small extent from the direct and uncrossed pyramidal tracts of the same side. Most of the motor fibres coming from the brain are contained in these pyramids, though others, as we shall afterwards see, first go to the pons, thence to the cerebellum, thence to spinal cord (secondary motor tract).

(*b*) Crossing the anterior pyramids transversely are a set of fibres, which, having their origin in the nucleus gracilis and nucleus cuneatus of the one side of the medulla, and having decussated in the middle line, emerge from the anterior median fissure, cross over the surface of the anterior pyramids and the olives of the opposite side to that from which they started, and go to join the restiform body. They are the SUPERFICIAL ARCIFORM FIBRES (figs. 48 and 49, page 78), and amongst them is a mass of grey matter, the NUCLEUS ARCUATUS (fig. 48, page 78).

(*c*) In the middle line behind the pyramids, between them and the central canal, are thick white bundles of fibres arranged in concentric curves. They spring from the region of the posterior columns, from the nuclei gracilis and cuneatus. They form the SUPERIOR PYRAMIDAL DECUSSATION, or decussation of the fillet (fig. 48, page 78). 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. Within this network are three longitudinal strands, the FILLET and the ANTERIOR and POSTERIOR LONGITUDINAL BUNDLES (figs. 48, 49).

2. **Lateral Area.**—Outside the formatio reticularis, between it and the surface, but behind the pyramids, is the (*a*) OLIVARY NUCLEUS (fig. 49, page 78) with the OLIVARY PEDUNCLES. This nucleus is covered superficially by the external arciform fibres. (*b*) Close to it are the ACCESSORY OLIVES (fig. 49, page 78). (*c*) Behind the olives you will see the NUCLEUS LATERALIS (fig. 48, page 78), the upward continuation of the anterior cornu of the spinal cord. (*d*) Ventral to the olive is the DESCENDING ANTERO-LATERAL or Löwenthal's tract, and behind the olive are (*e*) the ASCENDING ANTERO-LATERAL and (*f*) the PREPYRAMIDAL TRACTS (fig. 48, page 78).

3. **Posterior Area.**—Posterior to the nucleus lateralis appears (*a*) the grey TUBERCLE of ROLANDO (fig. 48, page 78), the enlarged head of the posterior horn of the spinal cord. On its outer side will be

seen the SPINAL ROOT of the 5TH NERVE (fig. 48, page 78). (*b*) Superficial to the tubercle of Rolando are the fibres of the DORSO-SPINO-CEREBELLAR TRACT, which are on their way, along with the arciform fibres, to the inferior cerebellar peduncles or restiform body. (*c*) Posterior and internal to the nucleus of Rolando is a mass of grey matter—the NUCLEUS CUNEATUS (fig. 48, page 78)—lying beneath the cuneate tubercle; and still nearer the middle line is another grey collection, (*d*) the NUCLEUS of the FASCICULUS GRACILIS (fig. 48, page 78).

In front of the nucleus cuneatus will be seen a special white rounded fasciculus, known as (*e*) the FASCICULUS SOLITARIUS (fig. 49, page 78), in part the descending root of the glosso-pharyngeal nerve.

Close to the middle line, internal to the nucleus cuneatus, lies (*f*) 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 fasciculus gracilis, and on each side of the posterior median groove, belongs to the floor of the 4th ventricle (fig. 50, page 82), and will be fully described with that cavity.

The next division of the brain to be considered is the metencephalon, comprising the pons and cerebellum.

II. PONS VAROLII.

(Figs. 43 and 46, Plate XI. Page 66.)

GENERAL OUTLINE.—**The Pons Varolii**—part of the metencephalon, the other part being the cerebellum

—is a broad white band which crosses transversely between the two halves of the cerebellum above the level of the anterior aspect of the medulla oblongata (fig. 43, page 66). In front it rests on the slope (clivus) formed by the basi-occipital and basi-sphenoid; behind it is hidden by the cerebellum. Composed of grey and white matter, it presents an upper and a lower border—an anterior and a posterior surface, and two lateral prolongations—the brachia pontis or middle peduncles of the cerebellum (figs. 43 and 46, page 66).

The UPPER BORDER is arched, being higher in the middle than at the sides. From it spring the cerebral peduncles. Two cranial nerves, the 3rd and 4th, are seen at this border, the former being nearer the middle line.

The LOWER BORDER, which, in front, marks the upper limit of the medulla, is horizontal, and is almost in contact with the upper margin of the pyramids and the olives (fig. 43, page 66). At this border are seen, from within out, the 6th, 7th, and 8th cranial nerves (fig. 43, page 66).

The ANTERIOR SURFACE of the pons is striated transversely, and is convex both from above downwards and from side to side. Along the middle line it presents a shallow vertical groove—the basilar groove—which lodges the basilar artery. On each side of this groove is a longitudinal elevation caused by the continuation upwards of the pyramids of the medulla.

The LATERAL ASPECT.—At the sides the pons becomes narrowed, and passes as two rounded bundles, one on each side, into the cerebellum, forming the *brachia pontis*. From the lateral parts of this aspect of the pons spring the 5th cranial nerves, and vertical lines through the points of attachment of these nerves are taken as the line of demarcation between the pons and its continuation the brachia pontis.

The POSTERIOR SURFACE of the pons has ill-defined limits, being continuous below with the medulla, above with the cerebral peduncles. Flattened from before backwards, it forms the upper part of the floor of the 4th ventricle, and will be described with that cavity (page 107).

The UPPER and LOWER SURFACES.—Transverse sections at the level of the upper and lower borders will show you the upper and lower surfaces of the pons continuous, in the one case, with the cerebral peduncles, in the other with the medulla oblongata.

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

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 hemisphere, the pons also is wanting.

CONSTITUTION OF THE PONS.—We shall consider the constitution of the pons according to the following table:—

Table of the Constitution of the Pons Varolii.

I. *White Matter of the Pons.*

1. Transverse fibres.
    - (1) Superficial.
    - (2) Deep—corpus trapezoideum.
2. Longitudinal fibres.
    - (1) Superficial.
        - (*a*) Pyramidal tracts .
            - Direct.
            - Crossed.
            - Uncrossed.
        - (*b*) Cortico-pontine .
            - Fronto-pontine.
            - Temporo- and occipito-pontine.
        - (*c*) Caudate cerebellar or intermediate bundle.
    - (2) Deep.
        - (*a*) Lemniscus or fillet
            - (1) Mesial or main fillet. Superior fillet.
            - (2) Lateral fillet.
        - (*b*) Longitudinal bundles
            - Posterior or mesial.
            - Anterior or tecto-spinal.
        - (*c*) Fasciculus teres.
        - (*d*) Antero-lateral ascending (Gowers) (ventro-spino cerebellar and spino-thalamic).
        - (*e*) Rubo-spinal or prepyramidal.
        - (*f*) Olivary fasciculus.
    - (3) Fibres of the 5th nerve with its descending root and fibres of the 6th, 7th, and part of the 8th cranial nerves.
    - (4) Formatio reticularis.
    - (5) Raphé.

II. *Grey Matter of the Pons.*

1. Nucleus pontis.
2. Superior olive.
3. Substantia gelatinosa of Rolando.
4. Nuclei of origin of 5th, 6th, 7th, and 8th nerves.
5. Locus cæruleus.

1. WHITE MATTER OF THE PONS.

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

The white or 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. **Transverse Fibres.**—(1) The SUPERFICIAL TRANSVERSE fibres appear on the ventral surface of the pons, and (2) the DEEP TRANSVERSE fibres lie behind the superficial longitudinal ones (figs. 52, 53, page 90). At the lower part of the pons, near the medulla, the deep set of transverse fibres forms a special collection, called, from its peculiar arrangement, the *trapezium* (fig. 52, page 90), which, as we shall afterwards see, is closely associated with the auditory nerve. Traced laterally, all the transverse fibres of the pons pass into the brachia pontis or middle peduncle of the cerebellum. They are connected either with the nucleus pontis of the same side or of the opposite side.

2. **Longitudinal Fibres.**—(1) The SUPERFICIAL LONGITUDINAL fibres (fig. 53, page 90) are mostly the upward continuation of (*a*) the *anterior pyramids* of the medulla. In transverse sections they appear as oval or rounded bundles behind the superficial transverse fibres, though many of them are intersected by these latter (fig. 53, page 90). Behind the pyramids are two scattered fasciculi—(*b*) the *cortico-*

FIG. 52.

Transverse Section through the middle of the Pons Varolii.

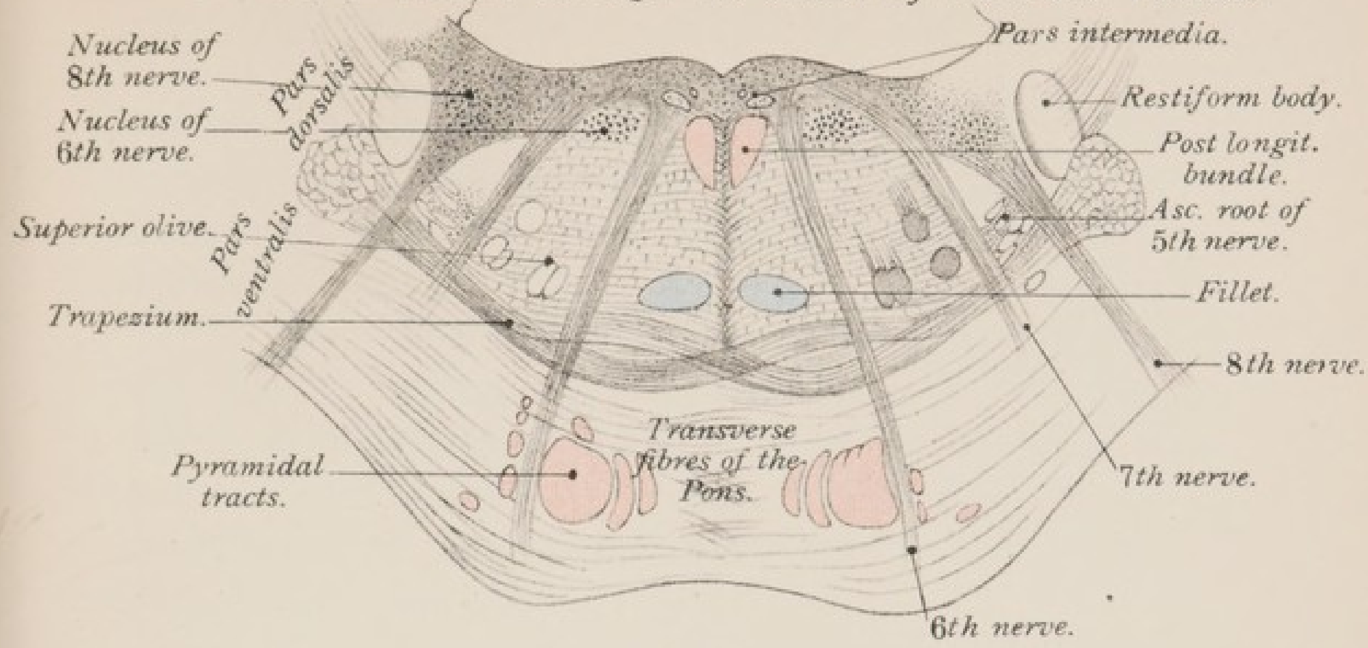


FIG. 53.

Transverse Section of upper part of Pons.

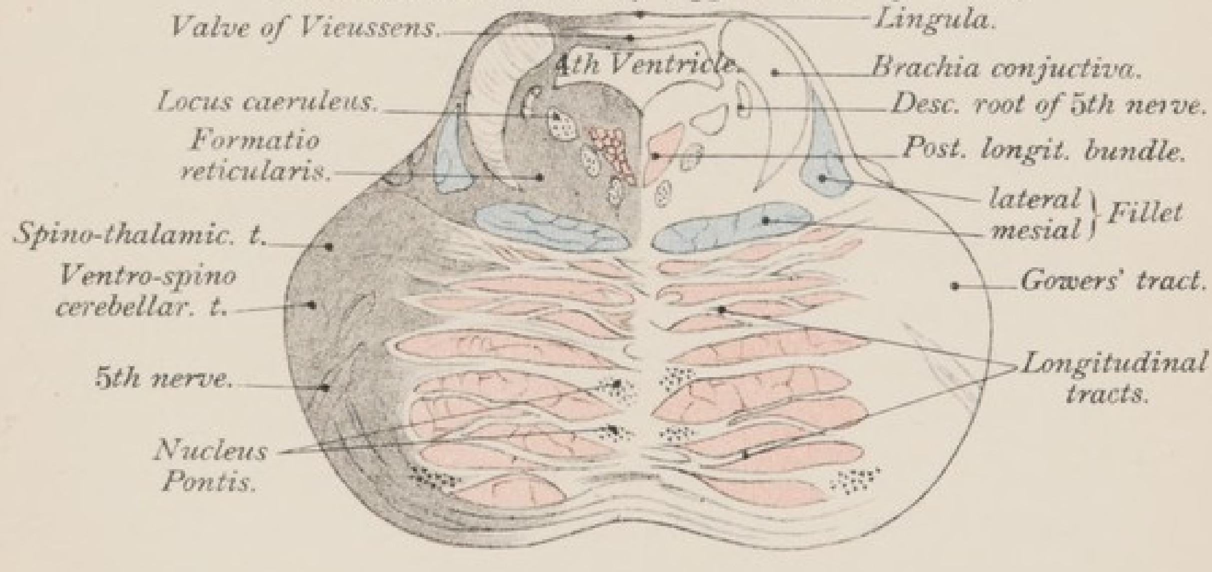
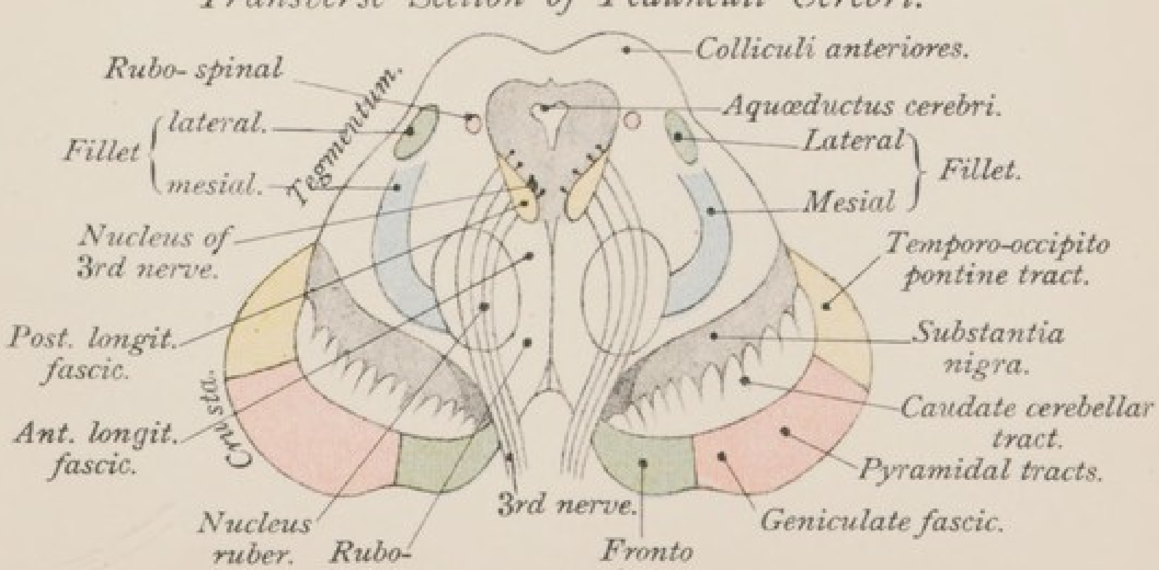


FIG. 54.

Transverse Section of Pedunculi Cerebri.



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pontine, and (*c*) the *caudate cerebellar*, both of which connect the cerebrum with the nucleus pontis and thence, through the brachia pontis, with the cerebellum.

(2) The DEEP LONGITUDINAL fibres (fig. 53, page 90) 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. The following distinct sets of longitudinal fibres should be noted.

(*a*) *Lemniscus* or *Fillet*.—(1) The main fillet forms a distinct white strand, near the mid-line in the ventral part of the formatio reticularis, just behind the pyramids (fig. 53, page 90). It is the continuation of the sensory decussation from the nuclei gracilis and cuneatus of the medulla. In the mid-brain it gives off the *superior fillet*.

(2) The *lateral fillet* lies to the outer side of the main fillet (fig. 53, page 90). It is the continuation of the fibres of the trapezium of the pons and of the striæ medullares (acusticæ) of the 4th ventricle. It is, therefore, part of the central auditory tract.

(*b*) The *longitudinal bundles*—anterior and posterior—already seen in the anterior column of the spinal cord and the dorsal aspect of the medulla, lie close to each other in the dorsal aspect of the pons near the mesial plane (fig. 52, page 90). The former, also called *tecto-spinal* or ventral longitudinal bundle, is connected with ocular and pupillar reflexes; the latter—the posterior longitudinal bundle—is by means of collaterals connected with the nuclei of the several motor cranial nerves.

(*c*) The *fasciculus teres* is the bundle of fibres seen near the middle line of the floor of the 4th ventricle. It contains fibres of the facial or 7th cranial nerve.

(*d*) The *ascending antero-lateral tract* (Gowers)—consisting of ventro-spino-cerebellar and spino-thalamic—is found in the lateral part of the formatio reticularis of the pons (fig. 53, page 90). It is the path through which sensations of touch, of temperature, and of pain reach the cerebrum; the spino-thalamic being a direct route, the ventro-spino-cerebellar an indirect one, through the cerebellum.

(*e*) The *rubo-spinal or prepyramidal tract* is a crossed descending tract from the red nucleus in the pedunculi cerebri. It lies behind the trapezium close to the lateral fillet with which its fibres are intermingled. Its use is unknown.

(*f*) The *olivary fasciculus* is found in the formatio reticularis dorsal to the mesial fillet. It ends in the inferior olive.

3. Transverse sections of the pons (figs. 52 and 53, page 90) will further show you the following additional fibres: the 5th nerve with its descending root; fibres of the 6th nerve, of the 7th or facial nerve, and of the pars intermedia of the facial; and, finally, fibres of the 8th nerve (see deep origin of cranial nerves, page 176).

4. **The formatio reticularis** is a network of fibres which occupies the tegmental part of the pons and is continuous with the formatio reticularis of the medulla.

5. **The raphé** is a mesial septum which lies behind the trapezium, beneath the median groove on the floor of the 4th ventricle. It is a continuation

of the raphé of the medulla, and, like it, is composed of fibres, partly nervous and partly neuroglia, which cross each other in every direction (fig. 52, page 90).

2. GREY MATTER OF THE PONS.

DISSECTION.—To see the grey matter of the pons you will require a series of transverse sections similar to those represented in plate XIV. figs. 52 and 53, page 90.

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

1. **The nucleus pontis,** situated on the ventral aspect of the pons, near the mesial raphé amongst the superficial transverse fibres. It consists of many scattered nerve cells, to which can be traced fibres from the cerebrum (cortico-pontine fibres); and fibres from the cerebellum (ponto-cerebellar fibres).

2. **The superior olivary nucleus** (fig. 52, page 90) is placed on the dorsal part of the pons, behind the trapezium, at some little distance from the middle line, in a region which would correspond to the prolongation of the lateral area of the medulla.

3. **Substantia gelatinosa Rolando** (fig. 52) is continuous with that of spinal cord and medulla.

4. **The nuclei** of origin of the 5th, 6th, 7th, and 8th cranial nerves (see 4th ventricle).

5. **The locus cæruleus**—a bluish spot, which will be described with the upper part of the floor of the 4th ventricle (page 110).

The arterial supply of the pons is derived from the basilar artery through the ponticular, posterior cerebral, and superior cerebellar branches.

III. CEREBELLUM.

(Plates XV. and XVI. Pages 94 and 104.)

The **Cerebellum,** or **Little Brain,** the second division of the metencephalon, is placed behind the pons and medulla, and, like the rest of the brain, is composed of grey and white matter. It occupies the two lower fossæ of the occipital bone, lying beneath the level of the tentorium cerebelli, which separates it from the posterior part of the cerebral hemispheres. Shaped like an oyster-shell, it is ellipsoidal in outline, with its long diameter transverse. It consists of a median division, called, from its worm-like appearance, the VERMIFORM PROCESS, of two lateral divisions, the CEREBELLAR HEMISPHERES, and of the three PEDUNCLES —superior, middle, and inferior—by means of which it is brought into relation with the cerebrum, with the pons, and with the medulla. The median division, the *vermis cerebelli* or vermiform process, though incorporated with the rest of the cerebellum, is considered as a separate division of the little brain. 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 lobes.

We shall consider the several parts of the cerebellum in the following order—(1) the hemispheres with (2) their lobes and gyri; (3) the peduncles; (4) the medullary vela; (5) the grey matter; and (6) the white matter.

Cerebellum.

FIG. 55. *Upper surface.*

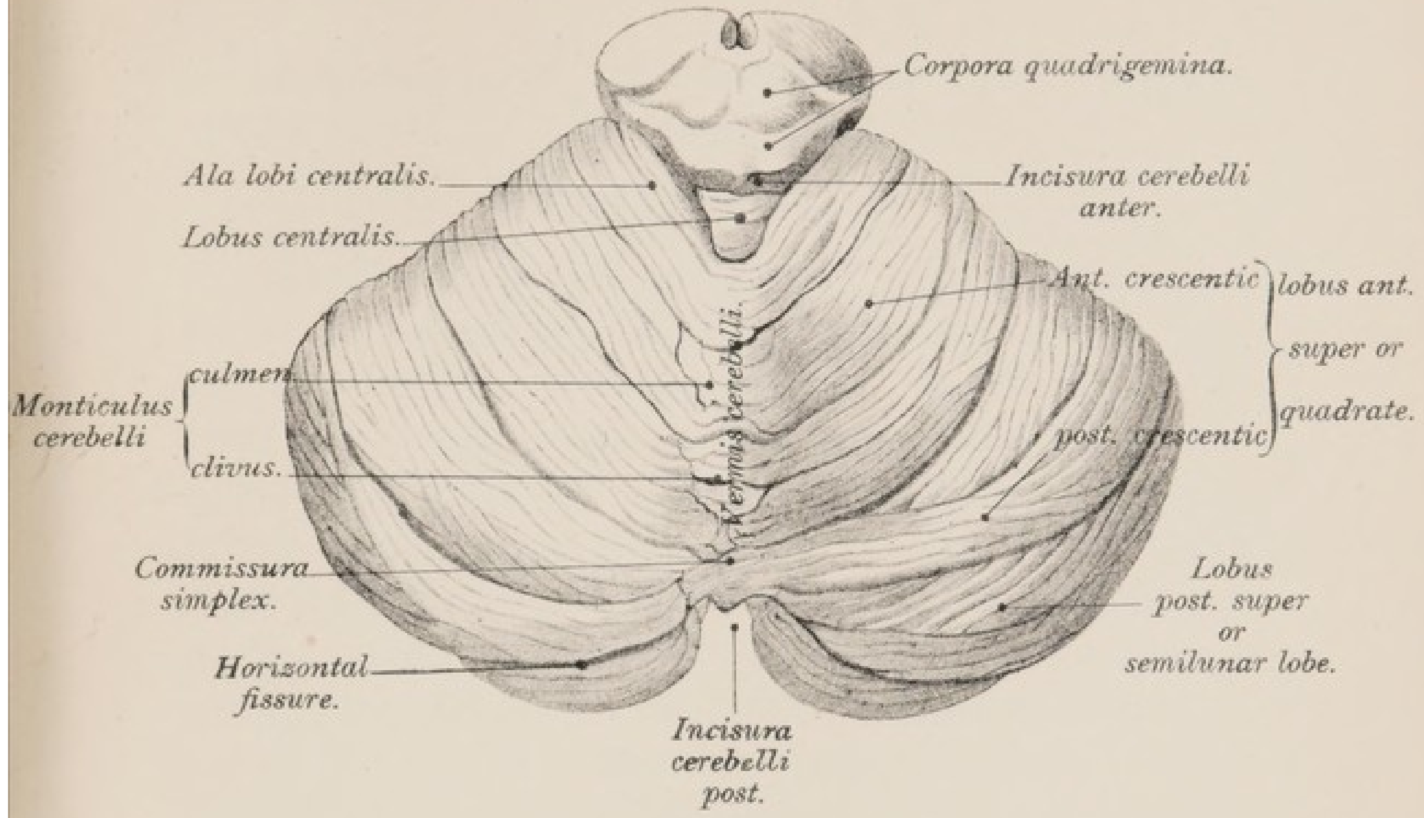
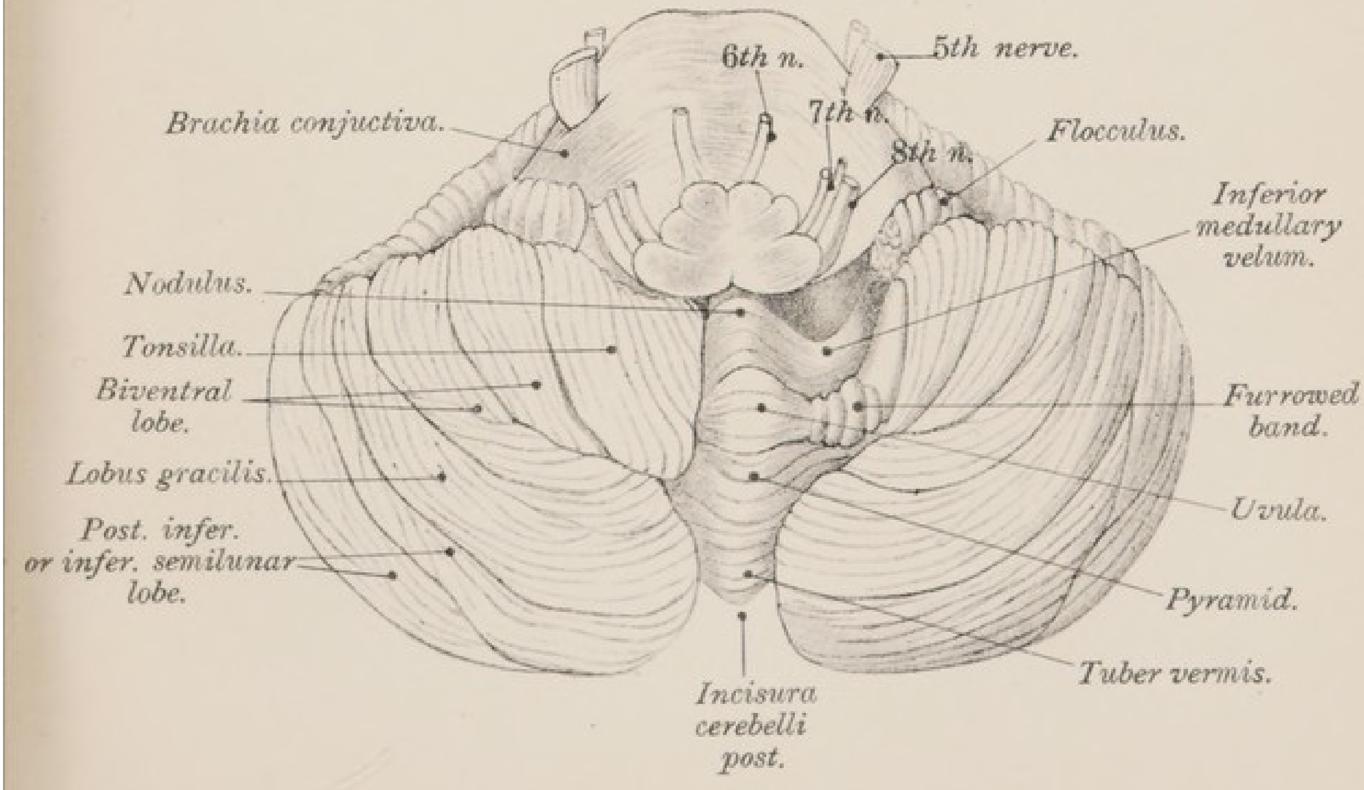


FIG. 56. *Under surface.*



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1. CEREBELLAR HEMISPHERES AND VERMIS CEREBELLI.

(Figs. 55, 56, Plate XV. Page 94.)

The Cerebellar Hemispheres present three surfaces—an anterior, a superior, and an inferior—the last two being separated from each other by a definite margin, in which runs a well-marked cleft, the GREAT HORIZONTAL FISSURE. The hemispheres are darker in colour than those of the cerebrum. They consist of a central white core, of a little central grey matter, and, on the surface, of numerous crescentic grey laminæ—cortex cerebelli—with their convexities backwards.

1. The UPPER SURFACES of the cerebellar hemisphere are concave, and are separated from each other, along the middle line, by a slightly raised longitudinal ridge, with a shallow groove on each side. This raised portion is the upper aspect of the VERMIS CEREBELLI, or *superior vermiform process* (fig. 55, page 94), and across it the two cerebellar hemispheres are continuous with each other, there being no definite line of demarcation between them (fig. 55, page 94).

2. The UNDER SURFACE of each hemisphere (fig. 56, page 94) is, on the other hand, convex, and is divided from its fellow by a wide, median, longitudinal hollow, the VALLECULA, in which you see the definite mesial division of the cerebellum—the VERMIS CEREBELLI, or *inferior vermiform process.* Posteriorly, the hemispheres are separated by a mesial notch—INCISURA CEREBELLI POSTERIOR—which receives the free anterior margin of the falx cerebelli.

3. The ANTERIOR SURFACE of the cerebellum presents in the middle line a wide notch—the INCISURA

CEREBELLI ANTERIOR—which lodges the pons Varolii and medulla, and in which, when these structures are removed, we see from above downwards—

In the middle line.

(*a*) The anterior end of the vermis cerebelli.

(*b*) The valve of Vieussens, or superior medullary velum.

(*c*) The cavity of the 4th ventricle.

At the sides are the cerebellar hemispheres, with—

(*a*) The three peduncles—superior, middle, and inferior.

(*b*) Outside the middle peduncle is the longitudinal sulcus which separates the upper from the lower surface. In this sulcus, near the middle peduncle, is lodged the flocculus, the inner end of which is continuous with the inferior medullary velum, a thin white lamina, which extends to the anterior end of the vermis cerebelli (fig. 56, page 94).

2. 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 thus formed are often exceedingly ill-defined, and, in the present state of our knowledge, are of little or no practical importance. A tabular list of them is given for the purpose of reference.

(1) On the *upper surface* of the cerebellar hemispheres the lobes, enumerated from before backwards, are as follow (fig. 55, page 94):—

(*a*) The ALÆ LOBULI CENTRALIS (fig. 55, page 94), situated near the centre of the anterior margin, and consisting of a few folia, which, in the middle line, are continuous with the central lobe of the vermis cerebelli (fig. 55, page 94).

(*b*) The ANTERIOR SUPERIOR and (*c*) the POSTERIOR SUPERIOR LOBES (fig. 55, page 94). These lobes are separated from each other by a more or less distinct sulcus, which arches transversely across the surface of each hemisphere. The anterior superior lobe, often called the QUADRATE LOBE, is divided into an anterior portion, named the *anterior crescentic*—lobus culminis or lobus lunatus anterior; and a posterior portion, the *posterior crescentic*—lobus clivi or lobus lunatus posterior (fig. 55, page 94). The posterior superior lobe is also called the superior semilunar lobe. Each of the lobes on the upper surface is continuous across the *vermis cerebelli* with the corresponding one on the opposite side.

(2) On the *under surface* of the hemispheres the lobes are better marked, and are more easily distinguished from each other than on the upper surface (fig. 56, page 94). Enumerated from behind forwards we find—

(*a*) A few folia, the POSTERIOR INFERIOR LOBE; or *inferior semilunar lobe*;

(*b*) The SLENDER LOBE—*lobus gracilis*;

(*c*) The BIVENTRAL LOBE;

(*d*) An oval mass, the AMYGDALOID LOBE or *tonsilla*; and, finally, (*e*) A fringe-like lobe, the FLOCCULUS (fig. 56, page 94).

(3) On the *upper aspect* of the *vermis cerebelli* (fig. 55, page 94) are—

(*a*) The LINGULA CEREBELLI, which blends with the superior medullary velum (fig. 45, page 66);

(*b*) The LOBULUS CENTRALIS;

(*c*) The MONTICULUS CEREBELLI, subdivided into *culmen monticuli*, continuous with the *lobus culminis*, and the *clivus monticuli*, continuous with the *lobus clivi*;

(*d*) The COMMISSURA SIMPLEX, or *folia cacuminis*.

(4) On the *under aspect* of the *vermis cerebelli* the lobes are—

(*a*) The TUBER VERMIS or VALVULÆ (fig. 56, page 94), placed between the posterior inferior and the slender lobes of opposite sides;

(*b*) The PYRAMID (fig. 56, page 94), between the biventral lobes;

(*c*) The UVULA (fig. 56, page 94), between the amygdaloid lobes, and connected with them by a grey band, called, from its ridged appearance, the *furrowed band* (fig. 56, page 94);

(*d*) The NODULE (fig. 56, page 94), or *laminated tubercle*, the pointed anterior end of the inferior vermiform process. It is placed between the flocculi, projects into the roof of the 4th ventricle, and is continuous with the inferior medullary velum (page 102).

3. PEDUNCLES OF THE CEREBELLUM.

The Peduncles of the Cerebellum are bilateral bands of white matter, three for each hemisphere — the superior, the middle, and the inferior. They severally connect the cerebellum to the pons — crura ad pontem; to the medulla — crura ad medullam; and to the cerebrum — crura ad cerebrum.

The Brachia Conjunctiva or SUPERIOR PEDUNCLES of the cerebellum are two white bands, right and left, hidden beneath the anterior part of the cerebellum. To see them you will require to divide the cerebellum by a vertical median incision and to draw the parts asunder (fig. 44, page 66). The *brachia conjunctiva*, or superior peduncles of the cerebellum, arise in the middle of the white substance of the hemispheres, behind the inferior cerebellar peduncles. Running upwards and forwards from the anterior aspect of the cerebellum, they reach the dorsal or tegmental part of the cerebral peduncles, and are there lost beneath the four rounded bodies called the corpora quadrigemina. At first the superior peduncles form the lateral walls of the upper part of the 4th ventricle, and leave between them a triangular interval, which is bridged over by a lamina of nerve substance — the VALVE of VIEUSSENS or *superior medullary velum* (fig. 45, page 66). As they ascend, the peduncles meet in the middle line, and form part of the roof of the 4th ventricle. At the sides the superior peduncles are separated from the middle peduncles by an oblique groove from which proceeds a delicate lamina—the band of Reil—or lemniscus lateralis, which will be again referred to under cranial nerves (see Auditory Nerve, page 186).

Constitution.—The fibres of which the brachia conjunctiva are composed come mostly from the corpus dentatum, a mass of grey matter in the interior of the cerebellum, but some also come from the cells of the cerebellar cortex. The majority decussate with the fibres of the peduncle of the opposite side, and then pass up as a distinct bundle, with those that do not decussate, and divide into ascending and descending branches. The former go to collections of nerve cells in the higher parts of the brain—to the red nucleus, to the optic thalamus, and to the cerebral cortex; the descending branches, on the other hand, pass down to the reticulum in the pons and medulla, and are there connected with the nuclei of the motor cranial nerves.

The Brachia Pontis or middle peduncles (figs. 43, 46, page 66; fig. 56, page 94) of the cerebellum—crura ad pontem—are best seen in front. They are merely the continuation into the cerebellum of the lateral part of the pons, that part which lies beyond the superficial origins of the fifth cranial nerves. Emerging from the lateral part of the white centre of the hemispheres, in front of the inferior peduncles, the middle peduncles pass towards the middle line, and, becoming incorporated with the pons, form its superficial and deep transverse fibres.

Constitution.—All the fibres of the brachia pontis become connected with the *nucleus pontis.* Most of them are connected with the nucleus pontis of the opposite side, a few only with that of the same side. Some of the fibres are commissural between the two halves of the cerebellum; others are the continuation of the cortico-pontine tracts.

The Restiform Body or INFERIOR PEDUNCLES (figs. 44, 45, page 66) of the cerebellum—crura ad medullam—constitute one of the lateral boundaries of the lower part of the 4th ventricle, and then ascend, between the superior and middle peduncles, into the white matter of the cerebellar hemispheres.

CONSTITUTION (fig. 45, page 66, and fig. 79, page 168).—The constitution of the restiform bodies is somewhat complex, for they consist (1) of a *spinal part,* composed of fibres from (*a*) the lateral column of the same side—dorso-spino-cerebellar or lateral cerebellar tract already described, as connecting the posterior spinal nerve roots, through the cells of Clark's column, with the superior vermis cerebelli of the same and opposite sides; (*b*) from the nuclei of the posterior column of the same side (arciform fibres) (fig. 79, page 168); and (*c*) from the nuclei of the posterior column of the opposite side (arciform fibres) (fig. 79, page 168). (2) Of an *olivary part*, composed of fibres from the opposite olives (fig. 79, page 168). (3) Of fibres uniting the roof nuclei of the cerebellum with the nuclei of origin of the motor cranial nerves. (4) Of fibres from the vestibular nucleus of the 8th nerve, and from the sensory nuclei of other cranial nerves. Most of the fibres of the restiform body end in the cells of the cortex of the superior vermis of the opposite side, but they give collaterals to the vermis of the same side.

4. MEDULLARY VELA.

1. **The Superior Medullary Velum**—VALVE of VIEUSSENS (fig. 45, page 66)—is a delicate sheet of nerve substance placed across the triangular interval left between the two superior cerebellar peduncles before they meet in the middle line. Triangular in shape, with its apex forwards, it forms part of the roof of the upper division of the 4th ventricle, and consists of a white lamina crossed on its upper surface by several transverse grey ridges, with intervening furrows, called the LINGULA CEREBELLI (fig. 45, page 66). The white and grey matter of the valve of Vieussens (superior medullary velum) are continuous at the sides with the white and grey matter of the cerebellar hemispheres.

2. **The Inferior Medullary Vela** — valves of Tarini—consist of two thin delicate semilunar sheets or laminæ of nerve substance like little swallows' nests, one on each side, hidden beneath the amygdaloid lobes of the cerebellum, which must be removed with great care to see them. By their inferior convex borders, each of these semilunar folds blends with the white substance of the inferior vermiform process and with the furrowed band; their anterior concave semilunar edges are free, or rather, are continuous with the layer of epithelium which lines the under surface of the pia mater roofing over the 4th ventricle. Externally these two semilunar folds are attached by a white band or peduncle to the flocculus; internally, a central part, very thin, continues the lateral portions across the middle line in front of the nodule (fig. 56, page 94).

5. 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 *nuclei cerebelli*.

1. CORTEX CEREBELLI.—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 or cloth 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. 58, page 104).

2. NUCLEI CEREBELLI.—The chief masses of grey matter in the interior of the cerebellar hemispheres are the CORPORA DENTATA, placed one in each hemisphere (fig. 58, page 104). 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. 58, page 104). Through this opening bundles of white nerve fibres enter the centre of the corpus dentatum. They can be traced from the brachia conjunctiva, from the superior medullary velum, and from the restiform body.

The other nuclei found in the white centre of the cerebellum are the nucleus globosus, the nucleus emboliformis, and the nucleus tecti or fastigii. They are situated near the middle line, internal to the corpus dentatum.

Minute Structure of the Grey Matter.

The grey cortex of the cerebellum consists of three layers (fig. 57, plate XVI. page 104)—

(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, of fine nerve fibres, and of nerve cells and their processes. The nerve cells are of two kinds (fig. 57, page 104).

(1) *Small molecular cells,* mostly situated in the outer part of the layer, are multipolar cells with many protoplasmic processes, and an axis-cylinder process which ramifies in this layer.

(2) *Large molecular 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 which, at right angles to its direction, gives off branches whose terminal twigs envelop the bodies of the cells of Purkinjé, seen in the next layer, in a basket-like network; hence they are called *basket cells* (fig. 57, page 104).

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. 57, page 104), or from their shape ANTLER CELLS. They are large flask-shaped cells, set at right angles to the

FIG. 57.

Cerebellum—Structure.

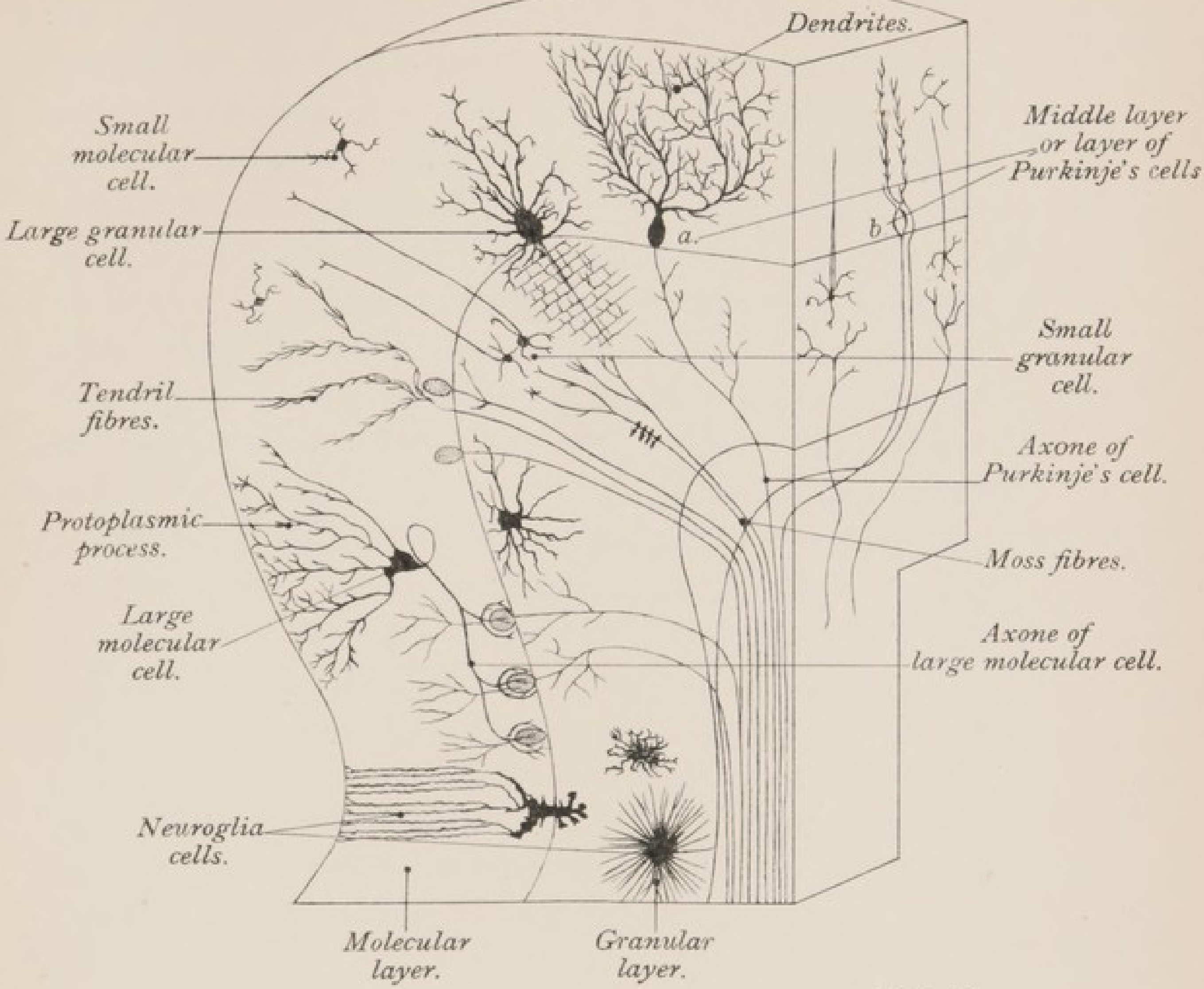


FIG. 58.

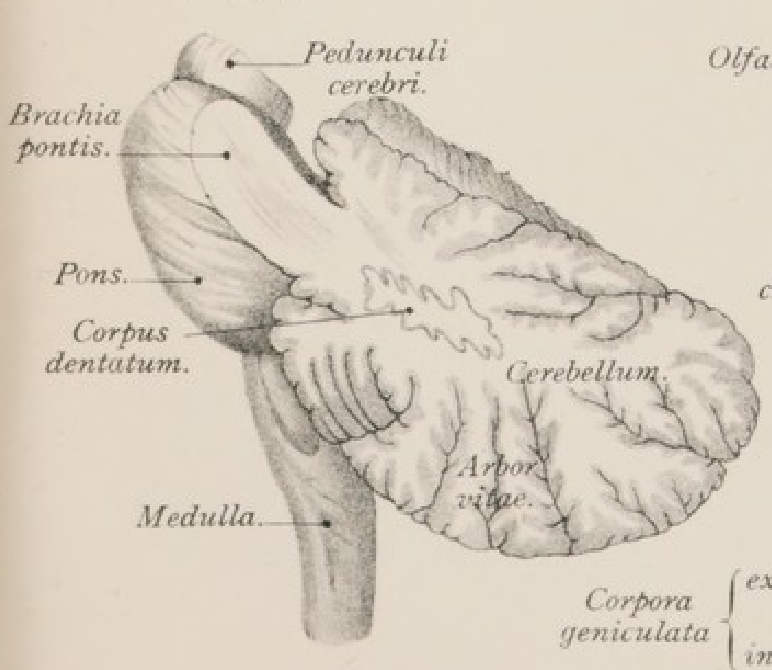
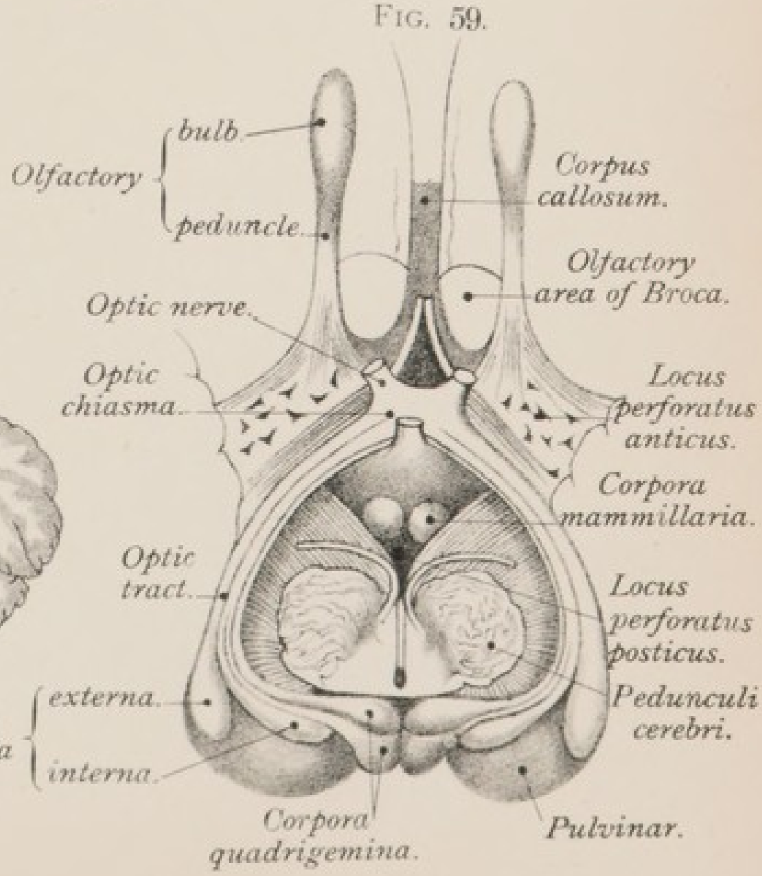


FIG. 59.



surface of the cerebellum. Their larger ends are the deeper, and give off a single slender process—the axis-cylinder process—which, after becoming medullated, sends off lateral branches, and enters the central white matter. Of the lateral branches some pass into the molecular layer, some spread out in the granular layer. The outer process of the cells is much thicker and larger, and breaks up into leaf-like branches, like the horns of a deer, hence the name antler cells. These branches, called dendrites or protoplasmic processes, spread out, like an espalier, in planes across the laminæ, so that they present different appearances according to the plane of the section (fig. 57, *a*, *b*, page 104). Ultimately they form a rich plexus, ramifying towards the surface. These ramifications end free, and do not anastomose with each other, nor with the processes of neighbouring 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. Both the base and branches of the dendrites of Purkinjé's cells are beset with a network of fine fibrillæ—called neuro-fibrillæ.

3. The INNER OR GRANULAR LAYER—*rust-coloured layer* of Turner—consists of nerve cells and of neuroglia cells embedded in a delicate matrix of fine interlacing fibrillæ.

Its nerve cells are of two kinds—small granular and large granular (fig. 57, page 104).

(1) The *small granular cells* are polyhedral in shape. Their protoplasmic processes end in little tufts of short thick branches (fig. 57, page 104). Their axis-cylinder process is very slender, and arises either from the body of the cell or from one of the protoplasmic

processes. Passing with an undulating course towards the molecular layer, the axis-cylinder process ends in two branches which run parallel with the laminæ of the cerebellum.

(2) The second kind of cells—the *large granular cells,* though scattered throughout the thickness of the granular layer, are mostly found in its outer part. They are stellate in shape and have axis-cylinder and protoplasmic processes, the former giving off numerous collaterals (fig. 57, page 104).

6. WHITE MATTER OF THE CEREBELLUM.

(Fig. 57, Plate XVI. Page 104.)

The White Matter of the cerebellum consists of three sets of fibres—(1) projection, (2) association, (3) commissural.

The projection fibres constitute the several peduncles of the cerebellum. The commissural bands extend from one hemisphere to the other, near the anterior and posterior ends of the vermis cerebelli; and the association fibres go from one convolution to another. These three sets of fibres constitute the entire white core of the cerebellum. They are either—

1. The axis-cylinder processes of the cells of Purkinjé already described (fig. 57, page 104); or

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. 57, page 104); or

3. A set of fibres—*climbing* or *tendril 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. 57, page 104), for they merely form a network round the attached ends and processes of the dendrites of the cells of Purkinjé (fig. 57, page 104).

The FUNCTIONS of the cerebellum are as yet unknown. It may contain psychical centres like the cerebrum. The classical experiments of Flourens point to the fact that it is a centre for the co-ordination of muscular movements, such as walking. Some hold that it is a centre which presides over equilibrium. Experiments published in Dr. Courmont's thoughtful and interesting work on the *Cerebellum and its Functions* show that the cerebellum may be an organ connected with the emotions. He 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 of the cerebellum the emotional side of the patient's character is markedly affected, whereas the intellectual aspect remains intact.

THE 4TH VENTRICLE.

(Fig. 44, Page 66, and Fig. 50, Page 82.)

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

In describing the posterior aspect of the medulla oblongata, on page 70, you will remember we treated of its lower or posterior division only; we now proceed to consider its anterior or upper half, that half which is connected with the 4th ventricle.

The 4th Ventricle is a conical-shaped space placed between the medulla and pons in front and the cerebellum behind. It is lodged in the fore part of the vallecula on the under surface of the cerebellum, and has a quadrilateral floor and a tent-like roof. 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, (7) the various collections of grey matter or nuclei beneath the floor, and, lastly, (8) its strands of nerve fibres.

I. **The Floor, or Anterior Wall of the 4th Ventricle** (fig. 44, page 66), is a diamond-shaped depression, of the figure of an heraldic lozenge, and resembles two triangles placed base to base. It looks backwards and upwards, and its lower or posterior part occupies the back of the medulla; its upper or anterior part the back of the pons. Its formation is due to the separation from each other of the walls of the posterior median fissure of the spinal cord, and the consequent opening out of the central canal of the cord, thus bringing the grey matter round that canal to the surface. Of its 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 on a level 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 MEDULLARES or *striæ acusticæ* (fig. 44, page 66), 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 portion belonging to the medulla, and an upper portion belonging to the pons (fig. 44, page 66), both of which are again subdivided, 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 medullares (fig. 44, page 66). On examining each of the lower divisions you will see, at about their centre, a small triangular depression called the INFERIOR or POSTERIOR FOVEA (fig. 44, page 66), the base of which is directed downwards, the apex upwards, 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 the following four distinct areas:—

1. The *inferior fovea* (fig. 44, page 66), the space enclosed within the sides of the triangular depression just described.

2. A raised area, which lies between the median furrow and the inner margin of the fovea. It forms the lower part of the *fasciculus* or *eminentia teres*, and is often called the *trigonum hypoglossi* (fig. 44, page 66).

3. The *trigonum acusticum*, with the *tuberculum*

acusticum, is enclosed between the lateral wall and the outer margin of the fovea (fig. 44, page 66). It is a part of a larger area, situated above the striæ medullares which cross it superficially.

4. The *ala cinerea—trigonum vagi*,—with the *eminentia cinerea*, is placed below the base of the inferior fovea (fig. 44, page 66).

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 (fig. 44, page 66), the SUPERIOR OR ANTERIOR FOVEA, between which and the central furrow is a prolongation of (1) the *fasciculus teres*. 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 (2) the *locus cœruleus* (fig. 44, page 66; fig. 50, page 82), due to a mass of pigmented nerve cells—substantia ferruginea—lying beneath.

II. **The Lateral Walls of the 4th Ventricle.**—The lateral boundaries of the lower half of the ventricular cavity are formed from below upwards by (1) the FASCICULUS GRACILIS and its CLAVA (fig. 44, page 66); (2) higher up, by the tapering end of the FASCICULUS CUNEATUS (fig. 44, page 66); and (3) highest of all by the RESTIFORM BODY or inferior peduncle of the cerebellum (fig. 44, page 66). The boundaries of the upper division of the floor are the BRACHIA CONJUNCTIVA or superior cerebellar peduncle (fig. 44, page 66) of the two sides.

III. **The Roof of the 4th Ventricle.**—The roof of the 4th ventricle is tent-like in shape—its apex projecting backwards towards the cerebellum. The lower half of the roof is formed by 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 of 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. 44, page 66). 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 *tænia* (fig. 44, page 66). The roof of the upper portion of the ventricle is formed partly by the BRACHIA CONJUNCTIVA—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 102).

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 with that which lines the cavities of the third and lateral ventricles of the brain.

V. **Openings into the 4th Ventricle.**—At its upper angle, the 4th ventricle communicates by a narrow channel, AQUÆDUCTUS CEREBRI, *aqueduct of Sylvius,* with the THIRD VENTRICLE (fig. 67, page 136); 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, a small rounded opening, the FORAMEN of

MAJENDIE, puts the ventricle in communication with the SUB-ARACHNOID SPACE; while at each side, near the lateral angles, are similar openings in the roof, between the cerebellum and medulla. Through these openings the cerebro-spinal fluid can find its way from the sub-arachnoid 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 of the pia mater which forms the roof of the 4th ventricle. These vascular fringes run along each side of the middle line of the roof, projecting towards the ventricle, though covered everywhere by the epithelium which follows all their windings and folds, and thus separates them from the cavity of the ventricle. Part of this plexus projects, 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 most of the cranial nerves.

(*a*) Nuclei beneath the *lower division* of the ventricular floor (fig. 44, page 66, and fig. 50, page 82):—

(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 not only occupies the lower part of this area, but also passes up under the striæ medullares. In its lower part it covers the NUCLEUS of the HYPOGLOSSAL or 12th nerve, and hence is often called the *trigonum hypoglossi*; and in coronal sections of the medulla at this level the fibres of the 12th nerve may be seen running

outwards and forwards from the nucleus beneath this area towards the periphery (fig. 49, page 78).

(2) The *trigonum acusticum* and its *tubercle* correspond in position to the tubercle of Rolando, and cover the AUDITORY NUCLEI (fig. 50, page 82). They extend beneath the striæ into the upper division of the ventricular floor.

(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. 50, page 82); in its upper part, and extending into the inferior fovea, are the nucleus of the VAGUS below (fig. 50, page 82) and of the GLOSSO-PHARYNGEAL above (fig. 50, page 82).

(*b*) The nuclei beneath the *upper division* of the ventricular floor, viz. that formed by the back of the pons, are the following:—

(1) Close to the lateral recesses are the SENSORY and MOTOR nuclei of the 5th nerve, the motor being internal, the sensory external (fig. 50, page 82);

(2) The NUCLEUS of the 6th nerve (fig. 50, page 82) 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;

(3) The NUCLEUS of the 7th or facial nerve is placed deeper, and internal to the 5th, but external to the nucleus of the 6th nerve (fig. 50, page 82);

(4) The outer or ACCESSORY NUCLEUS of the auditory or 8th nerve lies external to the facial nucleus.

These various nuclei will be again referred to in the section on the Superficial and Deep Origins of the Cranial Nerves, page 176.

VIII. **The White Matter** of this part of the medulla consists of the continuation of the pyramids, and, behind these, of the formatio reticularis, and of the three important longitudinal strands—the fillet, and the anterior and the posterior longitudinal bundles. The former is derived from the posterior columns, being in part a continuation of the sensory decussation; the latter are connected with the antero-lateral columns of the spinal cord, and can be traced up under the grey matter of the floor of the 4th ventricle to the crura cerebri.

IV. THE CEREBRUM.

General Outline.—The cerebrum is by far the largest division of the brain, and on an average weighs about 30 oz. Above, it occupies the vault of the cranium; below, at its base, it is lodged, in front and in the middle of its extent, 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 united across the middle line by a thick band of white matter, called the CORPUS CALLOSUM. Each hemisphere is ovoid in shape, and is composed of a white stalk or peduncle—the PEDUNCULI OR CRURA CEREBRI—surmounted by a convoluted grey crust, mapped out by furrows or SULCI into a series of larger or smaller folds called convolutions or GYRI.

Internally. the cerebrum consists of masses of grey matter—SUBCORTICAL GANGLIA; of strands of white nerve fibres—PROJECTION and ASSOCIATION FIBRES; of connecting bands—COMMISSURES; and of a large cavity, subdivided into smaller spaces, called VENTRICLES.

We shall describe—(1) the EXTERIOR or cortex of the cerebrum, with its FISSURES, LOBES, and GYRI; (2) the BASE; (3) the INTERIOR, with its VENTRICLES, its GANGLIA, its COMMISSURES and other WHITE STRANDS; and, finally, (4) the CEREBRAL PEDUNCLES or crura cerebri.

I. EXTERIOR OF THE CEREBRUM.

(Figs. 60, 61, Plate XVII. Page 118.)

The Grey Matter of the outer surface of the cerebrum is known as the greater hemispherical ganglion, CORTEX, or bark of the brain. It is divisible into a large upper part, called the mantle or pallium; and a small basal part, the rhinencephalon (see page 127).

Each hemisphere is a triangular pyramid, and presents three borders and three surfaces—an outer surface, convex; a mesial, plane and vertical; and an irregular under-surface or base. Examine—(1) the fissures, and (2) the lobes and gyri of these surfaces.

1. FISSURES OF CEREBRAL HEMISPHERES.

(Figs. 60, 61, Plate XVII. Page 118; Figs. 62, 63, Plate XVIII. Page 126.)

Of the **Fissures** or **Sulci** 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 or gyri, which, in most cases, have received definite designations.

Note.—The term *fissura* is often used to indicate those clefts only which cause corresponding elevations in the interior of the cerebrum—the remaining clefts being called sulci.

1. **The Inter-lobular Fissures** are the FISSURA CEREBRI LATERALIS or fissure of Sylvius, the SULCUS CEREBRI CENTRALIS or fissure of Rolando, and the PARIETO-OCCIPITAL FISSURE (figs. 60, 61, page 118).

(1) **The Fissura Cerebri Lateralis** or 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 brain substance. It is a deep cleft which begins near the middle line on the under surface of the hemisphere at a point called the anterior perforated spot (fig. 63, page 126); thence it runs transversely upwards and outwards on the base of the hemisphere to its lateral aspect, where it divides into two limbs—an anterior, short, *vertical*, ascending limb, and a posterior, which runs horizontally backwards on the surface of the hemisphere—hence called the *horizontal* limb (fig. 60, page 118). Sometimes there are two short limbs—the one being called anterior, the other vertical.

(2) **The Sulcus Cerebri Centralis** or FISSURE of ROLANDO (figs. 60, 61, page 118), found only in man and in apes, is one of the first fissures 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 cerebrum, it ends below near the anterior part of the horizontal limb of the lateral

fissure (Sylvius), but in most cases falls short of that fissure. It is not of uniform depth throughout, being deeper below than above.

(3) **The Parieto-occipital Fissure** appears on both the outer and inner surfaces of the hemisphere. The EXTERNAL PARIETO-OCCIPITAL FISSURE is a short cleft on the outer aspect of the hemisphere near its hinder end (figs. 61, 62, page 118); the INTERNAL PARIETO-OCCIPITAL FISSURE, continuous above with the external, is a well-marked and very constant fissure, and descends vertically on the mesial aspect of the hemisphere (fig. 61, page 118). It will be noticed with that surface.

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 sulcus.
2. Intra-parietal sulcus.
3. Sulcus temporalis superior or parallel.
4. Sulcus orbitalis or triradiate.
5. Collateral fissure.
6. Sulcus corporis callosi or callosal.
7. Sulcus cinguli or calloso-marginal.
8. Fissura calcarina or calcarine.
9. Hippocampal or dentate fissure.

They are figured in figs. 60, 61, page 118; figs. 62, 63, page 126.

2. LOBES AND CONVOLUTIONS OF CEREBRAL HEMISPHERES.

The cerebral hemispheres are at first perfectly smooth and without convolutions, and this developmental type is retained in the case of many animals —*e.g.* the insectivora. In the adult brain each cerebral hemisphere has five principal lobes. Of these, four are bounded by the inter-lobular 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*, and the *temporal*. 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 fissura cerebri lateralis (Sylvius), the margins of which must be separated in order to see it. Two other lobes are sometimes described—the *olfactory lobe* (see page 120), and the *limbic lobe* (see page 127).

I. **The Frontal Lobe** (figs. 60, 61, page 118) is pyramidal in shape, its rounded anterior end being called the frontal pole. It is bounded behind by the SULCUS CENTRALIS—*fissure of Rolando*—which separates it from the parietal lobe; below, by the FISSURA CEREBRI LATERALIS—*fissure of Sylvius*—which separates it from the temporal lobe; internally, by the GREAT LONGITUDINAL FISSURE, which separates it from its fellow of the opposite side. It has three surfaces—an *outer*, an *inner* or mesial, and an *inferior* or orbital.

The *outer surface* has four gyri; one, the ANTERIOR CENTRAL GYRUS or *ascending frontal convolution* (figs. 60, 61, page 118), runs parallel to and in front of the sulcus centralis (Rolando), and is limited in front by the præcentral sulcus (fig. 60, page 118); behind by the SULCUS CENTRALIS (Rolando). The rest of the surface in front of the gyrus is mapped out by two horizontal parallel sulci—the *superior* and *inferior*

PLATE XVII.

FIG. 60.

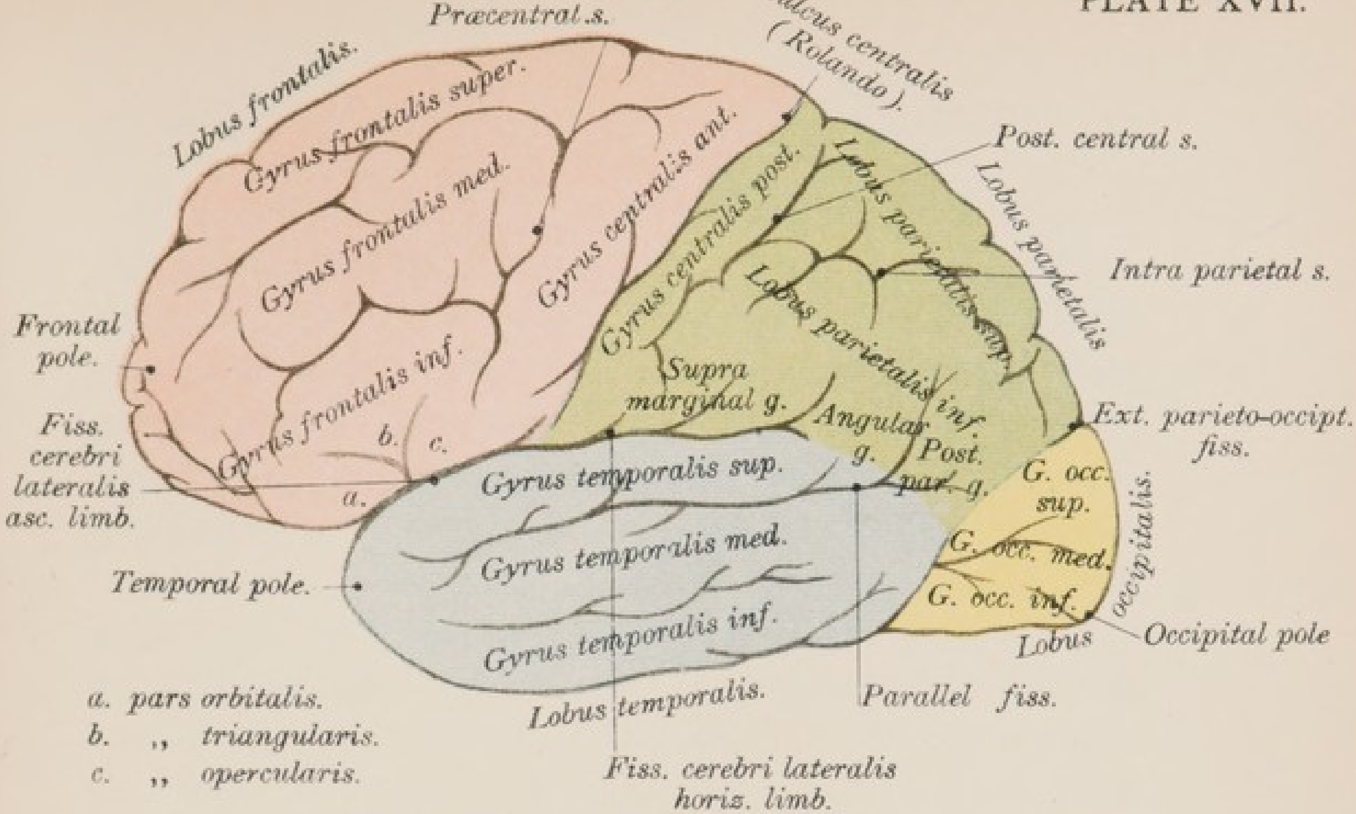
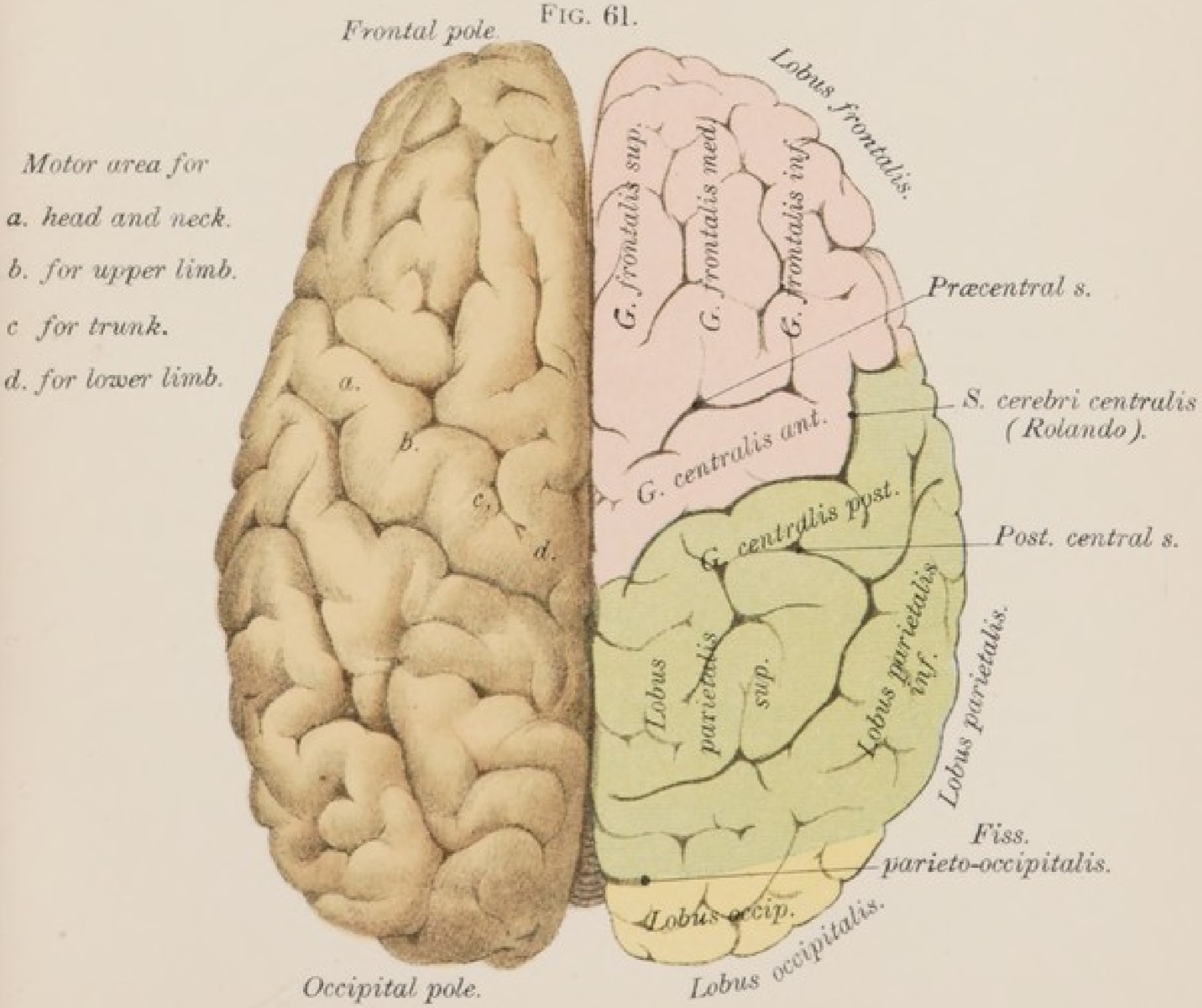


FIG. 61.



Lobes—Fissures—Convolutions of Cerebrum.

McLagan & Cumming, Edinr

frontal sulci; into three antero-posterior convolutions—the SUPERIOR, the MIDDLE, and the INFERIOR FRONTAL GYRI (figs. 60, 61, page 118), which are sometimes classed together under the term *pre-frontal* lobe. The posterior part of the left inferior frontal gyrus is called Broca's convolution. It deserves special notice, for it is supposed to contain the motor centre for speech, but doubt has, with much justice, been thrown on this statement, for there are cases recorded in which destruction of this centre has been unaccompanied with loss of speech (Aphasia). It curves round the anterior and vertical limbs of the fissura cerebri lateralis (Sylvius), by which means it can be subdivided into three parts—(*a*) an anterior part, *pars orbitalis*; (*b*) a middle part, *pars triangularis*; and (*c*) a posterior part, *pars opercularis* (fig. 60, *a*, *b*, *c*, page 118). This last is the part that contains the centre for speech.

The *orbital surface* of the frontal lobe, bounded on the inner side by the longitudinal fissure, and behind by the fissura cerebri lateralis (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 or SULCUS ORBITALIS—which subdivides the surface into three gyri, an INTERNAL ORBITAL, an ANTERIOR ORBITAL, and a POSTERIOR ORBITAL (fig. 63, page 126). They are each mere prolongations into this surface, though not directly, of the convolutions of the outer surface. Thus the superior frontal gyrus becomes continuous with the internal orbital, the middle with the anterior orbital, and the inferior with the posterior orbital.

On the surface of the internal orbital gyrus, lodged in a triangular sulcus—the OLFACTORY GROOVE—is a club-shaped body, the OLFACTORY BULB and its PEDUNCLE, which are sometimes regarded as a separate lobe. Traced backwards, the olfactory peduncle bifurcates behind into two white bands, the outer passing backwards towards the sulcus lateralis (Sylvius), where it is lost; the inner running to the side of the great longitudinal fissure. The small conical elevation between these two limbs is called the OLFACTORY TUBERCLE, or trigonum olfactorium, often regarded as the middle root of the olfactory peduncle. The area lying anterior and internal to the inner limb is known as the olfactory area of Broca (fig. 59, page 104). The portion of the internal orbital convolution internal to the olfactory groove is called the *gyrus rectus*. It is separated behind by a slight fissure from the area of Broca.

The Olfactory Lobe.—The olfactory bulb and its peduncle are developed as a hollow outgrowth of the fore brain, and are, as we have said, often regarded as a separate lobe. This lobe comprises the following parts—(1) an *anterior division*, consisting of (*a*) the olfactory bulb and its peduncle; (*b*) of the olfactory area of Broca; (*c*) of the trigonum olfactorium: and (2) a *posterior division*, consisting of the grey matter at the base of the brain, called the anterior perforated spot, crossed by the outer limb of the olfactory peduncle.

The *mesial surface* of the frontal lobe will be described with the corresponding surface of the hemisphere, page 125.

TABLE OF THE FRONTAL GYRI.

Frontal lobe	Outer surface	Gyrus centralis anterior or ascending frontal.
		Gyrus frontalis superior.
		Gyrus frontalis medius.
		Gyrus frontalis inferior.
	Inner surface	See mesial surface of hemispheres.
	Lower surface	Internal orbital.
		Anterior orbital.
		Posterior orbital.

II. **The Parietal Lobe** has an *inner surface* belonging to the inner aspect of the hemisphere (see Mesial Surface, page 125), and an outer surface, lateral and convex, which is bounded in front by the SULCUS CENTRALIS (Rolando), separating it from the frontal lobe; behind by the EXTERNAL PARIETO-OCCIPITAL FISSURE, separating it from the occipital lobe, and below by the FISSURA CEREBRI LATERALIS (Sylvius) and its projection backwards, separating it from the temporal lobe.

This surface is furrowed by two sulci—the one is directed downwards parallel to and behind the central sulcus (Rolando), and forms the posterior limit of the GYRUS CENTRALIS POSTERIOR or *ascending parietal convolution*; the other, the INTRA-PARIETAL SULCUS, often continuous with the last-named sulcus (fig. 60, page 118), arches from before backwards through the centre of the surface, and subdivides it into an upper division —the SUPERIOR PARIETAL LOBULE (fig. 60, page 118), and a lower division—the INFERIOR PARIETAL LOBULE (fig. 60, page 118). The inferior parietal lobule is again divisible into three parts—an anterior part, arching round the posterior end of the fissura cerebri lateralis (Sylvius), and called the SUPRA-MARGINAL GYRUS or convolution of the parietal eminence (Turner); a middle part, the ANGULAR GYRUS, behind the lateral fissure (Sylvius), and continuous round the hinder end of the parallel or superior temporal sulcus with the middle temporal gyrus; and a posterior, behind the angular gyrus, and called the POST-PARIETAL GYRUS (fig. 60, page 118).

The angular gyrus probably contains the centre through which we remember what we see (figs. 39 and 42, page 60). The central gyri—the ascending frontal and parietal and the paracentral lobule—contain the sensory-motor centres, the centres through which the mind stores up its memories of muscular movements (figs. 39 and 42, page 60). The anterior central is, however, more directly motor, the posterior central more directly sensory.

TABLE OF GYRI OF PARIETAL LOBE.

Parietal lobe	Outer surface	Posterior central or ascending parietal.	
		Superior parietal lobule.	
		Inferior parietal lobule	Supra-marginal. Angular. Post-parietal.
	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 gyri than any of the other lobes. Pyramidal in shape, with the apex or occipital pole backwards, it has three surfaces—an *external*, in contact with the parietal and occipital bones; an *internal*, forming part of the mesial surface of the hemisphere; and an *inferior*, continuous with the under surface of the temporal lobe, and resting on the upper surface of the tentorium cerebelli. 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 EXTERNAL PARIETO-OCCIPITAL FISSURE, and by a line drawn downwards from this fissure across the surface of the hemisphere to its lower margin (fig. 60, page 118). The other boundaries of the external surface are the margins of the hemisphere. Two longitudinal sulci divide the surface into three antero-posterior gyri—a SUPERIOR, a MIDDLE, and an INFERIOR OCCIPITAL (fig. 60, page 118); but these convolutions are by no means constant. In the ape the external surface of the occipital lobe is bounded in front by a distinct cleft, which is represented in man by a small sulcus—sometimes present—the sulcus lunatus ("Affenspalte").

The inner aspect and the posterior part of the outer aspect of the occipital lobes contain the centres connected with sight (fig. 42, page 60).

TABLE OF GYRI OF OCCIPITAL LOBE.

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

IV. **The Temporal Lobe** (fig. 60, page 118), occupying the middle fossa at the base of the skull, is conical in shape, its anterior end being called the temporal pole. It has three surfaces—an *upper*, a *lower*, and an *external* or lateral.

The *external surface* is bounded above by the SULCUS CEREBRI LATERALIS (SYLVIUS), which separates it from the parietal lobe; below, by the INFERIOR TEMPORAL 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 TEMPORAL; the upper two sulci separate from each other the SUPERIOR, the MIDDLE, and the INFERIOR TEMPORAL GYRI. The inferior fissure is, as we have said, the boundary between the outer and the lower surfaces.

The *upper surface* of this lobe is hidden within the lateral sulcus (Sylvius), and is marked out by somewhat inconstant sulci into two or three indefinite gyri. Along with the superior temporal gyrus, it contains the centres associated with hearing (fig. 39, page 60).

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 the temporal and the occipital lobes—the part in front of the groove being convex, and belonging to the temporal lobe; the part behind the groove being concave, and belonging to the occipital lobe. These two parts are taken together under the term occipito-temporal, and their gyri are two in number—a SUPERIOR and an INFERIOR OCCIPITO-TEMPORAL, separated from each other by the COLLATERAL FISSURE (see fig. 62, page 126). The fore part of this surface of the temporal lobe contains the cortical centres for taste (fig. 42, page 60).

TABLE OF GYRI OF TEMPORAL LOBE.

Temporal lobe	External surface	Superior temporal. Middle temporal. Inferior temporal.
	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 fissura cerebri lateralis (Sylvius), and cannot be seen unless you separate the sides of that fissure. Pyramidal in shape, it consists of five or six convolutions, called GYRI OPERTI (fig. 63, page 126), which are limited externally by a deep sulcus separating them from the adjacent gyri, collectively known as the OPERCULUM (fig. 63, page 126), and formed by the contiguous ends of the two central convolutions and of the inferior frontal and superior temporal gyri. In front and behind, the isle of Reil is separated by well-marked sulci from the frontal and temporal lobes respectively. It is subdivided by a sulcus—sulcus centralis—into an anterior part—pars frontalis, and a posterior part—pars temporalis.

VI. **Fissures and Gyri of the Mesial Surface of the Hemispheres** (fig. 62, page 126).—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. 62, page 126), which we shall take as our guide to the study of the gyri and sulci.

The CALLOSAL SULCUS or *sulcus corporis callosi.*—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 temporal lobe, ends in the notch of the *uncus* (fig. 62, page 126). Between the callosal fissure and the upper margin of the hemispheres lies the SULCUS CINGULI or *calloso-marginal fissure* (fig. 62, page 126), 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, where it turns upwards to the mesial borders of the hemisphere, a little behind the central fissure (Rolando) (fig. 62, page 126). It limits the extent of the frontal lobe on this surface of the hemisphere. The original direction of the sulcus cinguli is continued by a small fissure—*sulcus subparietalis*—which, along with the *sulcus cinguli*, separates the *gyrus fornicatus* below from the *marginal gyrus* and the *quadrate lobe* above.

The GYRUS CINGULI or *gyrus fornicatus*—convolution of the corpus callosum (fig. 62)—commences in front below the anterior end of the corpus callosum,

FIG. 62.

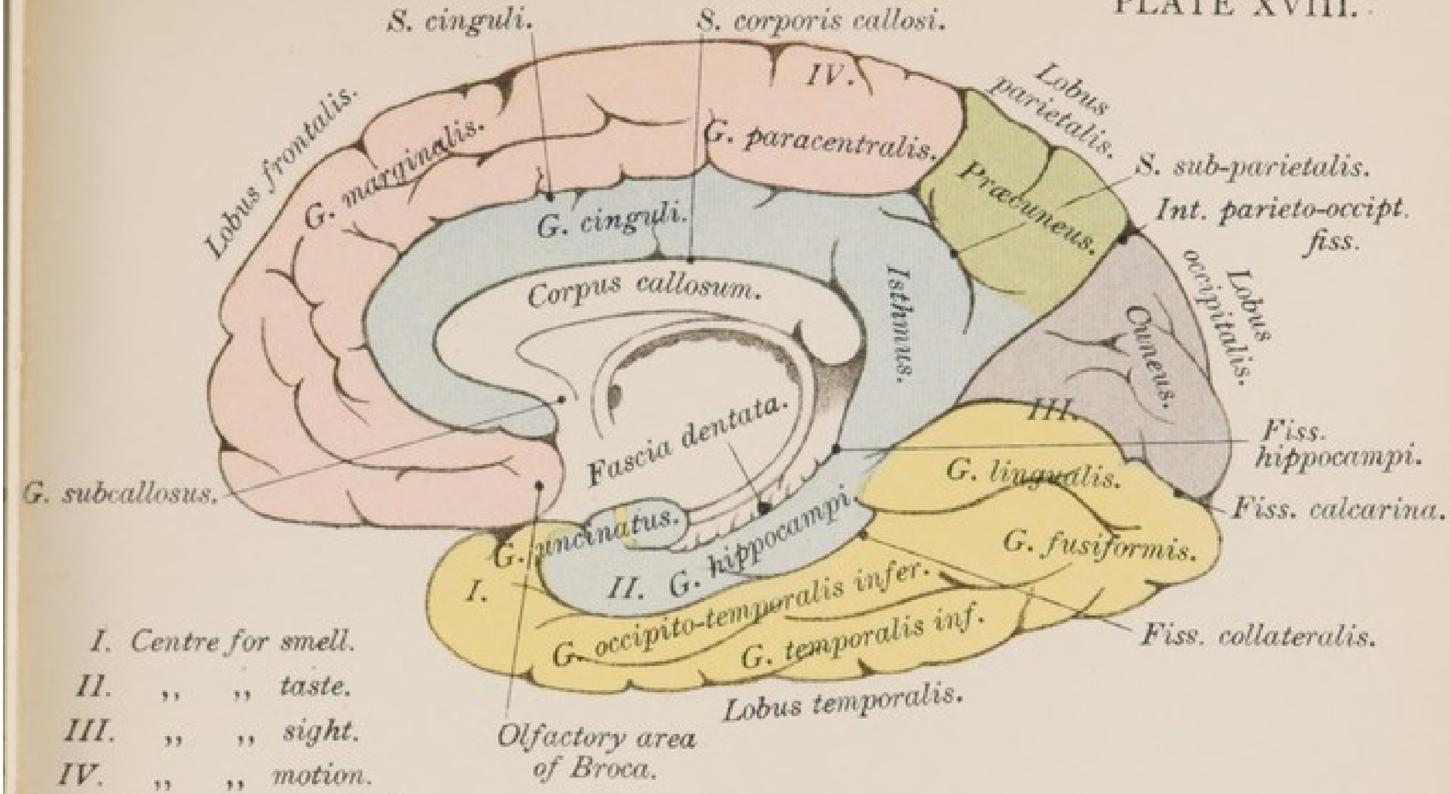
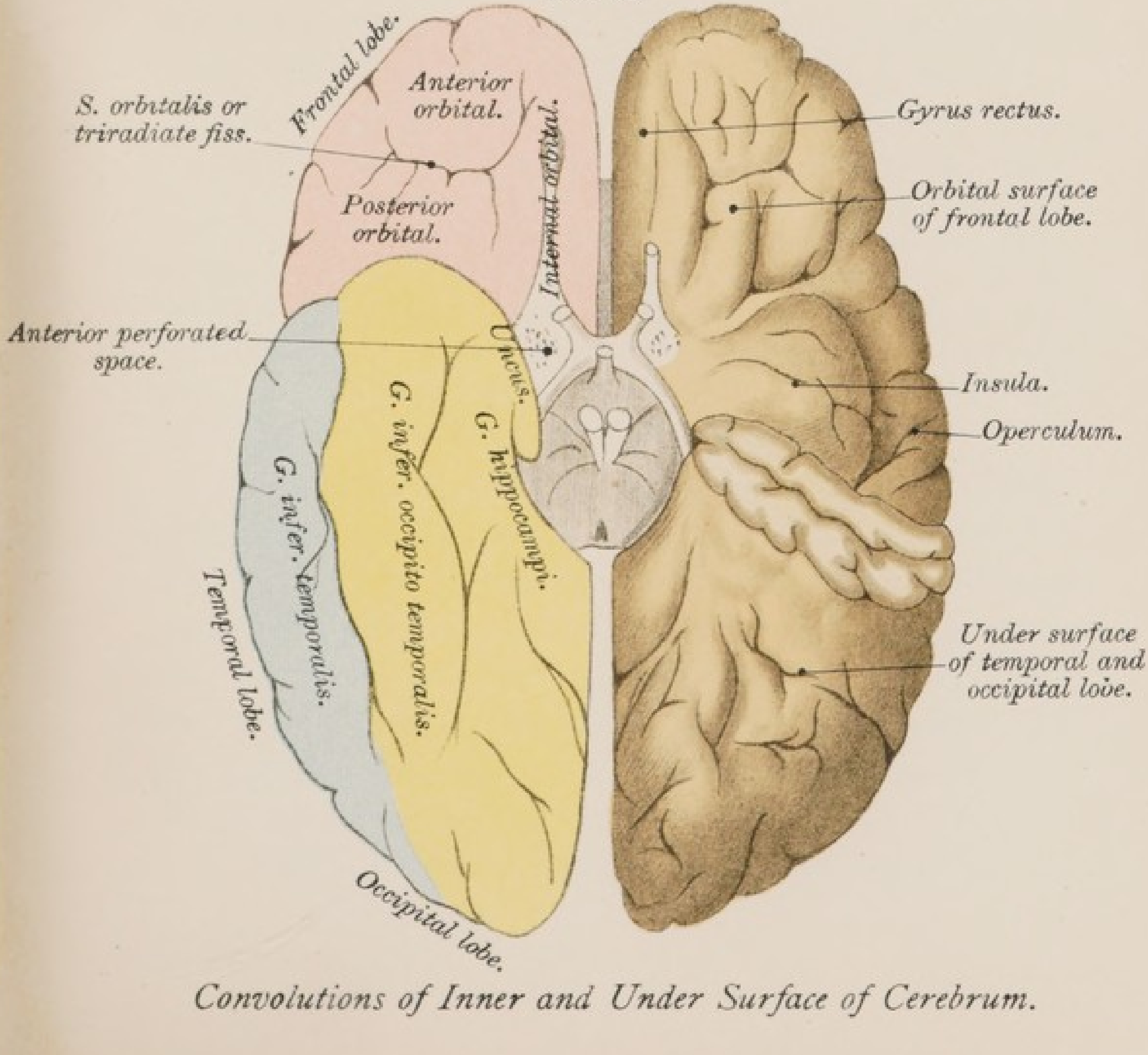


FIG. 63.



Convolutions of Inner and Under Surface of Cerebrum.

and, arching upwards and backwards over the body and round the posterior end of the corpus callosum, becomes slightly constricted—the *isthmus*—and then runs downwards and forwards, on the mesial edge of the temporal lobe, as the GYRUS HIPPOCAMPI or *superior occipito-temporal convolution*. It is also called the UNCINATE GYRUS, from the hook-like process—uncus gyri hippocampi—in which it ends in front (fig. 62, page 126), and in which is contained the cortical centre for smell. This group of convolutions, together with the septum lucidum, fornix, cornu ammonis, fascia dentata, fasciola cinerea, median and lateral longitudinal striæ, and the peduncles of the corpus callosum (subcallosal gyrus), forms the *limbic lobe* referred to on page 118. The olfactory lobe and the limbic lobe together constitute the rhinencephalon.

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

The MARGINAL CONVOLUTION (fig. 62, page 126), belonging, as we have seen, to the mesial surface of the frontal lobe, is continuous with the superior frontal gyrus. It begins at the anterior perforated space, and, skirting the upper edge of the hemisphere above the sulcus cinguli, becomes continuous above with the superior frontal gyrus. Inferiorly, it passes into the gyrus rectus of the orbital surface, and posteriorly it is limited by the vertical part of the sulcus cinguli (fig. 62, page 126). The hinder part of the marginal gyrus is called the *paracentral lobule* (fig. 62, page 126); it is the mesial aspect of the ascending frontal convolution.

The INTERNAL PARIETO-OCCIPITAL FISSURE (fig. 62, page 126) lies behind the vertical part of the SULCUS CINGULI, the two enclosing between them the mesial surface of the parietal lobe, called the QUADRATE LOBE or PRÆCUNEUS (fig. 62, page 126).

Below the internal parieto-occipital fissure will be seen the CALCARINE FISSURE (fig. 62, page 126), which runs forwards from the posterior border of the hemisphere to join the internal parieto-occipital fissure. They together enclose the wedge-shaped mesial aspect of the occipital lobe, called the CUNEATE LOBE or CUNEUS (fig. 62, page 126).

The FISSURA HIPPOCAMPI or *dentate fissure* (fig. 62, page 126), continuous behind with the callosal sulcus, ends in front, as we have already seen, in the notch of the uncus. This fissure separates the *hippocampal gyrus* from the *fimbria* or *tænia hippocampi*, which will be seen in the descending horn of the lateral ventricle.

The FASCIA DENTATA or *dentate convolution* is a notched gyrus, the free edge of the superficial grey matter of the hemisphere (fig. 63, page 126). It lies at the bottom of the dentate fissure, and is continuous in front with a small band—band of Giacomini—which crosses the uncus of the gyrus fornicatus, and behind with a thin grey lamina, the fasciola cinerea, and through it with the mesial and lateral longitudinal striæ of the corpus callosum. It is part of an abortive convolution which can be seen on opening up the fissure of the corpus callosum, and its continuation, the dentate fissure.

Projecting into the floor of the lateral ventricles, above the fimbria, through a fissure called the great transverse fissure (described on page 151), 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 143).

TABLE OF THE GYRI OF THE MESIAL SURFACE.

Gyri of Mesial surface	Gyrus fornicatus or gyrus cinguli. Marginal. Hippocampal and Uncinate. Dentate. Præcuneus or Quadrate. Cuneus. Paracentral lobule.

It may be well to note that besides the *motor* and *sensory areas* named above, the cerebral convolutions also contain other areas, *areas of association*—the significance of which is not yet understood. These comprise most of the frontal, parietal, temporal, and occipital lobes.

The various methods for locating these fissures and convolutions in relation to the scalp and to the skull will be found in your surgical works.

SUMMARY OF THE VASCULAR SUPPLY OF THE VARIOUS CORTICAL CENTRES.

1. The *cortical* areas for *touch*, for *speech*, and for *hearing*, and part of the cortical centre for *sight* are supplied by the *middle cerebral arteries*.

2. The *middle cerebral* also supplies both the *cortical* and *central* areas for *motion*; except that part of the cortical motor centre for the *lower limbs* which is situated in the paracentral lobule and in the contiguous part of the anterior central gyrus: these areas are supplied by the *anterior cerebral* arteries.

3. The *visual* paths and the *hemicentres* for *sight* are supplied by the *posterior cerebral* arteries.

Structure of the Cortex of the Cerebrum.

(Figs. 64 and 65, Plate XIX. Page 130.)

The Grey Matter of the cerebral cortex is arranged in several more or less distinct layers, composed of nerve cells and nerve fibres, of neuroglia, of blood-vessels, and of lymphatics.

Seen with the naked eye a vertical transverse section of the cerebral cortex shows six strata, alternately white and grey—three white and three grey. The white layers correspond to regions in which there are many nerve fibres gathered into transverse bundles; the grey layers to parts in which there are few such nerve fibres.

With the aid of the microscope four layers of the cortex are usually described according to the kinds of *nerve cells* met with in the various layers. Enumerated from without inwards they 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.**—This layer contains many neuroglia cells. Its nerve cells are of three kinds:—

FIG. 64. *Cerebrum—Structure.*

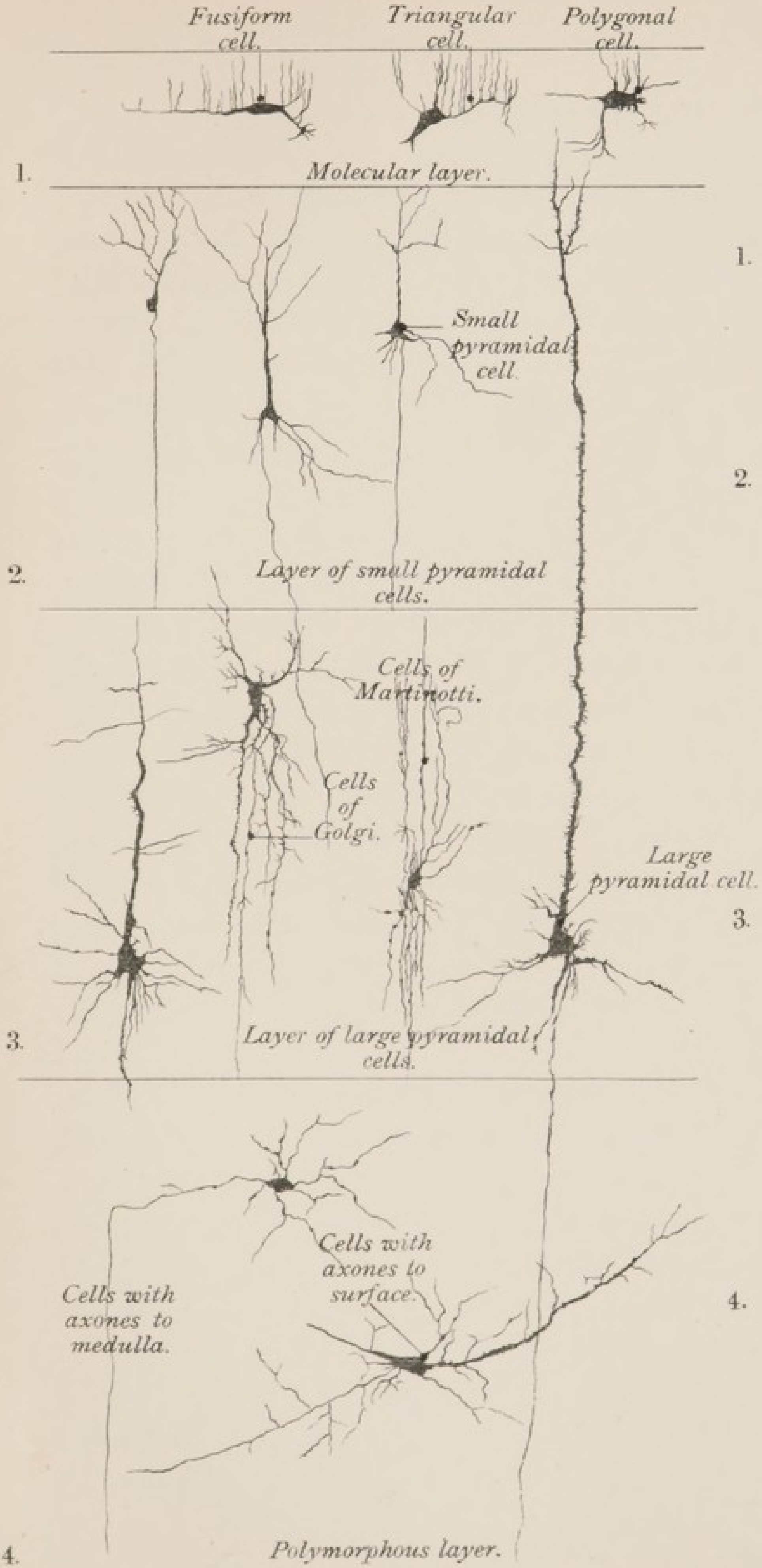
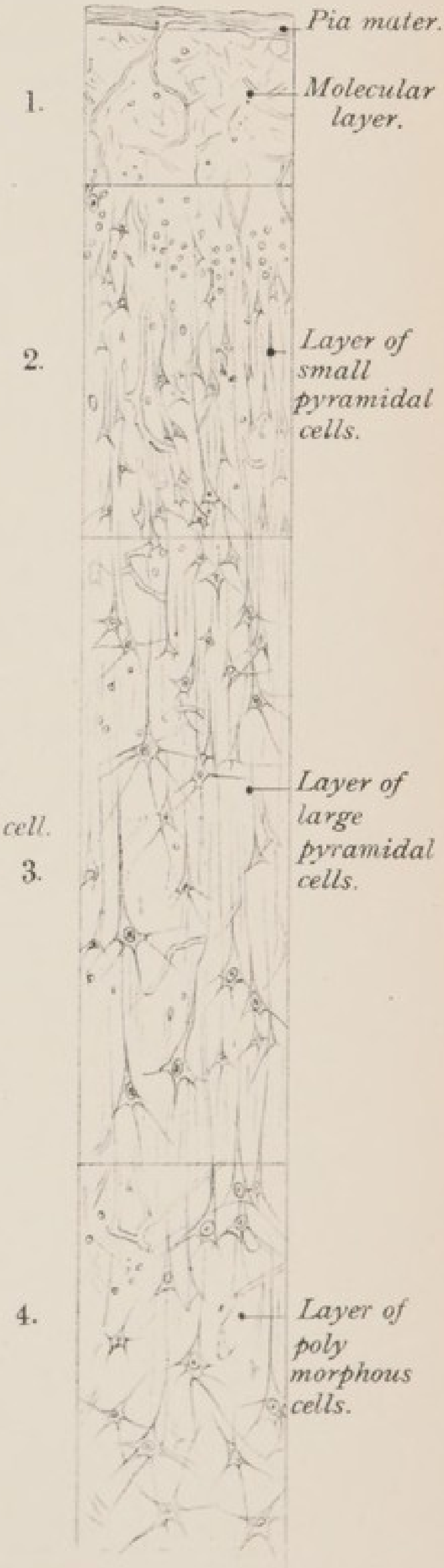


FIG. 65.



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(1) *Polygonal Cells,* which are scattered throughout the layer. They have several protoplasmic processes, and an axis-cylinder process; this last having a horizontal or an ascending direction, and ending free in this layer.

(2) *Fusiform Cells*—ovoid in shape, with their long axis horizontal, hence called horizontal cells (Cajal). They are bipolar, and have protoplasmic processes passing from each end of the cell. At some distance from the cell one of these processes gives rise to a long axis-cylinder process, which ends free in this layer.

(3) *Triangular Cells,* with usually three protoplasmic processes and several axis-cylinder processes, which ascend and end in the molecular layer.

2. **Layer of Small Pyramidal Cells.**—The cells of this layer are of small and medium size, and are, as indicated by their names, mostly pyramidal in shape, though those situated next to the molecular layer are polyhedral or star-shaped. The pyramidal cells have their apices directed towards the surface, and in structure resemble the pyramidal cells of the next layer.

3. **Layer of Large Pyramidal Cells**—Cells of Betz.—The cells of this layer are much larger than those of the last layer. They are pyramidal or polyhedral in shape, with their apices towards the surface and their bases towards the white substance. Each cell has an *axis-cylinder* and *protoplasmic processes.*

The *axis-cylinder process* descends from the centre of the base of the cell towards the subjacent white substance. In the upper part of its course this process gives off at right angles to its direction many side branches—collaterals—which run horizontally and branch dichotomously. The branches are granular, and end free in little knobs. In the lower part of its course the axis-cylinder process becomes tortuous, and gives off no collaterals. It ultimately ends in little tufts of branches in the grey matter at lower levels of the cerebro-spinal axis.

The *protoplasmic processes* or *dendrites* arise from the apex and from the lateral angles of the cells. They are beset with short thick spines (fig. 64, page 130). 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 (fig. 64, page 130) the cells vary much in size and in shape, being fusiform, ovoid, triangular, and star-shaped. They have ascending and descending protoplasmic processes. The axis-cylinder process, sinuous in its course, gives oft collaterals and ends in the white substance, either by bending at right angles to its original direction, or by T or Y shaped junctions with the fibres of the white matter.

Besides the several kinds of nerve cells just described, there are throughout the last three layers of the cortex two other kinds of cells :—

1. Cells with short axis-cylinder processes—*cells of Golgi* (fig. 64, nos. 4 and 5, page 130)—star-shaped, with branching protoplasmic processes, and with an axis-cylinder process, which, after a short course, ends free in dense tree-like branches.

2. Cells with ascending axis-cylinder processes—Martinotti. These cells are fusiform or globular in shape, and are mostly met with in the polymorphous layer. Besides their protoplasmic processes, they have an axis-cylinder process, which ascends from the apex of the cell towards the cortex, giving off

collaterals on its way. Ultimately this process ends in the molecular layer in tree-like branches beset with small spines, knobbed at their extremities.

Many authors divide the cerebral cortex into eight or more layers according to the shape and size of the cells, viz.—

1. Molecular layer.
2. Small pyramidal layer.
3. Median " "
4. Large " "
5. Stellate layer.
6. Large pyramidal—deep layer.
7. Median " " "
8. Polymorphous layer.

The *white* and *grey nerve fibres* found in the grey cortex are the dendrites (protoplasmic processes) and axis-cylinder processes of the nerve cells of the cortex, or of those at lower levels of the nervous system. In structure they are like the fibres of the spinal cord. Their arrangement is too complex for an elementary work of this kind.

Neuroglia pervades the entire cortex, passing especially along the line of its vessels. In structure it is similar to the neuroglia of the spinal cord described on page 30. It forms a superficial stratum under the pia mater, being here known as the superficial stratum of the molecular layer.

The blood-vessels and lymphatics have already been described (page 55).

The above may be regarded as the typical structure of the chief part of the cerebral cortex; but there are many differences in different regions, these differences in structure indicating, in all probability, differences in function, but space will not allow us to describe them.

II. BASE OF THE CEREBRUM.

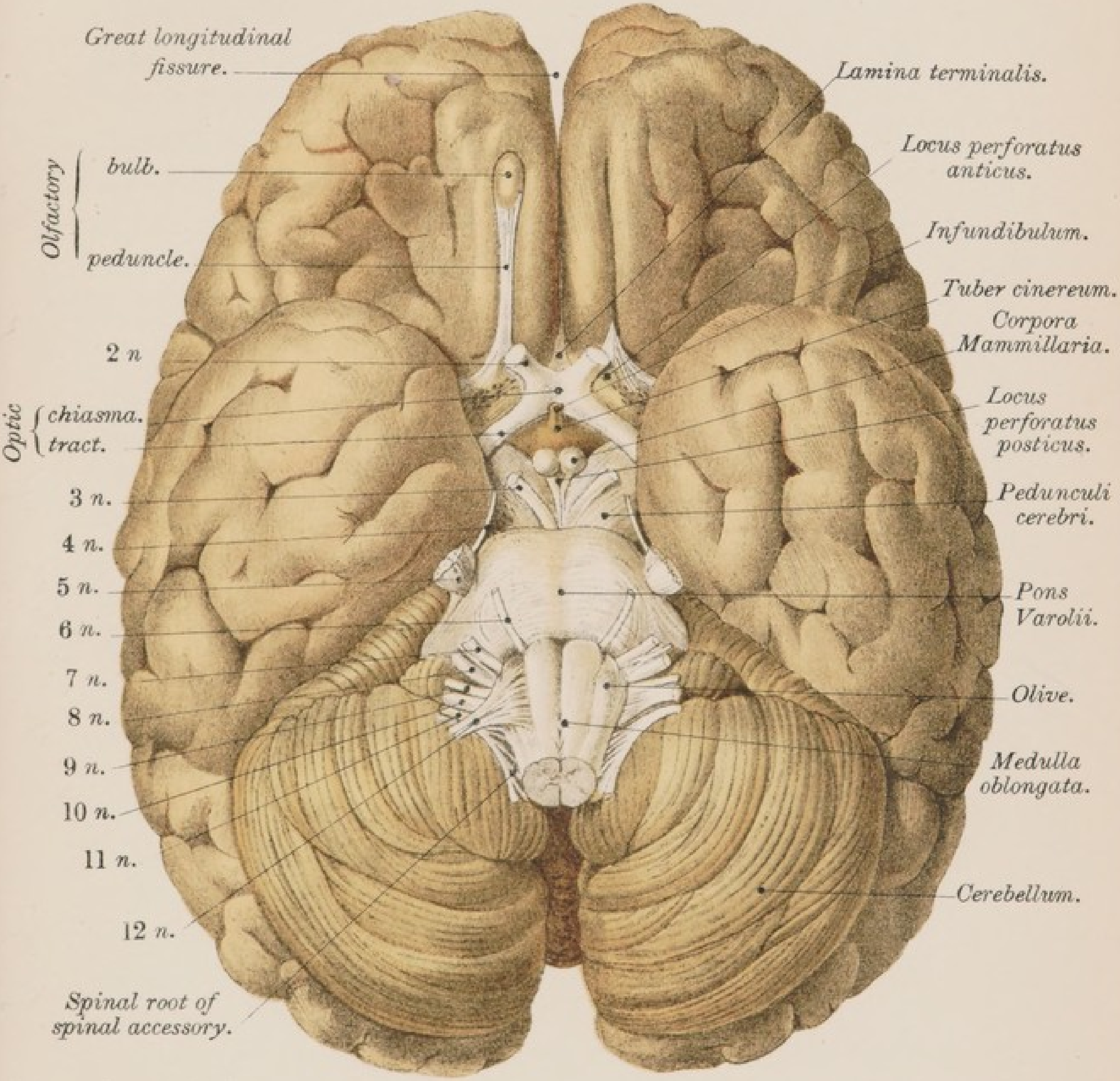
Though the heading of this section is "Base of the Cerebrum," it will be as well to consider the base of the entire brain, and not confine ourselves merely to the under surface of the cerebrum (fig. 66, plate XX. page 134).

The Base or under aspect of the brain is, as we have already seen, very irregular in shape. In connection with it we recognise the following structures: (1) the cerebellum; (2) the medulla; (3) the pons Varolii; (4) the cerebral peduncles or crura cerebri; (5) the under aspect of the frontal, temporal, and occipital lobes; (6) part of the great longitudinal fissure and of the lateral fissure (Sylvius); (7) the anastomosing circle of blood-vessels—the circle of Willis; (8) the interpeduncular space; and (9) the superficial origins of the cranial nerves. We shall now examine more particularly the interpeduncular space and the cranial nerves.

The *interpeduncular space* is the irregular area at the base of the brain, between the great longitudinal fissure in front, the under surface of the frontal and temporal lobes on each side, and the cerebral peduncles behind. This irregular-shaped interval is covered in by a delicate layer of grey and white matter which stretches across the middle line, and unites the under aspect of the hemispheres.

In this space commencing in front, at the longitudinal fissure (fig. 66, page 134), we see (*a*) the

FIG. 66.



Base of Brain.

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ANTERIOR END of the CORPUS CALLOSUM called the ROSTRUM. Hidden within the fissure and passing backwards and outwards from it towards the lateral fissure — fissure of Sylvius — are two narrow white bands, (*b*) the PEDUNCLES of the CORPUS CALLOSUM, between which lies a thin grey lamina, (*c*) the LAMINA CINEREA — *lamina terminalis.* Passing across the middle line, behind the median fissure, is a white band of nerve fibres, (*d*) the OPTIC CHIASMA or COMMISSURE, which is prolonged forwards at the sides into two rounded bundles, (*e*) the OPTIC NERVES; and backwards as flattened white strands, (*f*) the OPTIC TRACTS, which curve round the outer sides of the cerebral peduncles.

External to the optic commissure, at the root of the lateral fissure (Sylvius), and behind the olfactory peduncles, are two triangular shallow depressions, one on each side—the ANTERIOR PERFORATED SPACES (fig. 63, page 126), greyish laminæ, perforated for the passage of blood-vessels into the interior of the brain. These perforated grey laminæ are continuous internally with the lamina cinerea; externally, with the hemispheres. Across them run the external roots of the olfactory peduncles, and the peduncles of the corpus callosum. In the middle line, behind the optic commissure, is a small grey elevation—(*g*) the TUBER CINEREUM (figs. 63, page 126)—which is continuous with the lamina cinerea.

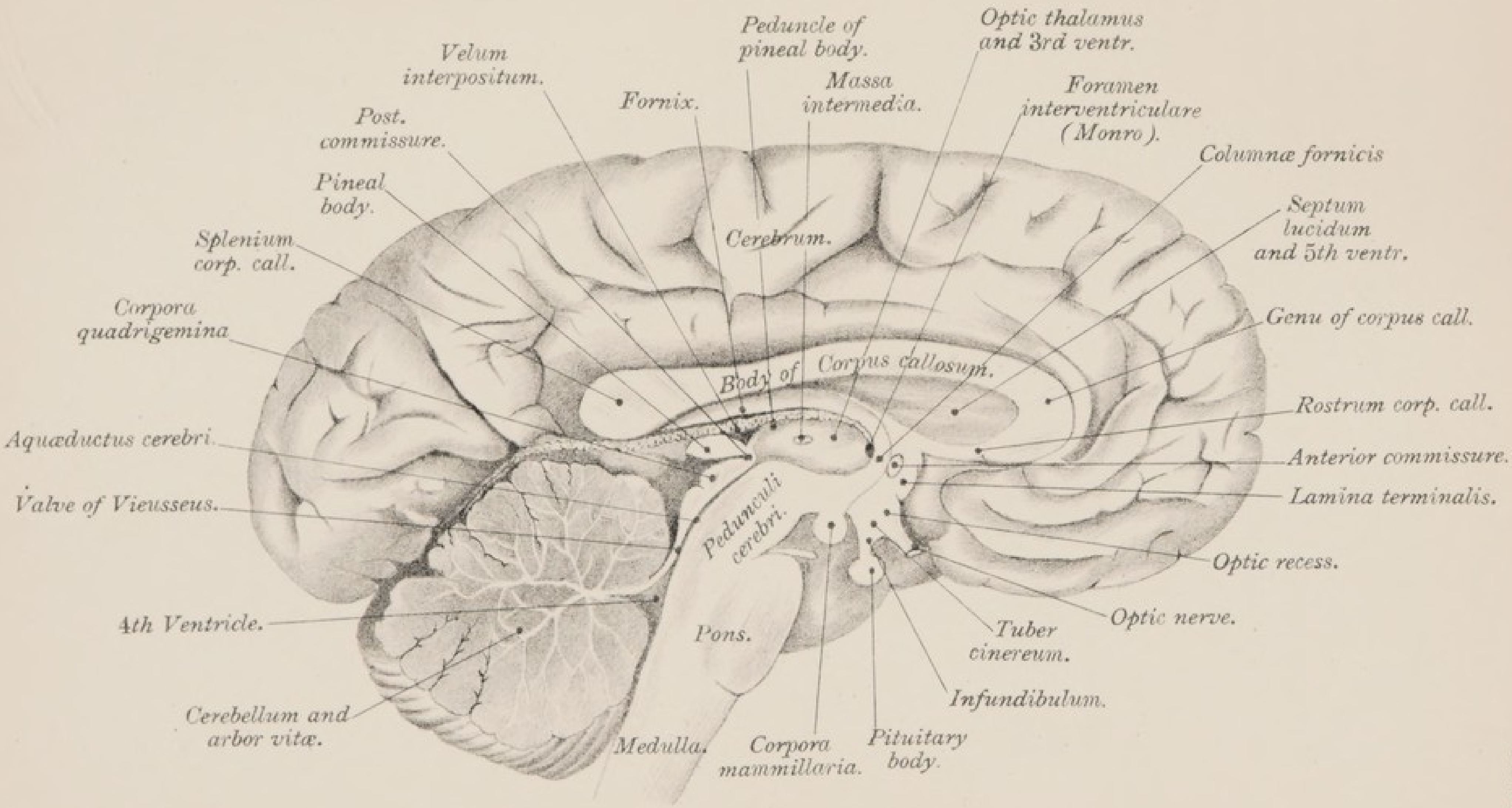
Projecting downwards from the tuber cinereum is a funnel-shaped process, (*h*) the INFUNDIBULUM (fig. 67, page 136), to the apex of which is attached (in the entire brain) the posterior of the two lobes of the (*i*) PITUITARY BODY (fig. 67, page 136).

Behind the tuber cinereum, between it and the cerebral peduncles, are two small rounded, pea-shaped nodules, (*j*) the CORPORA MAMMILLARIA or ALBICANTIA (fig. 66, page 134), which we shall afterwards see are closely connected with the fornix. Between the corpora mammillaria and the tuber cinereum is a small vascular, trefoil-shaped eminence — the EMINENTIA SACCULARIS—homologous with the saccus vasculosus of lower vertebrata. Behind the corpora mammillaria, between the diverging cerebral peduncles, lies the POSTERIOR PERFORATED SPACE—pons Tarini—a grey lamina similar to the anterior perforated space, and, like it, perforated for the passage of blood-vessels into the interior of the cerebrum (fig. 66, page 134).

Of these several structures the only ones requiring further notice at this stage are the pituitary body and the lamina cinerea.

1. The HYPOPHYSIS CEREBRI or PITUITARY BODY is usually left in the sella turcica when removing the brain. Oval in shape, it has a reddish colour, and consists of two lobes, an anterior and a posterior, separated from each other by the pars intermedia. The anterior lobe consists of network of connective tissue and of epithelial cells. It is originally a hollow prolongation from the pharynx, but subsequently becomes solid. The posterior lobe is a downward tubular prolongation of the floor of the diencephalon —the cavity from which the 3rd ventricle is formed. It consists of a reticulum of fine nerve fibres embedded in a network of connective tissue and neuroglia. The pars intermedia consists of epithelial cells like the anterior lobe. The pituitary body in some way modifies the nutrition of the body.

FIG. 67.



Mesial Section of Brain.

2. The LAMINA CINEREA is a triangular-shaped membrane, composed of two grey layers, right and left, separated from each other in the mid-line by a very thin portion, almost transparent—the *lamina terminalis*—which closes the 3rd ventricle below and in front. Placed between and attached to the peduncles of the corpus callosum in front, the lamina cinerea is continuous behind with the tuber cinereum, and at the sides with the anterior perforated spaces. The lamina terminalis is the remains of the central part of the original wall of the anterior cerebral vesicle (see Development, page 212).

TABLE OF OBJECTS SEEN ON THE BASE OF THE BRAIN.

(Fig. 66, Plate XX. Page 134.)

1. The Cerebellum.
2. The Medulla.
3. The Pons.
4. The Crura Cerebri.
5. Interpeduncular space.
   - (a) Posterior perforated spot.
   - (b) Corpora mammillaria or albicantia
   - (c) Eminentia saccularis.
   - (d) Hypophysis cerebri or pituitary body.
   - (e) Infundibulum.
   - (f) Tuber cinereum.
   - (g) Optic commissure — optic nerves—optic tracts.
6. Anterior perforated spots.
7. Corpus Callosum—rostrum—peduncles.
8. The Cranial Nerves.
9. Under aspects of frontal, temporal, and occipital lobes.
10. Fissura cerebri lateralis (Sylvius) and part of great longitudinal fissure.
11. Blood-vessels—Circle of Willis.

Cranial Nerves.—We may now turn our attention to the superficial origins of the cranial nerves.

1. On the under aspect of the frontal lobe, lying in the olfactory groove, is the olfactory bulb, often called the 1st nerve. From it arise the olfactory nerves :—

2. Springing from the fore and outer part of the optic commissure on each side are the optic nerves—the 2nd nerves.

3. At the upper or anterior border of the pons, internal to the crura cerebri, are the 3rd nerves—motores oculi.

4. At this same border, but external to the cerebral peduncles, are the 4th nerves—pathetici.

5. At the side of the pons, where it becomes the middle peduncle of the cerebellum, are the 5th nerves—trifacial.

6. At the lower border of the pons, near the middle line, are the 6th nerves—abducentes.

7. At a little distance from the middle line are the 7th—facial—and 8th—auditory nerves.

8. On the side of the medulla, behind and external to the olivary body, are the 9th nerve—glosso-pharyngeal, 10th nerve—vagus, and 11th nerve—spinal accessory,—in this order from above downwards.

9. In front of and internal to the olivary body arises the 12th nerve—hypoglossal.

TABLE OF CRANIAL NERVES.

	NAMES.	
1st nerve.	Olfactory—sense of smell.	
2nd ,,	Optic—sense of sight.	
3rd ,,	Oculo-motor—motor.	
4th ,,	Patheticus or Trochlearis—motor.	
5th ,,	Trigeminus or Trifacial—mixed, *i.e.* motor and sensory.	
6th ,,	Abducens—motor.	
7th ,,	Facial—mixed.	
8th ,,	Auditory—sensory . .	Cochlear division—hearing. Vestibular division—equilibrium.

9th	nerve.	Glosso-pharyngeal—mixed.
10th	,,	Vagus—mixed.
11th	,,	Spinal Accessory—motor.
12th	,,	Hypoglossal—motor.

(For the further account of these nerves, see Superficial and Deep Origins of the Cranial Nerves, page 176.)

III. INTERIOR OF THE CEREBRUM.

(Fig. 68, Page 140; Fig. 72, Page 148.)

GENERAL OUTLINE.—We now proceed to examine the interior of the cerebrum. This we do by a series of horizontal and vertical sections (see Dissection, page 141).

Above the level of the corpus callosum, each hemisphere consists of a solid white central core—*centrum ovale*, composed of strands of nerve fibres, surrounded externally by a wavy layer of grey matter—the *cerebral cortex.*

Ventricles.—Below the level of the corpus callosum, however, the interior of the cerebrum is occupied by an irregular cavity, the remains of the neural canal from the walls of which the brain and spinal cord are developed (see Development). This cavity, somewhat T-shaped in coronal section (fig. 77, page 164), is subdivided by partitions 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 each hemisphere. Uniting these various ventricles with each other are narrow passages or channels, constricted portions of the original neural tube. Thus, in front, as we shall afterwards see, are the FORAMINA INTERVENTRICULARES—*foramina of Monro*—which connect the lateral ventricles with the 3rd ventricle and with each other (fig. 67, page 136); and behind is the passage called the AQUÆDUCTUS CEREBRI—*aqueduct of Sylvius*—or iter a tertio ad quartum ventriculum (fig. 67, page 136).

Basal Ganglia.—Besides the white nerve matter and the central cavity, the interior of the cerebrum is occupied by large masses of grey matter—ganglionic masses, *basal ganglia*—the chief of which are the CORPORA STRIATA, which belong to the telencephalon; the OPTIC THALAMI and the CORPORA GENICULATA, which belong to the diencephalon; and the CORPORA QUADRIGEMINA, which belong to the mesencephalon (see Development, page 209). Each hemisphere, therefore, forms a kind of shell enclosing and overlapping the basal ganglia.

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

We shall describe—(1) the VENTRICLES, with their communications and septa; (2) the BASAL GANGLIA; (3) the COMMISSURES and other STRANDS of FIBRES; but, before doing so, we shall give *seriatim* the dissections required to expose these several parts, so that the subsequent description of them may be less disconnected and more easily understood.

Lateral Ventricles.

FIG. 68.

C.C. *Corpus callosum.*

N.C. *Nucleus caudatus of corpus striatum.*

S.T. *Stria terminalis*

O.T. *Optic thalamus.*

C.P. *Choroid plexus.*

F. *Fornix—posterior pillar.*

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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 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 majus*, under which term is included the whole area now exposed. The upper surface of the corpus callosum is marked by a mesial groove, the *raphe*, 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 of 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. 68,	page 140).
(2)	The stria terminalis or 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 down-

wards and outwards into the temporal lobe—the *descending* or *lateral horn.*

In the posterior horn you will see the *hippocampus minor* and the *bulb* of the posterior horn (fig. 70, page 144); in the descending horn, the *hippocampus major*, the *pes hippocampi* (fig. 70, page 144), the *tænia hippocampi*, and part of the *choroid plexus* of the lateral ventricles (fig. 70, page 144).

C. To expose the Fornix, the Septum Lucidum, and the 5th Ventricle (Fig. 70, Page 144).

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 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 the two are blended together. This will expose the *body of the fornix.*

D. To expose the Velum Interpositum and the 3rd Ventricle (Fig. 71, Page 146, and Fig. 72, Page 148).

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 *columnæ fornicis* or *anterior pillars of the fornix*, and the *foramina interventriculares* or *foramina of Monro*; behind are the *pineal gland* and its *peduncles*; the *posterior commissure*, the *corpora quadrigemina*, and the *aquæductus cerebri* or *aqueduct of Sylvius*; while crossing the space transversely is the *middle commissure* or *massa intermedia.*

Cerebrum—Lateral Ventricle.

FIG. 69.

A.C.	*Anterior cornu.*	F.Mi.	*Forceps minor.*
N.C.	*Nucleus caudatus.*	G.C.C.	*Genu corporis callosi.*
S.T.	*Stria terminalis.*	M.L.S.	*Median longitudinal striæ.*
O.T.	*Optic thalamus.*	B.C.C.	*Body corporis callosi*
C.P.	*Choroid plexus.*	S.C.C.	*Splenium corporis callosi.*
H.Mi.	*Hippocampus minor*	F.Ma.	*Forceps major.*
P.C	*Posterior cornu.*		

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I. VENTRICLES OF THE BRAIN.

(Figs. 68, etc., Plates XXII., etc., Pages 140 to 148.)

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 neural canal, and are continuous with each other and with the ventricle or central canal of the spinal cord. The 5th ventricle, on the other hand, belongs to a different category from 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 neural 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 107).

THE LATERAL VENTRICLES.

(1st and 2nd.)

The LATERAL VENTRICLES, or ventricles of the hemispheres, are two irregular crescent-shaped cavities, right and left, hollowed out in the substance of the cerebral hemispheres (fig. 68, page 140, and fig. 70, page 144). Placed back to back, each ventricle consists of a central part or BODY, and of three prolongations or recesses called the ANTERIOR, the POSTERIOR, and the descending or LATERAL HORNS (fig. 70, page 144).

The Body of the Ventricle 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 roo. and sloping floor meet and blend with the substance of the hemispheres.

The *roof* of the lateral ventricles is formed by the CORPUS CALLOSUM.

The *floor* presents from before backwards—(*a*) a small part of the CORPUS CALLOSUM where it turns down in the longitudinal fissure; (*b*) a club-shaped eminence — the NUCLEUS CAUDATUS of the corpus striatum; (*c*) 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 (*d*) the STRIA TERMINALIS or *tænia semicircularis.* Resting on the optic thalamus is (*e*) the vascular fringe—the CHOROID PLEXUS of the lateral ventricles; and, finally, close to this fringe, nearer the middle line, is (*f*) the thin, sickle-shaped, free edge of the BODY of the FORNIX.

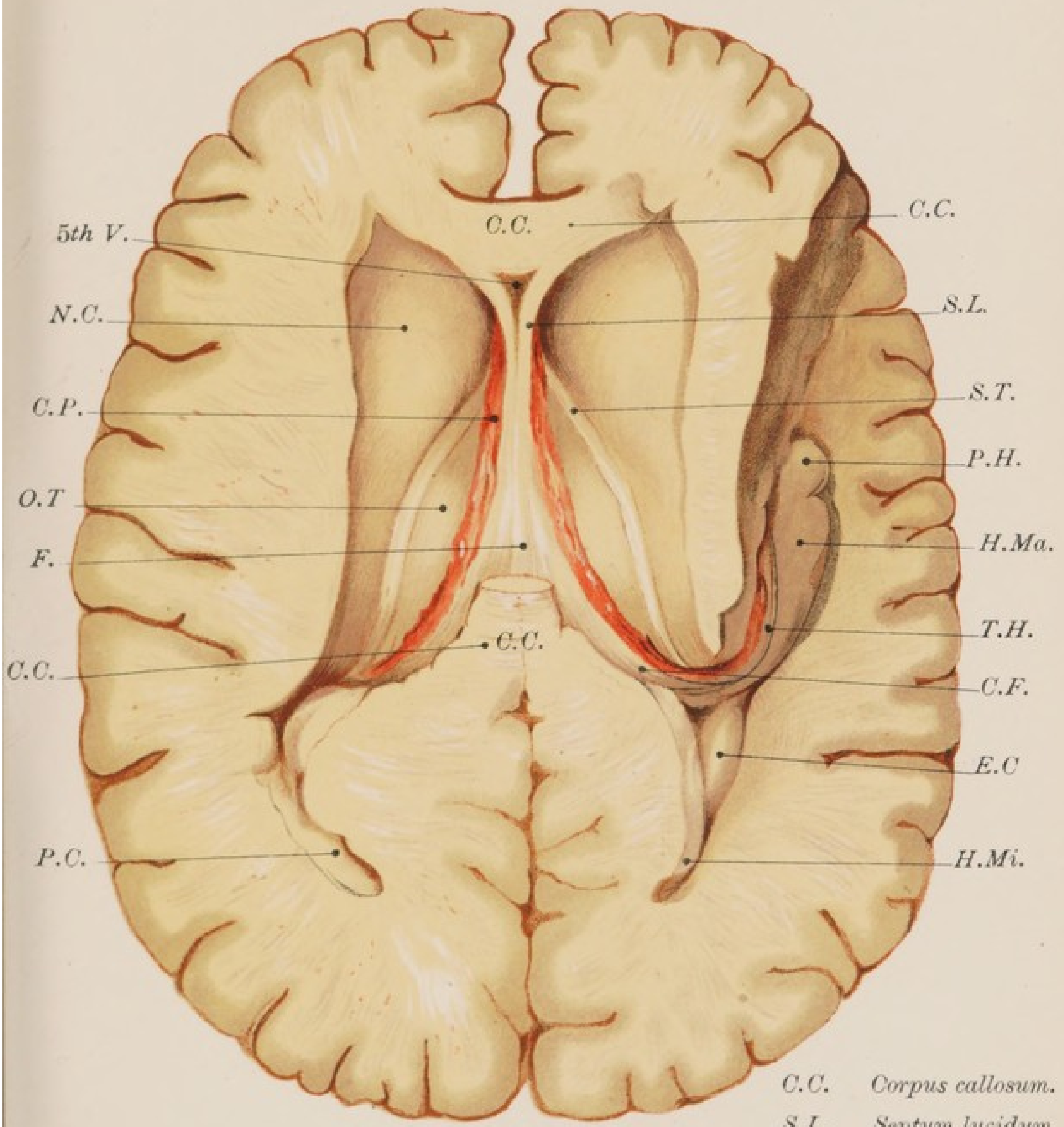
In front, the *inner wall* of the ventricle is formed by a thin, double, vertical, triangular, mesial partition —the SEPTUM LUCIDUM—which extends between the corpus callosum and the fornix. Behind, however, the septum lucidum tapers to a point, and the floor, formed by the fornix, and the roof, formed by the corpus callosum, blend together in the middle line, so that there is no longer an inner wall.

Externally, the floor, which slopes upwards and outwards, meets the roof in the mass of the hemispheres, so that there is no outer wall.

The Cornua of the Ventricles are three in number—anterior, posterior, and lateral or descending (figs. 70, etc., page 144).

Cerebrum—Lateral Ventricles.

FIG. 70.



C.C. *Corpus callosum.*
S.L. *Septum lucidum.*

5th V. *5th Ventricle.*
N.C. *Nucleus caudatus.*
C.P. *Choroid plexus.*
O.T. *Optic thalamus.*
F. *Fornix.*
C.C. *Corpus callosum.*
P.C. *Posterior cornu.*

S.T. *Stria terminalis.*
P.H. *Pes hippocampi.*
H.Ma. *Hippocampus major.*
T.H. *Tinea hippocampi.*
C.F. *Crura fornicis.*
E.C. *Eminentea collateralis.*
H.Mi. *Hippocampus minor.*

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1. **The Anterior Cornu** or horn is a short conical, curved, horn-shaped cavity, which turns 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*, its *anterior wall*, and its *floor* are formed by the CORPUS CALLOSUM; its *inner wall* by the SEPTUM LUCIDUM; while *behind* is the NUCLEUS CAUDATUS.

2. **The Posterior Cornu** or horn is a similar recess, passing outwards at first, then backwards and inwards into the substance of the occipital lobe.

Its *roof* is formed by the CORPUS CALLOSUM; its *floor* by the substance of the occipital lobe and by an oval prominence—the HIPPOCAMPUS MINOR, caused by the calcarine sulcus seen on the mesial surface of the hemisphere (fig. 75, page 154). Above the hippocampus is a slight ridge—the BULB of the POSTERIOR HORN—caused by a radiating bundle of fibres of the corpus callosum, and called the *forceps minor*.

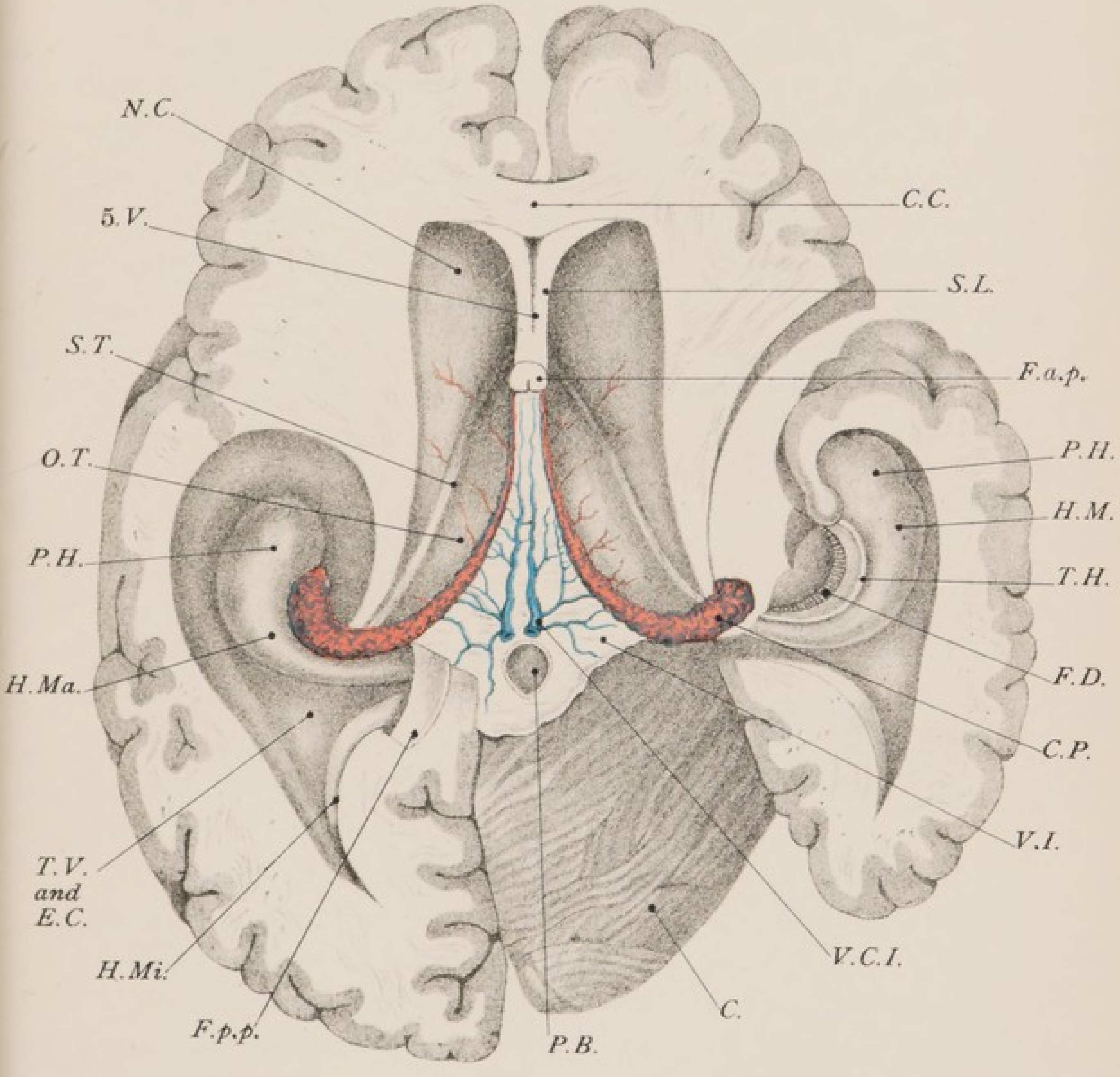
3. **The Lateral Cornu**—descending or inferior horn—curves round the posterior end of the optic thalamus as a bent finger-like passage with its convexity outwards. It runs first backwards and outwards, then downwards, forwards, and finally inwards (B.O.D.F.I.) in the substance of the temporal lobe (fig. 70, page 144).

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

In the *floor* of the passage lies a curved elongated projection following the bend of the horn, and called the HIPPOCAMPUS MAJOR or 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 crura fornicis or posterior pillars of the fornix. Above and internal to the fimbria is the CHOROID PLEXUS of the lateral ventricles, which at this point projects into the ventricular cavities through the lateral part of what is known as the *great transverse fissure* of the cerebrum (see page 151). Below the fimbria is the free edge of the grey matter of the cortex, which, owing to the notched appearance caused by the entrance over its free edge of the branches of the choroidal artery, receives the name FASCIA DENTATA. The choroidal artery carries with it into the lateral ventricles a process of pia mater—the *velum interpositum*—in the free margin of which the branches of the artery break up into the choroid plexus of the lateral ventricles (see Velum Interpositum, page 150).

At the point where the lateral and posterior horns diverge from each other you will see a triangular area—the trigonum ventriculi—marked by a slight eminence—the EMINENTIA COLLATERALIS—varying in size in different subjects. It is caused by the collateral fissure on the surface of the brain (fig. 75, page 154).

FIG. 71.



N.C. *Nucleus caudatus.*
5.*V.* *5th ventricle.*
S.T. *Stria terminalis.*
O.T. *Optic thalamus.*
P.H. *Pes hippocampi.*
H.Ma. *Hippocampus major.*
T.V. *Trigonum ventriculi.*
E.C. *Eminentia collateralis.*
H.Mi. *Hippocampus minor.*
F.p.p. *Fornix (posterior pillars) cut.*
P.B. *Pineal body.*

C.C. *Corpus callosum.*
S.L. *Septum lucidum.*
F.a.p. *Fornix (anterior pillars) cut.*
P.H. *Pes hippocampi.*
H.M. *Hippocampus major.*
T.H. *Tænia hippocampi.*
F.D. *Fascia dentata.*
C.P. *Choroid plexus.*
V.I. *Velum interpositum.*
V.C.I. *Venæ cerebri internæ.*
C. *Cerebellum.*

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

Communications.—Between the fornix in front and the optic thalami behind are two slit-like openings, one on each side—the FORAMINA INTERVENTRICULARES (Monro) (fig. 67, page 136). By means of these openings the two lateral ventricles communicate directly with the 3rd ventricle, and indirectly with each other. Through these same foramina, as we shall afterwards see, the choroid plexuses of the lateral ventricles are continuous with those of the 3rd ventricle.

THE 3RD VENTRICLE.

The 3RD VENTRICLE (fig. 72, page 148; fig. 77, page 164) is the narrow, vertical, cleft-like space situated in the middle line of the cerebrum, between the two 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.

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

In its *floor* are the dorsal part of the cerebral peduncles and the structures contained within the interpeduncular space at the base of the brain (fig. 67, page 136), viz. the LOCUS PERFORATUS POSTICUS, the CORPORA MAMMILLARIA, the EMINENTIA SACCULARIS, the TUBER CINEREUM, the INFUNDIBULUM, and the OPTIC CHIASMA.

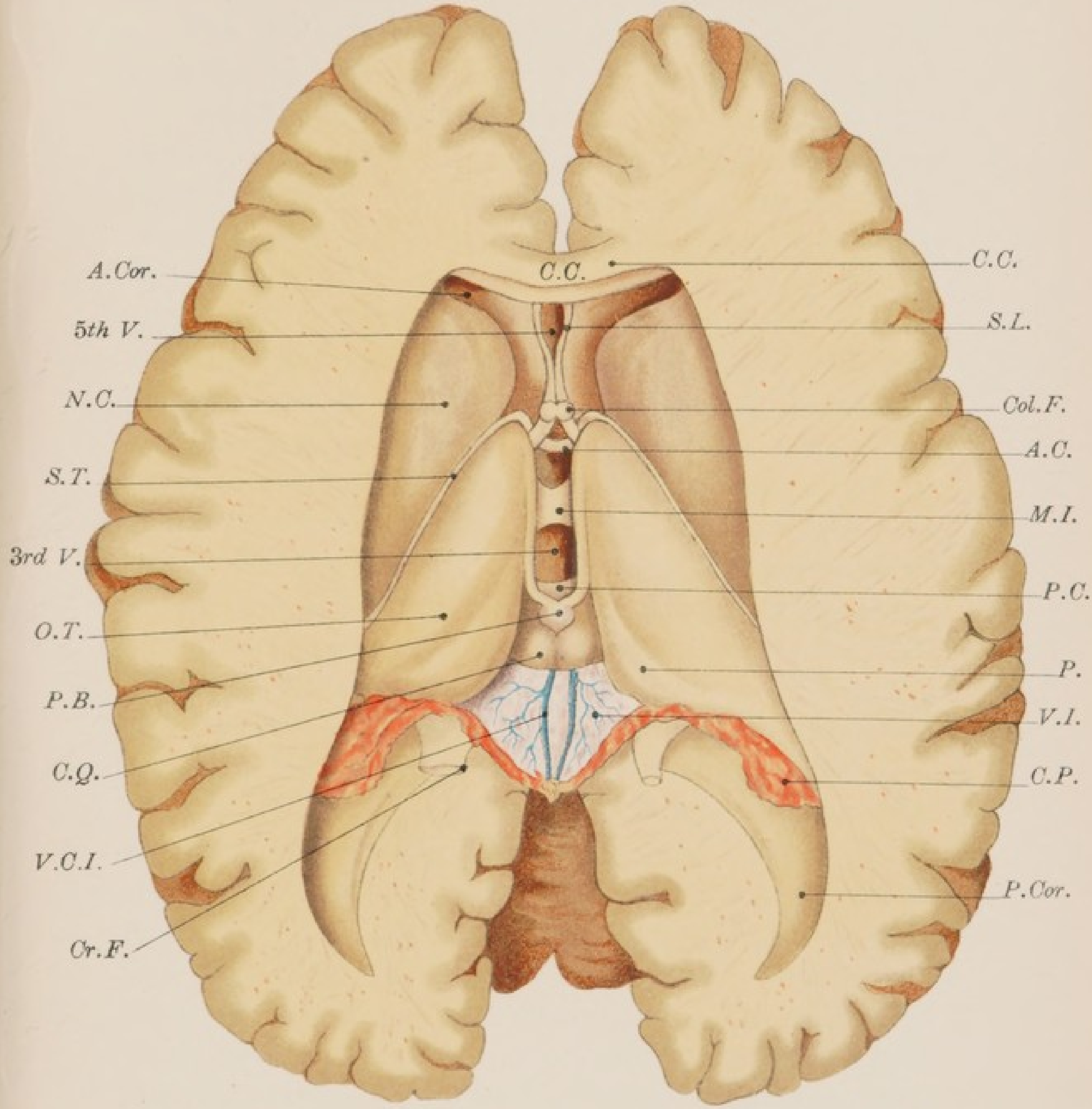
In *front*, the ventricle is limited by the COLUMNÆ FORNICIS, or *Anterior Pillars* of the *Fornix*, by the ANTERIOR COMMISSURE, and by the LAMINA CINEREA and TERMINALIS; *behind*, by the AQUÆDUCTUS CEREBRI (Sylvius) and by the POSTERIOR COMMISSURE, above which is the base of the PINEAL GLAND. At the *sides* the walls of the cavity are formed by the inner or vertical faces of 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 delicate, broad, grey band—the MASSA INTERMEDIA—the middle, soft, or grey commissure. In the floor, between the lamina terminalis and the optic chiasma, is a slight recess, the optic recess.

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 aquæductus cerebri (Sylvius). This grey matter comes to the surface of the brain, at the posterior perforated spot, at the tuber cinereum, and at the lamina cinerea.

Communications.—The 3rd ventricle communicates in front, through the FORAMINA INTERVENTRICULARES (Monro) with the lateral ventricles; behind, through a narrow passage—the AQUÆDUCTUS CEREBRI (Sylvius)—with the 4th ventricle; and below, at the

Cerebrum—3rd Ventricle.

FIG. 72.



A.Cor.	*Anterior cornu.*	*C.C.*	*Corpus callosum.*
5th V.	*5th Ventricle.*	*S.L.*	*Septum lucidum.*
N.C.	*Nucleus caudatus.*	*Col.F.*	*Columnæ fornicis.*
S.T.	*Stria terminalis.*	*A.C.*	*Anterior commissure.*
3rd V.	*3rd Ventricle.*	*M.I.*	*Massa intermedia.*
O.T.	*Optic thalamus.*	*P.C.*	*Posterior commissure.*
P.B.	*Pineal body.*	*P.*	*Pulvinar.*
C.Q.	*Corpora quadrigemina.*	*V.I.*	*Velum interpositum.*
V.C.I.	*Venæ cerebri internæ.*	*C.P.*	*Choroid plexus.*
Cr.F.	*Crura fornicis.*	*P.Cor.*	*Posterior cornu.*

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fore part of the floor, by a conical-shaped passage with the infundibulum—ITER AD INFUNDIBULUM.

The 4th ventricle was described on page 107; but it would be well to re-read the section at this stage.

The **5th Ventricle** and the **Septum Lucidum** (Dissection, page 142).—The *Septum Lucidum* is the thin, double, vertical, mesial partition, composed of two layers, which separates the lateral ventricles from each other in front (fig. 67, page 136; fig. 72, page 148; fig. 77, page 164). Triangular in shape, it fills up the interval between the concavity of the knee-shaped bend of the corpus callosum and the anterior pillars 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. Between the two layers of which it is composed, it encloses a narrow slit-like cavity, the 5TH VENTRICLE, or ventricle of the septum, which is placed in front of, and at a higher level than the 3rd ventricle. 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 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, and, like the rest of the lateral ventricles, 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 does it in any way communicate with them.

As we shall see in the section on "Development," the septum lucidum was originally part of the wall of the hemispherical vesicle which became cut off from the general surface by the development of the corpus callosum and fornix (page 213).

The Velum Interpositum (Dissection, page 142) is a thin horizontal partition, which you have already seen in the roof of the 3rd ventricle, and in the floor of the lateral ventricles (fig. 73, page 150). It is a fold of pia mater, which enters the brain through what is known as the great transverse fissure of the cerebrum, thus appearing in the 3rd and lateral ventricles, though separated from their cavities by the epithelium of the ependyma. Triangular in shape, with its apex forwards and its base backwards, the velum interpositum has the same extent as the body of the fornix, so that it reaches from the foramina interventriculares (Monro) in front to the back part or splenium of the corpus callosum behind, beneath which, after investing the pineal gland, it will be seen to be continuous with the rest of the pia mater on the cerebrum and cerebellum (fig. 29, page 44). At the sides, the free edges of the velum interpositum project into the floor of the lateral ventricles, and rest on the upper surfaces of the optic thalami, round the hinder ends of which they pass down into the descending horns of the lateral ventricles, being still continuous with the pia mater of the rest of the brain.

Choroid Plexus (fig. 71, page 146; fig. 73, page 150).—The choroid plexus consists of tortuous ramifications of small blood-vessels, covered with vascular papillæ, over which is a layer of epithelium. Projecting downwards along the middle line of the under aspect of the velum interpositum are two of these vascular fringes—the choroid plexuses of the 3rd ventricle—covered everywhere, however, by the

Velum Interpositum.

FIG. 73.

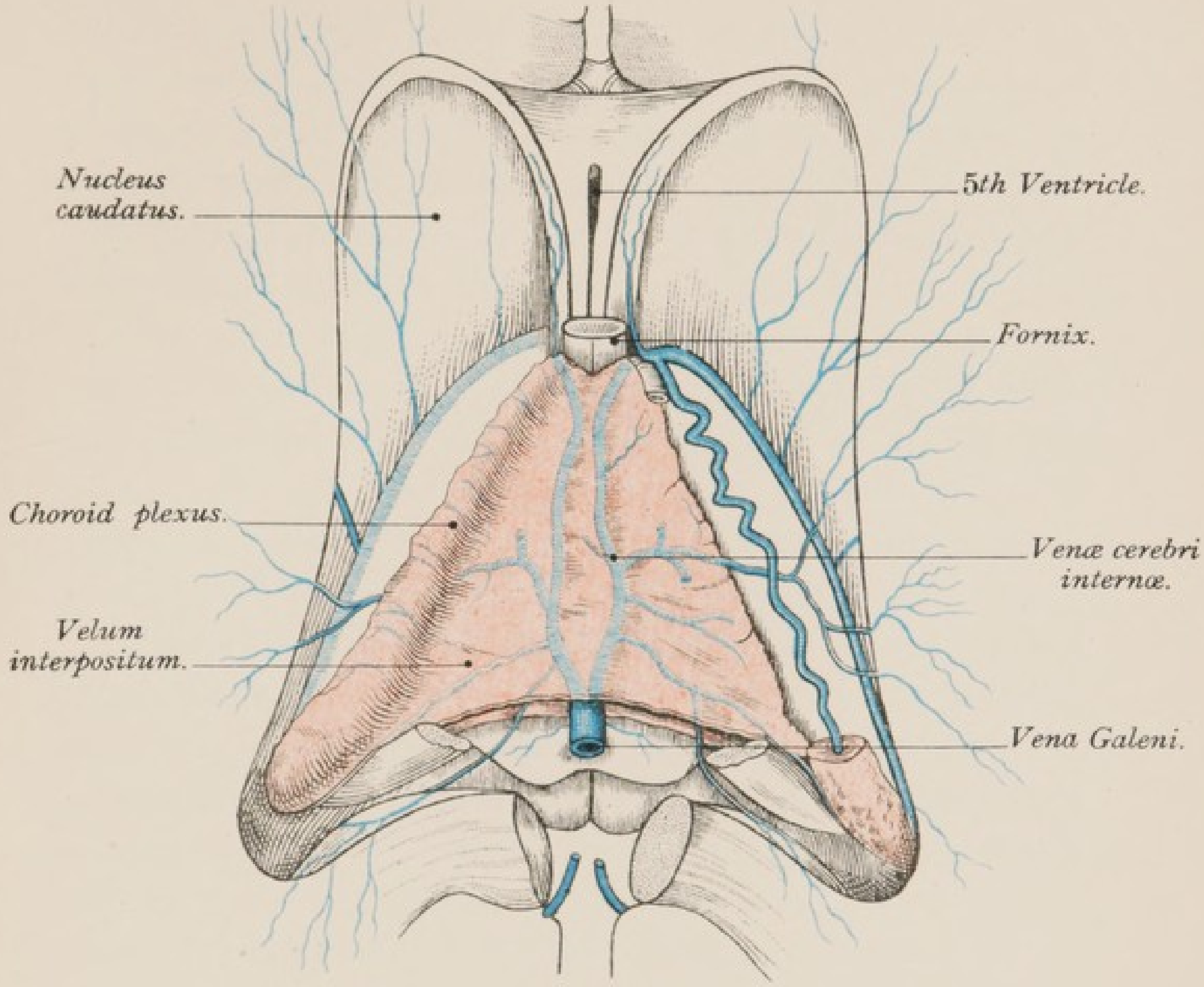
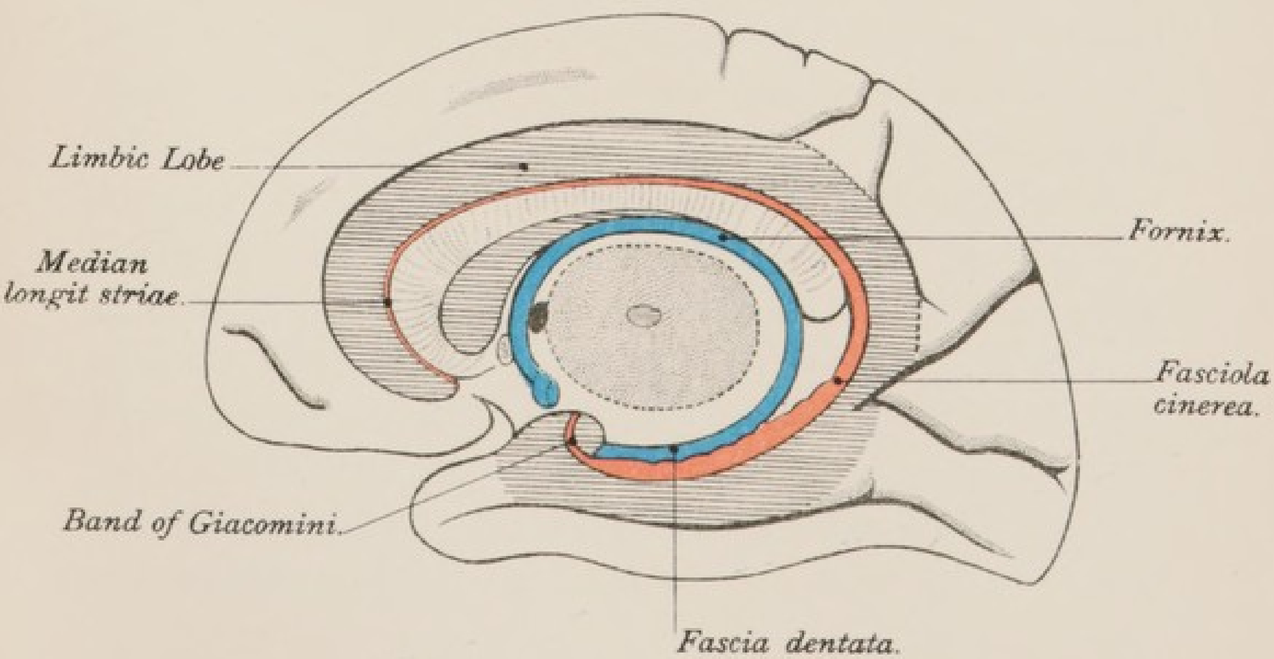


FIG. 74.



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epithelium which forms the roof of that cavity. In each lateral margin of the velum interpositum are similar vascular fringes—the choroid plexuses of the lateral ventricles, which extend from the foramina interventriculares (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 interpositum, as we have just seen, becomes continuous with the rest of the pia mater through the great transverse fissure. As the vascular fringes pass down the lateral horns, they give a prolongation into the posterior horn.

The Venæ Cerebri Internæ (fig. 73, page 150) are two veins which gather up the blood from the corpora striata and from the choroid plexuses, and run backwards, side by side, between the layers of the velum interpositum. Ultimately, uniting to form a single vein—the *vena magna cerebri* or *vena Galeni*—they discharge their blood into the straight sinus.

The Great Transverse Fissure of the cerebrum (fig. 71, page 146) is the large artificial cleft which is made into the lateral ventricles when the pia mater and choroid plexuses, with the epithelium covering them, are torn away from the posterior part of the brain, beneath the fornix, and from the descending cornua of the lateral ventricles. The fissure thus formed is horseshoe-shaped; its central part corresponds to the base of the fornix, its lateral parts to the descending horns of the lateral ventricles. Through this fissure the pia mater and choroid plexuses project into the ventricles, though, as we have before noted, everywhere separated from their cavity by the epithelium which covers them.

The convex or posterior lip of the fissure is bounded *near the middle line* by the posterior part of the corpus callosum and fornix; *on each side* by the free margins of the hemisphere—viz. the fimbria and the fascia dentata.

The concave or anterior lip of the fissure is bounded *near the middle line* by the corpora quadrigemina and cerebral peduncles; *on each side* by the posterior part of the optic thalami.

II. BASAL GANGLIA.

(Fig. 68, Plate XXII. Page 140; Fig. 75, Plate XXVIII. Page 154.)

Under this heading are usually described the four 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 amygdaloid nuclei, the corpora quadrigemina, the corpora geniculata, and the locus niger. The corpora geniculata will be described with the optic thalami; the corpora quadrigemina and the substantia nigra with the pedunculi cerebri.

1. **The Corpora Striata** are two in number, one in each hemisphere. They 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 white substance of the hemisphere (fig. 75, page 154, and fig. 77, page 164).

The Nucleus Caudatus—the *intra-ventricular* portion of the corpus striatum,—so called from its shape (fig. 78, page 164), has been described as a pear-shaped, kite-shaped, pyriform or pyramidal eminence. It has a pinkish-grey colour, and appears in the fore part of the floor of the lateral ventricles (fig. 75, page 154). 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 (fig. 75, page 154). Its larger end or head is directed forwards, and its posterior end or tail, gradually tapering to a point, passes backwards outside the optic thalamus, where it turns downwards, outwards, and forwards, into the roof of the descending horn of the lateral ventricle. It can be traced as far as the tip of the temporal lobe, where it ends in the amygdaloid nucleus, an outgrowth of the cerebral cortex in this region. The nucleus caudatus may thus be said to be horseshoe-shaped and to form an arch with its concavity forwards, one end of the arch being made by the head of the nucleus, the other end by its tail (fig. 78, page 164).

The Nucleus Lenticularis—the *extra-ventricular* part of the corpus striatum—can only be seen in sections of the hemispheres (fig. 75, page 154; fig. 77, page 164). In horizontal sections it appears as a longitudinal grey mass, shaped like a double convex lens (lenticularis). It is placed external to both the nucleus caudatus and to the optic thalamus, being separated from them by a strand of white nerve fibres, called the *internal capsule* (fig. 75, page 154; fig. 77, page 164). In coronal 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. 77, page 164). The internal and middle portions have a paler hue, hence the name *globus pallidus* applied to them; the external segment is darker, and is called the *putamen*—clippings, shells (fig. 77, page 164). In front and below the nucleus caudatus and the nucleus lenticularis are continuous with each other, and with the grey matter at the anterior perforated space.

Claustrum.—External to the nucleus lenticularis will be seen a narrow longitudinal band or streak of grey matter—the *claustrum*—separated from the nucleus lenticularis by a strand of white nerve fibres, the *external capsule* (fig. 75, page 154), and from the contiguous grey matter of the isle of Reil by a second white strand, the white matter of the isle of Reil. Thus, enumerated from within outwards, we have (fig. 75, page 154, and fig. 77, page 164)—

(1) The nucleus caudatus.

(2) The internal capsule.

(3) The nucleus lenticularis.

(4) The external capsule.

(5) The claustrum.

(6) A strand of white fibres—the white matter of the isle of Reil.

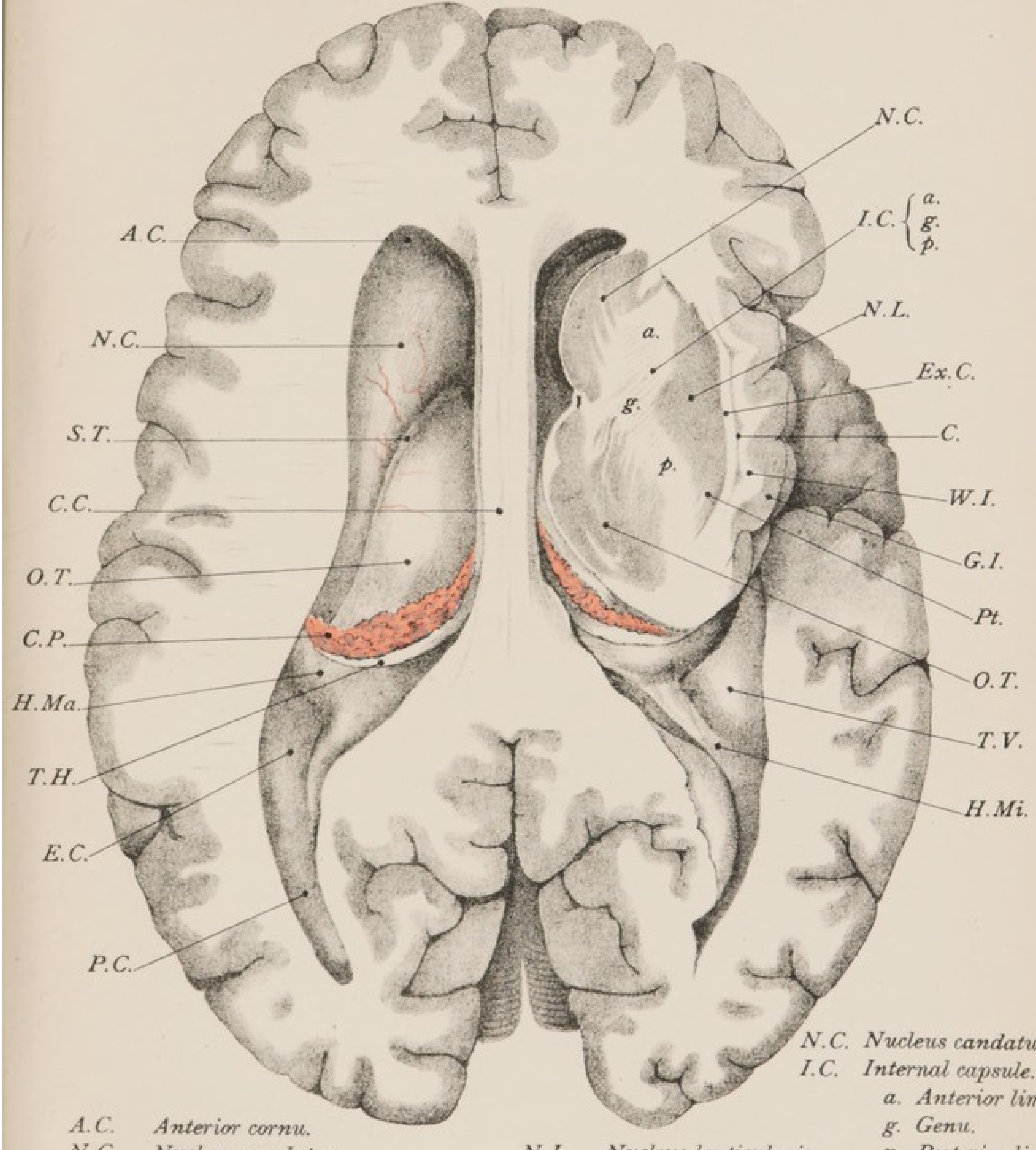
(7) The grey matter of the surface—the grey matter of the isle of Reil (fig. 75, page 154).

The nucleus lenticularis, the claustrum, and the tail of the caudate nucleus are continuous below and in front with the amygdaloid nucleus, which is a thickened part of the cortex of the temporal lobe. It is seen at the anterior end of the descending horn of the lateral ventricles.

By some authors the claustrum is regarded as part of the lenticular nucleus, by others as a well-developed fifth layer of the cerebral cortex.

2. **The Optic Thalami** are two large, oval, convex

FIG. 75.



N.C. *Nucleus candatus.*
I.C. *Internal capsule.*
a. *Anterior limb.*
g. *Genu.*
p. *Posterior limb.*

A.C. *Anterior cornu.*
N.C. *Nucleus caudatus.*
S.T. *Stria terminalis.*
C.C. *Corpus callosum.*
O.T. *Optic thalamus,*
C.P. *Choroid plexus.*
H.Ma. *Hippocampus Major.*
T.H. *Tænia hippocampi.*
E.C. *Eminentia collateralis.*
P.C. *Posterior cornu.*

N.L. *Nucleus lenticularis.*
Ex.C. *External capsule.*
C. *Claustrum.*
W.I. *White matter of Isle of Reil.*
G.I. *Grey matter of Isle of Reil.*
Pt. *Putamen.*
O.T. *Optic thalamus.*
T.V. *Trigonum ventriculi.*
H.Mi. *Hippocampus minor.*

prominences, right and left, placed above the cerebral peduncles, but behind and internal to the corpora striata, from which they are separated by the *striæ terminales* (tæniæ semicirculares). Forming part of the floor of the lateral ventricle and the walls of the 3rd ventricle, each optic thalamus consists of a central grey core, covered on the surface by a stratum of white matter. They have four surfaces and two ends, and, where they enter into the formation of the ventricular cavities, are clothed by ependyma and epithelium. Their anterior end is rounded—*anterior tubercle*; and their posterior and external end swells out into a prominence—the *posterior tubercle* or *pulvinar* (fig. 72, page 148)—which overhangs both the brachia of the corpora quadrigemina, and the two oval nodules called the *corpora geniculata interna* and *externa* (fig. 59, page 104). The pulvinar, where it is free, forms part of the roof of the descending horn of the lateral ventricle.

The *upper* (*horizontal*) *surface* of the thalami optici appears in the floor of the lateral ventricles. Resting upon it is the velum interpositum, which carries the choroid plexus in its outer free edge. The *under surface*, in its hinder part, is placed above the pedunculi cerebri (tegmentum, fig. 59, page 104, and fig. 67, page 136), while more in front it lies over the corpus albicans and the tuber cinereum.

The *inner* (*mesial*) *surfaces* of the optic thalami are vertical and form the lateral walls of the 3rd ventricle. Along them run the peduncles of the pineal body, and above these a shallow groove, the sulcus of Monro, which marks the upper limit of this surface. Passing transversely between the optic thalami is the *massa* *intermedia* or grey commissure. *Externally* the optic thalami are limited by the posterior part of the internal capsule and by the nucleus caudatus.

In front of the optic thalami are the nucleus caudatus and the columnæ fornicis or anterior pillars of the fornix (fig. 67, page 136, and fig. 72, page 148), the latter, afterwards, passing to the base of the brain through the substance of the optic thalamus. Between the optic thalami and the anterior pillars of the fornix are the slit-like clefts—the interventricular foramina (Monro) (fig. 67, page 136)—by means of which the lateral ventricles communicate with the 3rd ventricle.

Behind the optic thalami are the crura fornicis or posterior pillars of the fornix, winding down the descending horn of the lateral ventricle (fig. 70, page 144).

STRUCTURE.—The optic thalami are chiefly composed of grey matter arranged as three nuclei—anterior, outer, and inner (fig. 75, page 154). The course and relations of its white tracts are not yet fully understood.

Both the functions and the morphology of the basal ganglia are undecided. Anatomical appearances seem to be in harmony with the view that these ganglia are terminal stations of certain tracts of the cerebral peduncles: the corpora striata being secondary centres connected with motion; the optic thalami with sensation. In man they 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 oval eminences—the *corpora geniculata interna* and *externa*,—the internal being smaller and mesial to the external, and separated from it by a band of white fibres, one of the roots of the optic tract (fig. 59, page 104).

These geniculate bodies consist of a grey core and of a white cortex. From each proceeds a white band which joins the optic tracts. The band from the internal pair has, however, nothing to do with sight. Similar strands connect the external geniculate bodies to the anterior, and the internal to the posterior pairs of corpora quadrigemina.

The Corpus Pineale or PINEAL GLAND is a reddish, vascular, oval body, situated in the middle line above the orifice of the aquæductus cerebri (Sylvius), in the fore part of the longitudinal groove between the corpora quadrigemina. Firmly attached to the velum interpositum, which gives it a special covering (fig. 72, page 148), this so-called gland is a backward prolongation of the 3rd ventricle and 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 columnæ fornicis or anterior pillars of the fornix. On its ventral aspect, the pineal body is connected with the posterior commissure.

STRUCTURE.—The pineal body is composed of follicles, separated by connective tissue, and filled with epithelial cells, with corpora amylacea, and with calcareous particles, called brain sand. It is probably a rudimentary eye.

The *Arterial Supply* to the *Basal Ganglia* is derived from the anterior, middle, and posterior cerebral arteries.

It will be more fully considered with the arteries to the *Capsules*, page 167.

III. WHITE STRANDS.

White Matter.—The white nerve substance of the brain lies beneath the surface grey matter, and, like that of the spinal cord, is composed both of grey and of white or medullated nerve fibres. The medullated fibres are transverse, longitudinal, and vertical in direction. They are the axis-cylinder processes of the nerve cells of the various layers of the cortex, or of cells at lower levels of the cerebro-spinal system, and are divisible into three groups :—

(1) *Commissural fibres*, which connect identical parts of the two hemispheres.

(2) *Association fibres*, which connect different parts of the same hemisphere.

(3) *Projection fibres*, which connect the grey matter of the hemispheres with the lower parts of the cerebro-spinal axis.

I. The COMMISSURES of the brain are the corpus callosum, the anterior, middle, and posterior commissures.

CORPUS CALLOSUM.

(Fig. 69, Plate XXIII. Page 142 ; Fig. 67, Page 136.)

The Corpus Callosum is, as you already know, the *longitudinal* white band of *transverse* nerve fibres which arches from before backwards, in the middle line, between the two cerebral hemispheres, and connects them together. About four inches long, it forms the floor of the great longitudinal fissure, the roof and part of the floor of the lateral ventricles. It reaches further forwards than backwards, and is thicker at the ends than in the middle of its extent, being 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. 67, page 136). Becoming gradually smaller it then forms a narrow median band—the ROSTRUM (fig. 67, page 136)—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 spots at the root of the fissura cerebri lateralis (Sylvius), and were there lost. Between the peduncles lies the lamina terminalis.

Posteriorly, on the other hand, the corpus callosum ends in a thickened, free, rounded border or base—the SPLENIUM (fig. 67, page 136). From the outer ends of the splenium, two horn-shaped bundles of fibres, the forceps major, diverge into the occipital lobes; and two similar bands, the forceps minor, can be traced from the genu into the frontal lobes (fig. 69, page 142).

The *upper surface* of the corpus callosum is covered by a thin layer of grey matter, and is marked along the middle line by a longitudinal groove—the *raphé*—parallel to which, on each side, you will see two or more faint lines—the *median longitudinal striæ* (nerves of Lancisi) (fig. 69, page 142, and fig. 74, page 150). Externally, under cover of the overhanging edge of the gyrus cinguli (fornicatus), are similar longitudinal striæ—*lateral longitudinal striæ* (tæniæ tectæ—covered bands). The median striæ, when traced forwards, are joined in front by a prolongation of the lateral striæ, and descend with them round the anterior end of the corpus callosum to the peduncles of the corpus callosum; behind, on the other hand, the striæ can be traced into a fine grey lamina—the fasciola cinerea—and then into the fascia dentata (fig. 74, page 150). The striæ longitudinales, the fasciola cinerea, and the fascia dentata form the abortive convolution connected with the sense of smell. It is referred to on pages 127, 177.

In the middle line, the *under surface* of the corpus callosum rests, in the posterior half of its extent, upon the upper surface of the body of the fornix, to which it is closely adherent, especially near the splenium. In its anterior half, its under surface is connected with the vertical mesial partition—the *septum lucidum*—which fills up, as we have seen, the space left between the fornix behind and concavity of the knee-shaped bend of the corpus callosum in front (fig. 67, page 136, and fig. 72, page 148).

Laterally, the transverse fibres of the corpus callosum, at first, form the roof of the lateral ventricles, and then spread out into the white substance of the hemispheres, between the fibres of the corona radiata.

STRUCTURE.—The corpus callosum consists of white nerve fibres which are in the main transverse, a few only being longitudinal. The transverse fibres, as they pass into the hemispheres, diverge in all directions, and go, along with the fibres of the *corona radiata*, to the grey matter of the cortex. They start from the pyramidal cells of the one or the other side of the cortex, and end in ramifications in the pyramidal and molecular cell layers of the opposite side. Many of them are collaterals from the projection system of fibres.

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

The *anterior*, *middle*, and *posterior commissures* are connected with the 3rd ventricle (fig. 67, page 136; fig. 72, page 148).

The Anterior Commissure is a round white cord which passes transversely across the middle line in front of the columnæ fornicis—anterior pillars of the fornix, between them and the lamina terminalis. It connects together the two olfactory lobes, and the two temporal lobes.

The Massa Intermedia—the middle or 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. It is not known whence its fibres come nor where they end.

II. The ASSOCIATION FIBRES are, as you know, those which connect together different parts of the same hemisphere. The *fornix* is the chief bundle; the minor strands are given in the table, page 164.

THE FORNIX.

(Fig. 70, Plate XXIV. Page 144.)

Beneath the corpus callosum, and more or less blended with it, especially behind, is a longitudinal system of association fibres—the FORNIX. It is an arched white band, which can be traced from the hippocampus major to the corpora mammillaria. The fibres of which it is composed spring as two riband-like bands—the FIMBRIÆ—one on each side, from the free surface of the hippocampus major, in the descending horn of the lateral ventricles (fig. 70). Ascending from the concave edge and from the free surface of the hippocampus the two bands or pillars—CRURA FORNICIS—wind 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, which separates it from the optic thalami and from the 3rd ventricle. *Behind*, by its base it blends with the splenium of the corpus callosum. *In front*, its fibres diverge and go downwards and forwards from the apex of the body, as two cylindrical finger-like processes—lying side by side—the COLUMNÆ FORNICIS or anterior pillars of the fornix, which can be traced to the base of the brain, to the *corpora mammillaria*. In this course they lie first in front of, then in the substance of, the optic thalami, but behind the anterior commissure which separates them from the lamina terminalis. At the base of the brain, the pillars make an 8-shaped twist on themselves, form the cortex of the corpora mammillaria, and end in the grey core of these white bodies, from which new fibres ascend, as the bundle of Vicq d'Azyr, to the optic thalami (fig. 81, page 168). As they descend in front of the optic thalami, the anterior pillars of the fornix form, as already explained, one of the boundaries of the small circular foramina—the interventricular foramina (Monro).

At *the sides*, the body of the fornix appears as thin, free, sickle-shaped edges, which rest upon the velum interpositum and enter 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 columnæ and crura fornicis or anterior and posterior pillars of the fornix.

Where the crura fornicis (posterior pillars) diverge from each other, there will be found a triangular space filled up by transverse fibres of white matter. It is called the *lyra* or *psalterium*, and the transverse fibres are commissural between the two hippocampi. 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 Stria Terminalis—*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 (nucleus amygdalæ).

The other association fibres are given in the following table :—

TABLE OF ASSOCIATION FIBRES.

1. Fibres which unite adjacent convolutions.
2. Fibres which unite more distant convolutions, viz. :
   (*a*) Superior longitudinal fasciculus, which connects the convolutions of the frontal, temporal, and occipital lobes.
   (*b*) Inferior longitudinal fasciculus runs through the entire length of the temporal and occipital lobes and unites their convolutions.
   (*c*) The cingulum runs parallel with the convex surface of the corpus callosum. It extends from the anterior perforated space to the hook of the uncinate gyrus.
   (*d*) Uncinate fasciculus connects the frontal pole and the orbital convolutions with the temporal pole.
   (*e*) The perpendicular fasciculus has a vertical course in front of the occipital lobe. It connects the inferior parietal lobule with the fusiform lobe.

III. PROJECTION FIBRES (see page 158).—The chief projection systems of fibres are contained in the internal and external capsules.

INTERNAL AND EXTERNAL CAPSULES.

(Fig. 75, Plate XXVIII. Page 154.)

In treating of the Basal Ganglia you will remember we referred to two strands of white fibres, the INTERNAL and EXTERNAL CAPSULES, the former lying internal to, the latter external to the nucleus lenticularis. Of these so-called capsules, the internal is of the greatest clinical importance, for through it travel the chief

PLATE XXIX.

FIG. 76.

Wall of Lateral Ventricle.

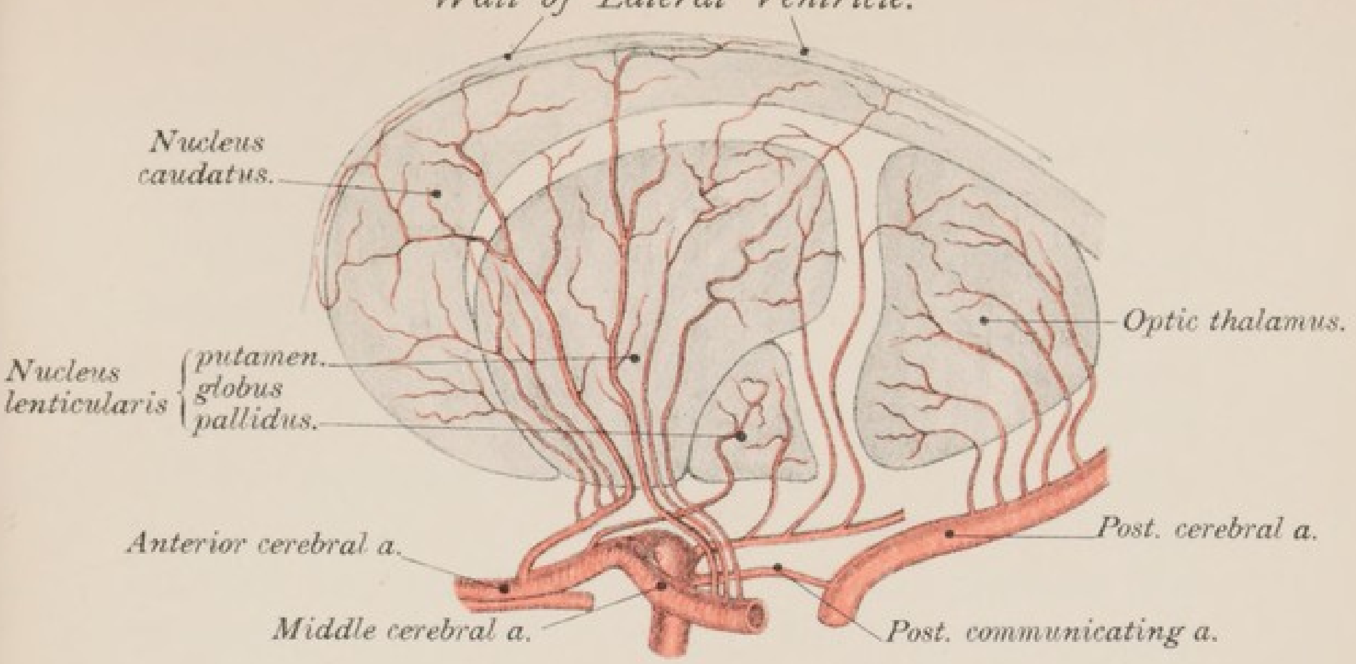


FIG. 77.

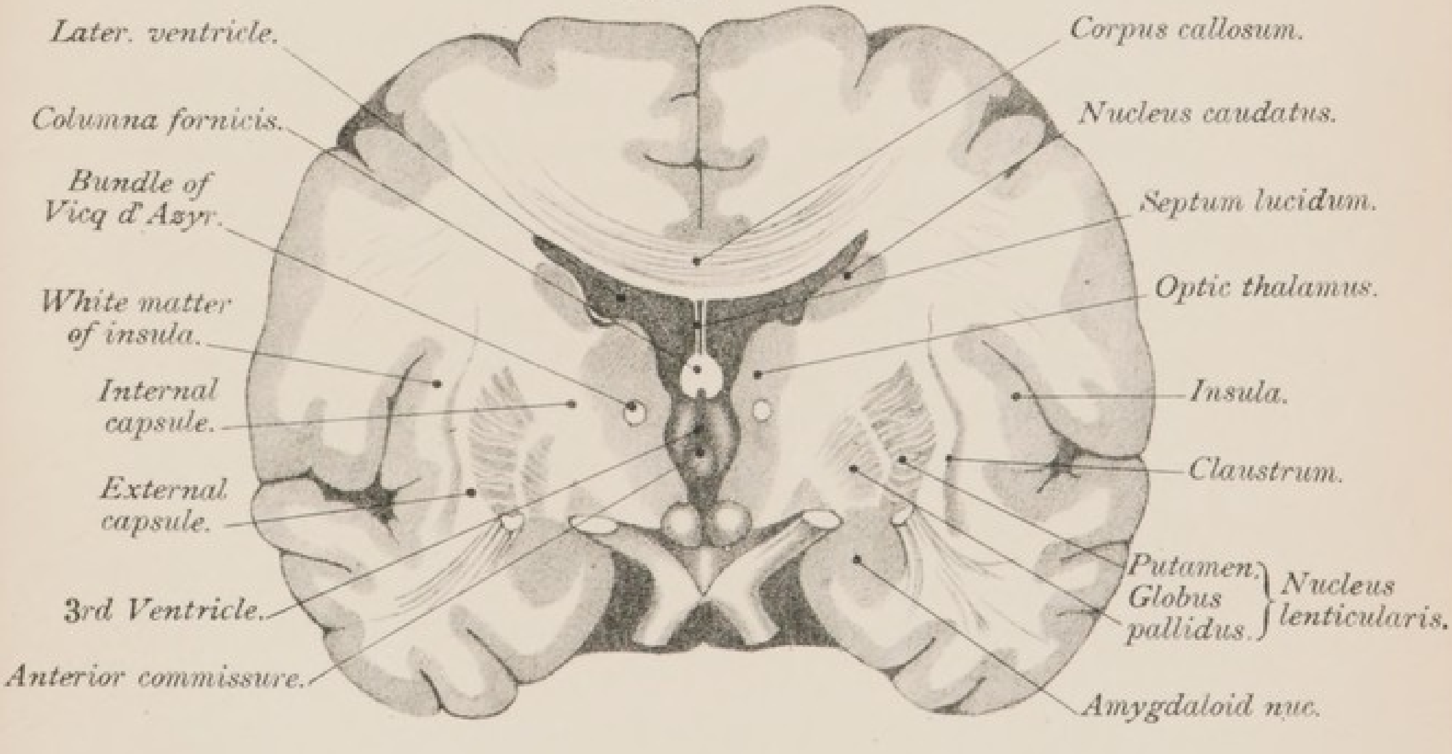
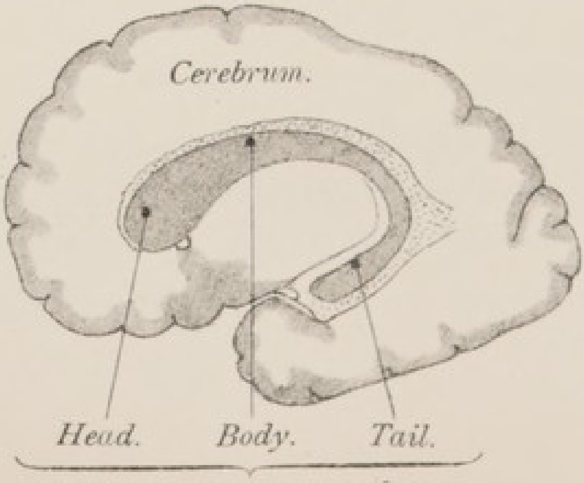


FIG. 78.



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motor and sensory tracts on their way to or from the cerebral cortex.

The Internal Capsules (fig. 75, page 154).—Seen in horizontal section, each internal capsule appears as a longitudinal semi-lunar shaped band of white matter with its convexity directed towards the middle line. It can be divided into three portions—an *anterior*, a *middle*, 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 *middle division* or GENU. The inner capsule therefore has three parts: (1) a knee-shaped bend—the *genu*; (2) a part in front of the knee—*pars frontalis*; and (3) a part behind the knee—*pars occipitalis*. This capsule contains all the fibres of the fore part of the pedunculi cerebri of the same side, except those that go to the basal ganglia. 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 pedunculi cerebri form a radiating, hollow, fan-shaped group of nerve fibres—the CORONA RADIATA—which spread out into the cerebral cortex.

CONSTITUTION OF THE CAPSULES.—In the internal capsule there are the following sets of fibres:—

1. *Posterior Limb.*—(*a*) The tracts forming the knee, and the anterior two-thirds of the posterior limb of the inner capsule are *motor* in function, and are in relation respectively, from before backwards, with the centres for the ocular, oro-lingual, facial, brachial, trunk, and crural muscles. Injury to this portion of the

inner capsule results in loss of motion on the opposite side of the body.

(*b*) Mingled with the motor fibres are others which connect the central convolutions with the nucleus pontis, and, through this nucleus, with the cerebellum of the opposite side. This tract is a *secondary motor tract*. It is ultimately connected with the anterior spinal nerve roots of the opposite side to that at which it left the brain.

(*c*) The posterior third or more of the hinder division of the inner capsule contains *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. These sensory strands, however, unlike the motor, do not form compact bundles, but are mingled with the motor fibres to the lower limbs.

Behind the above-named sensory strands are (1) the *temporo-occipito-pontine* fibres, from the temporal and occipital lobes to the nucleus pontis; (2) the fibres of the *optic radiation*, connected with the centres for sight (fig. 80, page 168); and (3) the fibres of the *auditory radiation*, connected with the centres for hearing.

Thus we see that the posterior limb of the internal capsule and the region immediately behind it carry

(1) Sensations of touch, of temperature, and of pain;

(2) Sensations from muscles and from joints;

(3) Sensations of sight and of hearing.

It may be well to note that the motor fibres for the upper limb are arranged in a different order in the internal capsule from what they are in the cerebral cortex; for whereas in the *cortex*, from above downwards, we have the *centres* for the

Shoulder, elbow, wrist, fingers;

In the *capsule*, from before backwards, we have the *fibres* for the

Fingers, wrist, elbow, shoulder.

2. The *Anterior Limb* of the internal capsule, that part in front of the knee-shaped bend, carries fibres from the basal ganglia—corpus striatum and optic thalamus, and from the fore part of the cerebral cortex—fronto-pontine tracts.

The External Capsule is the thin longitudinal strand of white matter which lies between the nucleus lenticularis and the claustrum. It mostly consists of association fibres, though the tracts which compose it, and their functions, are undecided.

ARTERIAL SUPPLY OF THE CAPSULES AND OF THE BASAL GANGLIA.

When describing the middle cerebral artery, page 56, we saw that it gave off a ganglionic system of arteries—the lenticular, lenticulo-striate, and the lenticulo-optic. The *lenticular* artery supplies the inner and middle parts of the lenticular nucleus and the internal capsule; the *lenticulo-striate* artery is distributed to the outer part of the lenticular nucleus, to the external capsule, and to the caudate nucleus; the *lenticulo-optic* artery goes to the outer and posterior part of the lenticular nucleus and to the outer part of the optic thalamus. The lenticulo-striate artery is called the artery of cerebral hæmorrhage. The fore part of the caudate nucleus is, however, also supplied by the anterior cerebral, and the optic thalamus is supplied by the posterior cerebral and posterior communicating.

Fig. 76, plate XXIX. page 164, will give you an idea of the arterial supply to the capsules and to the basal ganglia.

IV. PEDUNCULI CEREBRI.

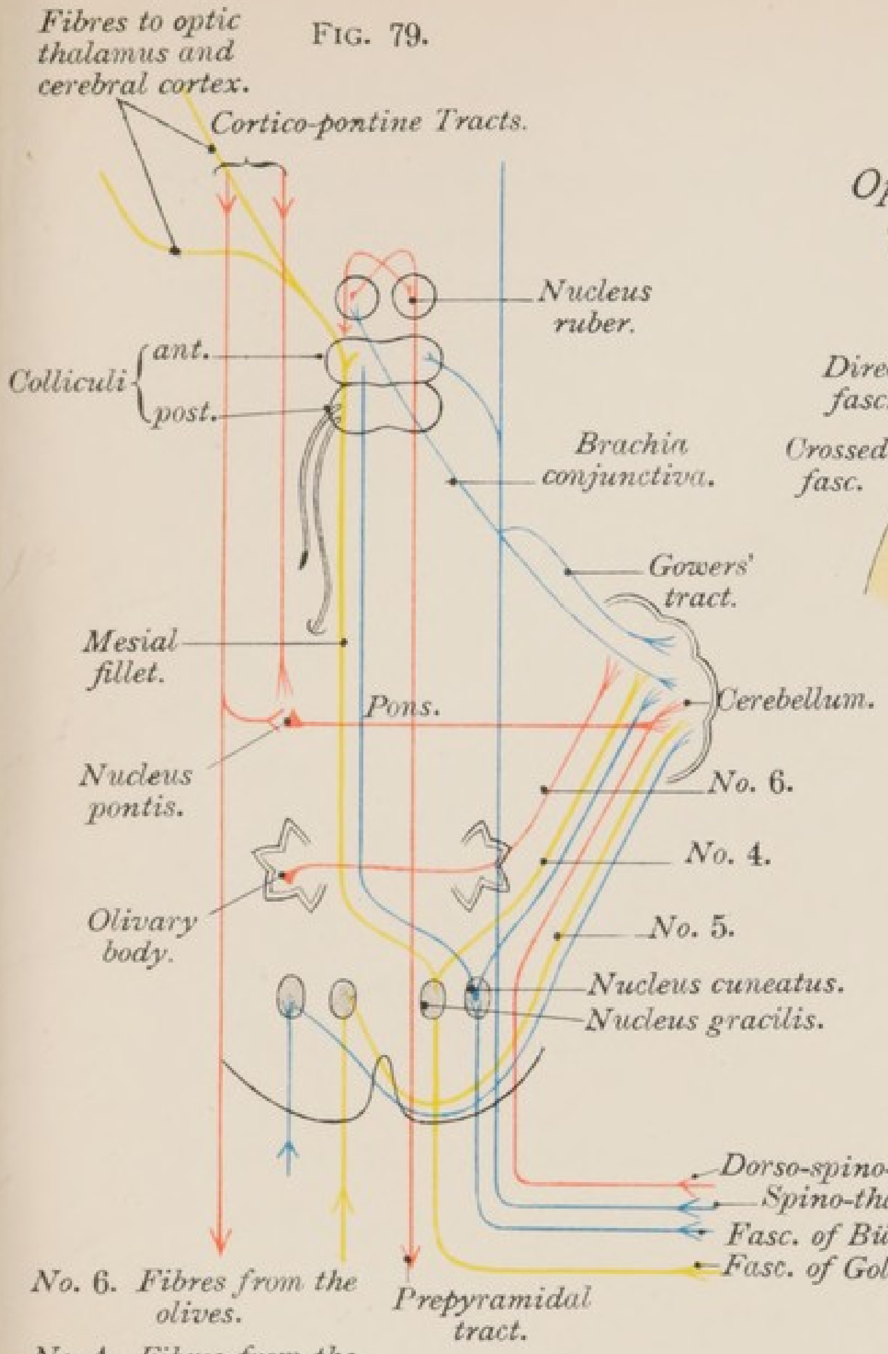
(Fig. 54, Plate XIV. Page 90.)

The pedunculi or crura cerebri belong to that subdivision of the brain called the mesencephalon, or mid-brain. This subdivision also comprises the corpora quadrigemina, the lamina quadrigemina, and the aquæductus cerebri (aqueduct of Sylvius).

The Cerebral Peduncles (fig. 43, page 66) are the two cylindrical masses which you see springing, in front, from the upper margin of the pons. Though on their ventral aspect, the two peduncles are separated from each other by a shallow, vertical mesial groove, they are, in the greater part of their extent, blended together into one mass, the only line of division between them being a mesial raphé. Diverging from each other, and enlarging as they ascend, they soon enter the base of the cerebral hemispheres and bury themselves beneath the optic thalami.

Between the peduncles, where they diverge, will be found the posterior perforated space and two little white bodies, the corpora mammillaria or albicantia (fig. 59, page 104); winding round the outer side of the crura are the optic tracts above, and the 4th nerves below; on their inner side is a groove, the oculomotor groove, from which the 3rd nerve takes its

FIG. 79.



No. 6. Fibres from the olives.

No. 4. Fibres from the nucl. gracilis and cuneatus.

No. 5. External arciform fibres.

FIG. 80.

Optic Nerves and Tracts.

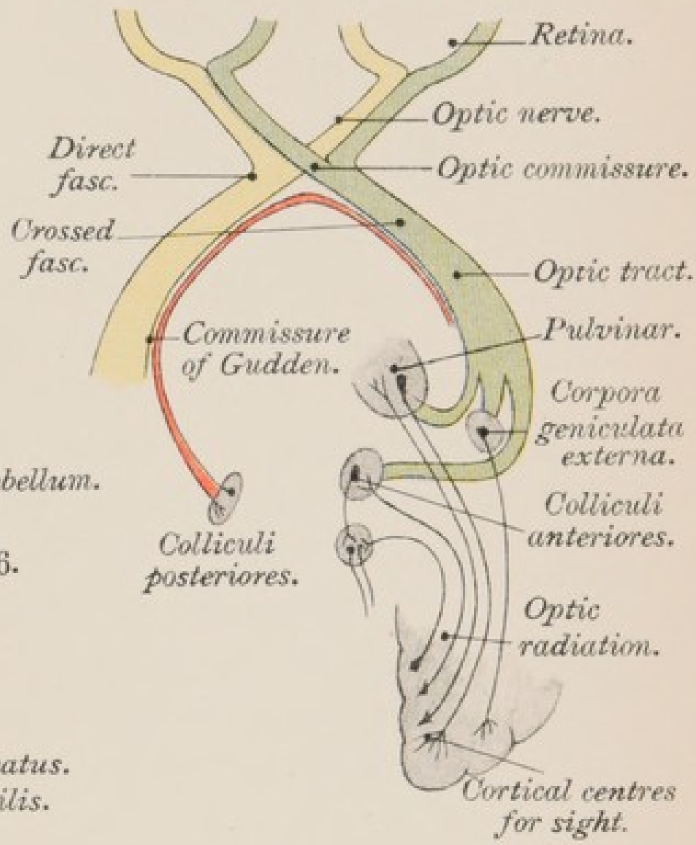
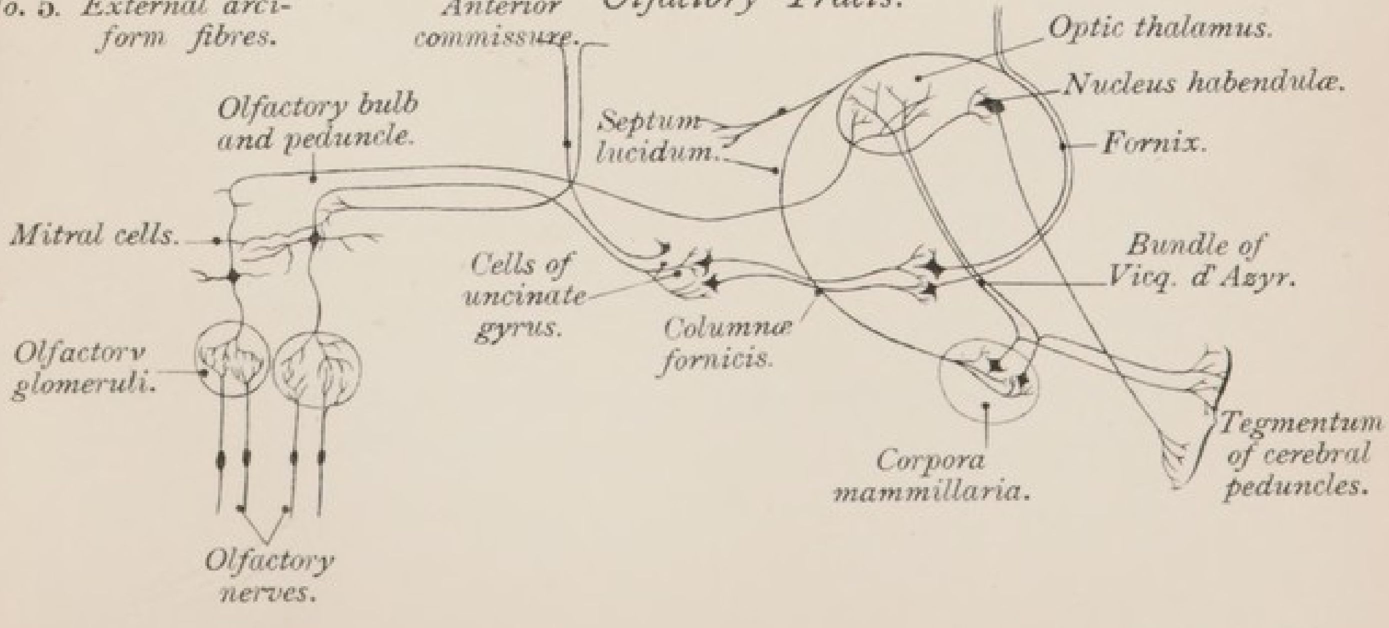


FIG. 81.

Olfactory Tracts.



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superficial origin; and on their dorsal aspect are four rounded tubercles—the corpora quadrigemina—with the lamina quadrigemina, beneath which runs the aquæductus cerebri (Sylvius).

CONSTITUTION OF THE PEDUNCULI CEREBRI.—A section at right angles to the cerebral peduncles will show you that they each consist of two portions, a posterior or dorsal, called the TEGMENTUM, and an anterior or ventral, called the CRUSTA, PES, or BASIS. These two parts of the crura are separated from each other by a narrow stratum of grey matter, called, from its dark colour, the SUBSTANTIA NIGRA, or LOCUS NIGER, the position of which is indicated on the surface by the oculomotor groove internally, and by another slight groove, the lateral sulcus, externally (fig. 54, page 90).

The constitution of the cerebral peduncles is given in the subjacent table:—

TABLE OF THE CONSTITUTION OF THE PEDUNCULI CEREBRI.

The Cerebral Peduncles consist of two parts, a dorsal part, the tegmentum, and a ventral part, the crusta.

I. The Tegmentum.
  A. Its grey matter consists of—
    The formatio reticularis with
      (*a*) Scattered nerve cells, and
      (*b*) Two specific groups of nerve cells.
        (1) The stratum griseum or centrale, or grey matter of the aquæductus cerebri
          (1) Nucleus of 3rd nerve.
          (2) Nucleus of 4th nerve.
          (3) Upper nucleus of 5th nerve.
        (2) The red nucleus.
  B. The white matter consists of—
    1. Longitudinal fibres.
      (1) Brachia conjunctiva or superior peduncles of the cerebellum.

(2) Tract of the fillet { (1) Main fillet giving off upper fillet. (2) Lateral fillet. }
(3) Anterior longitudinal bundle.
(4) Posterior longitudinal bundle.
(5) Spino-thalamic tract.
(6) Rubo-spinal tract, prepyramidal, Monakow's bundle.
(7) Descending root of the 5th cranial nerve.
(8) Olivary bundle.

2. Transverse fibres, viz. those of the 3rd and 4th cranial nerves.

II. Crusta or Basis.
(1) Pyramidal tracts.
(2) Cortico-pontine tracts. { (*a*) Fronto-pontine. (*b*) Temporo-occipito-pontine. }
(3) Caudate cerebellar tracts.

III. Substantia nigra or locus niger, separating the crusta from the tegmentum.

I. **The Tegmentum** (fig. 54, page 90) 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. We shall study, first, the grey, then the white matter of the tegmentum.

(*a*) The *Grey Matter* of the tegmentum consists of the *formatio reticularis* continuous with that of the pons and medulla. In this reticulum we find both scattered nerve cells; and two definite collections, the one being the STRATUM GRISEUM or the grey matter of the aqueduct of Sylvius; the other the RED NUCLEUS (*nucleus tegmenti*) (fig. 54, page 90).

The *red nucleus* lies beneath the anterior pair of corpora quadrigemina (colliculi anteriores), and consists of multipolar nerve cells, and is the primary termination of the superior cerebellar peduncles.

The *Stratum Griseum* or grey matter of the aquæductus cerebri extends through the entire length of the aqueduct. It gives origin to the 3rd and 4th cranial nerves. Lying a little more external is the upper nucleus of origin of the 5th cranial nerve.

(*b*) The *White Matter* consists of longitudinal and of transverse fibres.

1. Of the *Longitudinal Fibres* the chief strands are :—

(1) The *brachia conjunctiva* or superior cerebellar peduncles, which by means of their ascending branches connect the cerebellum with the opposite red nucleus, and thence, through the optic thalamus, with the opposite cerebral cortex.

(2) The *tract of the fillet*, a bundle of oblique fibres on the outer side of the red nucleus (fig. 54, page 90). When traced upwards, it divides into the *main fillet*—the chief sensory strand from the medulla to the optic thalami and to the cerebral cortex (see page 199); and the *lateral fillet*, which ends in the colliculi posteriores or posterior pair of corpora quadrigemina, and which is the upward continuation of the central auditory path from the opposite cochlear nucleus.

The main fillet gives off the *superior fillet* to the colliculi anteriores.

(3) The *anterior* or *ventral longitudinal bundle*, tecto-spinal tract, lies close to the posterior longitudinal bundle. Decussating with its fellow in the mesial raphé, it descends through the pons and medulla to the anterior funiculus of the spinal cord.

(4) The *posterior longitudinal bundle*, already noticed with the funiculus proprius of the anterior

column of the spinal cord and with the dorsal aspect of the medulla and pons, is now seen beneath the grey matter of the aquæductus cerebri (fig. 54, page 90), in close relation to the nuclei of the 3rd and 4th cranial nerves. Its functions are undecided, but it is associated with the motor nuclei of cranial nerves, co-ordinating the nerves of opposite sides.

(5) The *spino-thalamic tract*, a part of Gowers' tract, ascends with the fibres of the fillet. It carries sensations of touch, of temperature, and of pain from the opposite side of the body.

(6) The *rubo-spinal tract*—Monakow's bundle—prepyramidal tract, starts in the red nucleus of the one side, and, crossing the mesial line to the opposite side, descends through the lateral part of the pons and medulla to the lateral column of the spinal cord, where it is found in front of the crossed pyramidal tract. It ends in the cells of the anterior cornu. By its means, along with the brachia conjunctiva, both being, as you know, crossed strands (fig. 79, page 168), the cerebellum of the one side is brought in relation to the spinal cord of the same side.

(7) The *descending root* of the 5th cranial nerve passes through the crura interna to the brachia conjunctiva and ends at the motor nucleus of the 5th nerve in the upper division of the floor of the 4th ventricle.

(8) The *olivary bundle* connects the lenticular nucleus with the superior olive.

2. Of the *Transverse Fibres*, the chief bundles are those which constitute the fibres of the 3rd and 4th cranial nerves on their way from their deep to their superficial origins (fig. 54, page 90).

FIG. 82. *Pedunculi cerebri.*

FIG. 83.

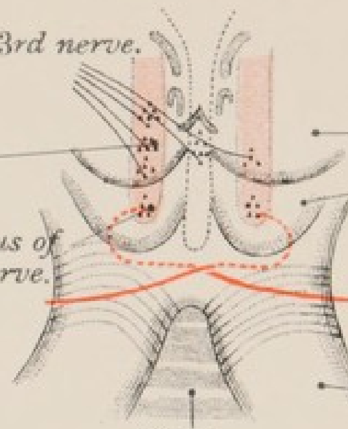


FIG. 84.

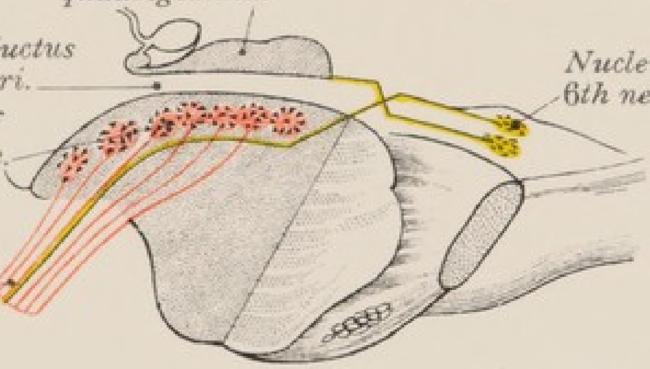


FIG. 85.

Section of pons.

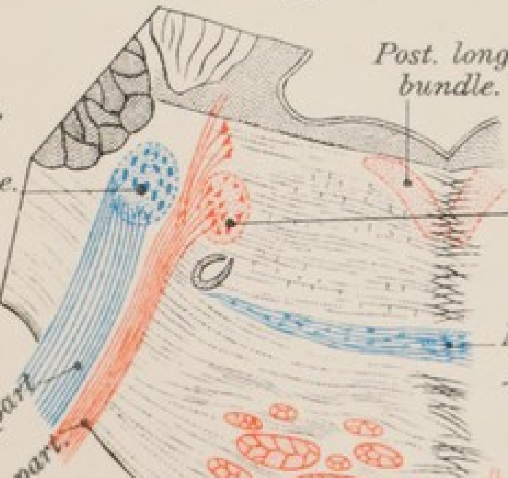
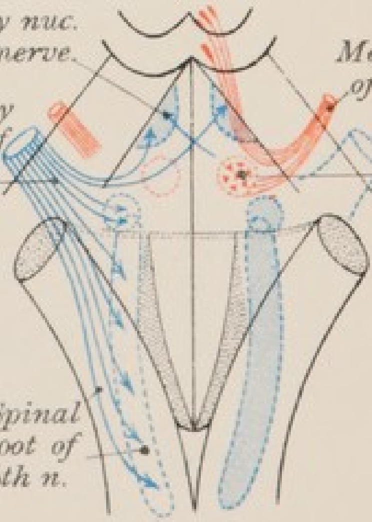


FIG. 86.

Fourth Ventricle.



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II. **The Crusta, Pes, or Basis**—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 other strands are superadded, for transverse sections of the crusta are much larger than those of the pyramids. The following are the various tracts of fibres of the crusta:—

(1) The *pyramidal tracts,* motor strands from the cortex cerebri, occupy the middle and inner part of the crusta. They are divisible into two parts—an external, the pyramidal tracts proper; and an internal, the geniculate fasciculus, which comes from the genu of the internal capsule. The latter contains fibres connected with the motor part of the 5th nerve, with the 7th and 12th nerves, and hence with the muscles of mastication, of the face and of the tongue (fig. 54, plate XIV. page 90).

(2) The *cortico-pontine tract,* which passes from the cerebral cortex to the nucleus pontis, and then to the opposite half of the cerebellum. This tract, as it travels through the crus, forms two groups: the one occupies the posterior external part of the crusta, and is called the *fasciculus lateralis,* or temporo-pontine tract; the other group mingles with the geniculate and pyramidal fibres; it is the fronto-pontine tracts.

(3) The *stratum intermedium* or *caudate cerebellar fibres,* or boundary layer of the pes, probably comes from the caudate nucleus.

The relative positions of these tracts to each other will be understood by reference to fig. 54, page 90.

III. **The Substantia Nigra** is a semi-lunar band of grey matter placed between the two divisions of the cerebral peduncles. It is characterised by darkly pigmented nerve cells—hence the name. It extends through the whole length of the peduncles. Through it pass the roots of the 3rd nerve before they emerge at the oculomotor groove (fig. 54, page 90). Its connections and uses are unknown.

As we have already seen, the two pedes are quite distinct from each other, whereas the two tegmenta are merely separated by the median raphé.

The Corpora Quadrigemina (fig. 44, page 66) are the 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, below and behind the pineal gland and behind the aquæductus cerebri (Sylvius). The anterior pair, the larger, are called the *colliculi anteriores,* the posterior pair, the smaller, the *colliculi posteriores,* and they rest upon a thin lamina—the lamina quadrigemina—beneath which runs the cerebral aqueduct (Sylvius). Laterally, each pair is prolonged into two white bands or cords—the *anterior* and *posterior brachia* (fig. 59, page 104). The anterior or superior brachium passes between the pulvinar and the corpus geniculatum internum, thence to the external geniculate body and to the optic tract, of which it is the direct root; the posterior or inferior brachium runs forwards and outwards, and disappears beneath the corpus geniculatum internum, to reach the optic thalamus.

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. The posterior pair of corpora quadrigemina and the corpora geniculata interna are connected with hearing, for they both receive fibres from the lateral fillet. The anterior pair of corpora quadrigemina and the corpora geniculata externa are connected with sight.

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 Aquæductus Cerebri (Sylvius) is the narrow passage between the 3rd and 4th ventricles (fig. 67, page 136). Behind, 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—the stratum griseum—continuous with the grey matter—locus cæruleus—of the 4th ventricle. From this grey matter arise the 3rd, the 4th, and part of the 5th cranial nerve.

Summary.—Thus we see that the cerebrum consists of a convoluted cortex, of basal ganglia, of four true ventricles, united by narrow passages, and of white strands constituting commissural, projection, and association fibres.

V. ORIGINS OF THE CRANIAL NERVES.

The Cranial Nerves have each three origins: a *superficial* origin, a *deep* origin, and a *cortical* origin.

By the term *superficial origin* we mean the points at which the several nerves are attached to the surface of the brain; their *deep origins*—sub-cortical—are the several deep-seated nuclei with which they are connected; their *cortical origins* or *terminations* are the centres in the cerebral cortex from or to which they can be ultimately traced.

1. **The Olfactory Nerves**—1st pair—consist of about twenty fine non-medullated nerve filaments, which are distributed to the upper part of the olfactory mucous membrane. They reach the olfactory glomeruli of the olfactory bulbs by passing through the holes in the cribriform plate of the ethmoid. The roots of the olfactory peduncles have already been noticed (page 120). They are two in number: a *mesial root*, and a *lateral root*. The *mesial root* goes in part to the callosal and sub-callosal gyrus, and in part to the area of Broca (fig. 59, page 104). The *lateral* or *outer* root can be traced to the locus perforatus anticus (fig. 59, page 104), and thence to the extremity of the temporal lobe, where it blends with the anterior end of the gyrus hippocampi—the uncinate gyrus. By means of these two roots the olfactory peduncle is connected with the two ends of the limbic lobe. The well-marked bundle of fibres which connects the peduncle to the trigonum olfactorium—the small triangular area between these roots—is sometimes regarded as a third root. Besides the above distinct roots, some of the fibres of the olfactory tract go

FIG. 87.

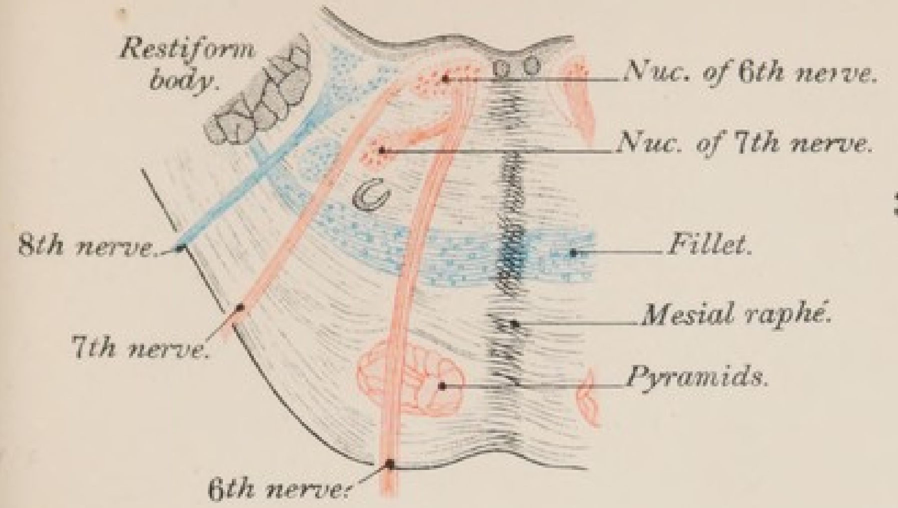


FIG. 88.

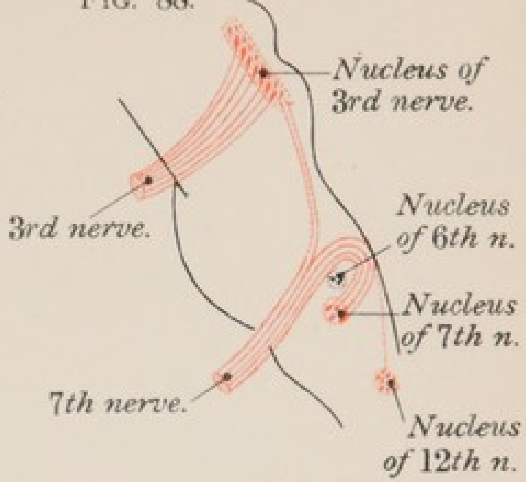
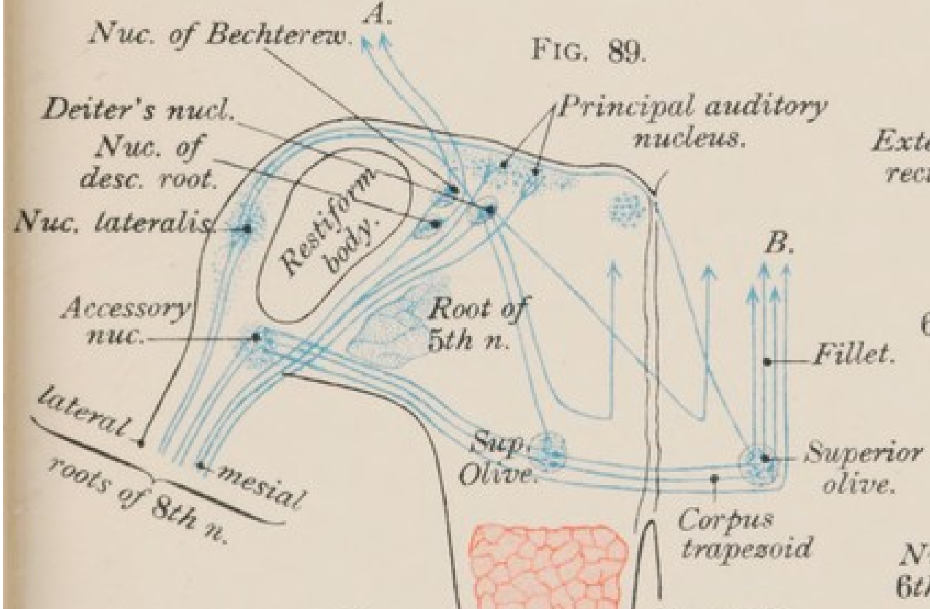


FIG. 89.



A. Fibres to cerebellum.

B. Fibres to { post. long. bundle.
nuc. of 3rd and 6th nerves.
colliculi poster.
corpora geniculata inter.
temporal cortex.

FIG. 90.

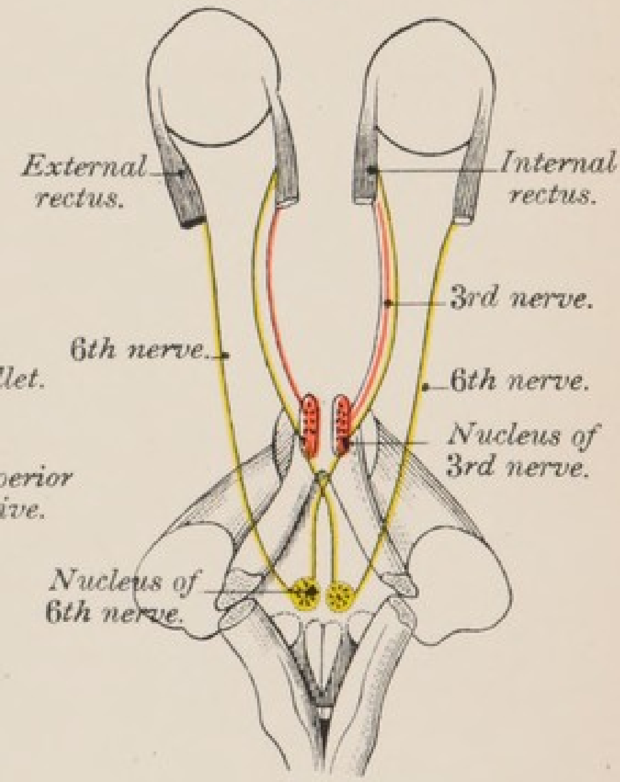


FIG. 91.

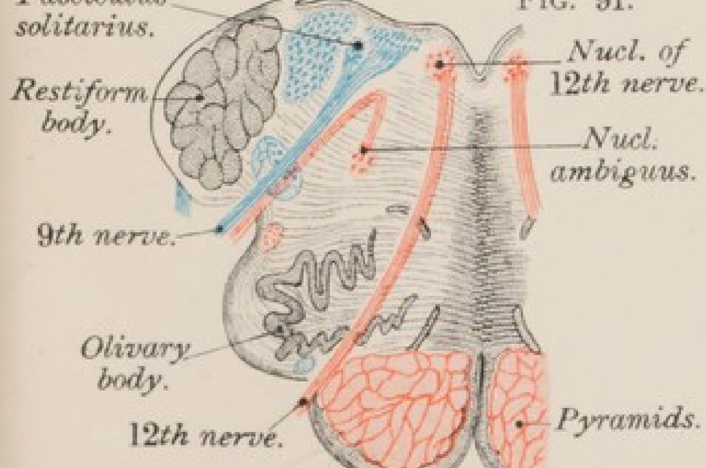
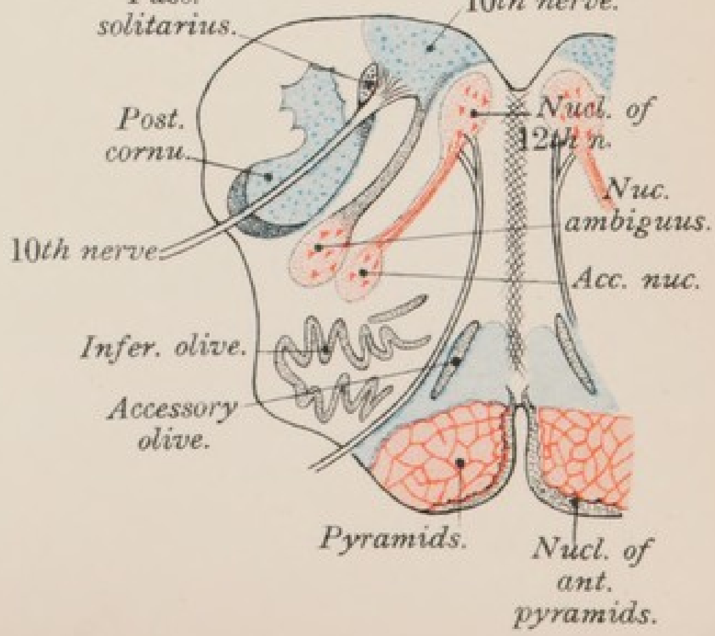


FIG. 92.



to the anterior end of the thalamus; others pass through the anterior commissure to the opposite cerebral cortex, and to the opposite olfactory bulb.

The central connections of the olfactory nerves are figured in fig. 81, plate XXX. page 168. They are the following groups of association fibres: the cingulum, the uncinate fasciculus, and the fornix; further connections are the septum lucidum, the optic thalamus, the corpora mammillaria, and the tegmentum of the cerebral peduncles.

The *Cortical Centres* are the *uncinate gyrus* of the *same* side (fig. 42, page 60); and through the anterior commissure, the uncinate gyrus of the *opposite* side.

It is worthy of note that in animals with well-developed organs of smell the gyrus hippocampi, the striæ longitudinales, 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.

2. **The Optic Nerves**—2nd pair—can be traced from the eyeballs, through the optic foramina to the mesial band—the optic commissure or *chiasma* in which they partially decussate (fig. 80, page 168). From this commissure they run backwards as the *optic tracts* round the outer sides of the crura cerebri, and then bifurcate into an internal limb, which goes to the CORPORA GENICULATA INTERNA, and an external limb, which can be traced to the PULVINAR of the optic thalamus, to the CORPORA GENICULATA EXTERNA, and to the anterior pair of the corpora quadrigemina —COLLICULI ANTERIORES (fig. 59, page 104, and fig. 80, page 168). These are the *sub-cortical centres* for sight, and they degenerate when the eye of a young

animal is destroyed (fig. 80, page 168). In the optic chiasma and tracts there are three sets of fibres: (1) an *outer* set, the *direct fasciculus*, which lies on the outer side of the chiasma and tract, and which comes from the *temporal* half of the corresponding retina; (2) a *mesial* set, the *crossed fasciculus*, which comes from the nasal half of the corresponding retina and decussates with the fibres of the opposite side, so that those of the right eye reach the left tract, and those of the left eye the right tract; (3) an *internal* set, which passes from one tract to the other and then back to the brain without entering the eye; this set is known as the commissure of Gudden (fig. 80, page 168); it connects together the colliculi posteriores of the two sides; it has nothing to do with sight.

The *Cortical Centres* are situated in the occipital lobes, in the *cuneate* and *lingual* lobes, and in the *outer aspect* of the *occipital pole* (figs. 39 and 42, page 60; fig. 62, page 126), and are connected with the sub-cortical centres by means of a bundle of fibres, the *optic radiation.* This radiation, which contains both afferent and efferent fibres, passes from these centres backwards through the sub-lenticular portions of the internal capsule.

The roots of the optic tracts, which we trace to the corpora geniculata interna, have no real connection with vision, as they do not undergo atrophy like the other roots when the eyes are destroyed.

The centres for sight are connected with the centre for articulate language in the frontal lobe; with the auditory centre in the temporal lobe; and with the centre for visual memory in the angular gyrus of the parietal lobe.

The 3rd Nerves (figs. 82, 83, 84, page 172) take their *superficial origins* at the OCULOMOTOR GROOVES, on the inner side of the pedunculi cerebri, close to the upper border of the pons Varolii. They spring from the fore part of a longitudinal column of cells, on each side of the middle line, in the grey matter of the FLOOR of the AQUÆDUCTUS CEREBRI (Sylvius) (fig. 50, page 82, and figs. 83, 84, page 172). This collection of cells is called the *oculomotor nucleus.* It lies beneath the colliculi anteriores, and is a continuation of the grey matter of the anterior horn of the spinal cord. Traced from the cells of this nucleus—the *deep origin* —the fibres of the 3rd nerves pass through the posterior longitudinal bundle, through the red nucleus, and through the locus niger (fig. 82, page 172), to the oculomotor groove—their *superficial origin*—on the inner side of the cerebral peduncles.

The nuclei of the 3rd nerves are closely connected with the nuclei of the 4th and 6th nerves; the nucleus of the 6th nerve of the one side being united by means of the posterior longitudinal bundle with the nucleus of the opposite 3rd nerve (fig. 84, page 172). There is probably a partial decussation of the fibres of the 3rd nerve, these decussating fibres supplying the opposite internal rectus. The nucleus of the 3rd nerve gives rise to two sets of fibres :—

(1) Those to the voluntary part of the levator palpebræ superior and to the extrinsic muscles of the eyeball, except the external rectus and the superior oblique.

(2) Those to the intrinsic muscles of the eyeball, viz. the sphincter pupillæ, and the ciliary muscle. This connection, however, is not a direct one, but

through the lenticular ganglion and the short ciliary nerves.

TABLE OF THE NUCLEI OF THE THIRD NERVE.

Nuclei of the 3rd Nerve	I. A Superficial Group	1. A mesial set, to the ciliary muscle	Through the lenticular ganglion and short ciliary nerves.
		2. A lateral set, to the sphincter pupillæ	
	II. A Deep Group	1. A mesial set	To internal rectus.
			To inferior rectus.
		2. A lateral set	To levator palpebræ superior.
			To the inferior oblique.

The 4th Nerves will be seen on the outside of the pedunculi cerebri, between the cerebrum and the cerebellum (fig. 66, page 134). They are small and slender, and arise from a NUCLEUS—*deep origin*—in the wall of the AQUÆDUCTUS CEREBRI (Sylvius) behind that of the 3rd nerve (fig. 83, page 172), and beneath the colliculi posteriores. The 4th nerve is connected with the nucleus of the 6th nerve of the opposite side. After leaving their nuclei of origin, the 4th nerves pass backwards and outwards through the peduncles, then inwards to the SUPERIOR MEDULLARY VELUM—*superficial origin*—where they decussate, so that the left nerve comes from the right nucleus, and *vice versa* (fig. 83, page 172). Hence it follows that the right 4th nerve supplies the left superior oblique.

The 5th Nerves take their *superficial origin* from the sides of the pons, near its upper margin. They arise by two roots,—a large one, *sensory—ganglionic*, and a small, *motor—aganglionic* (fig. 66, page 134). The small—MOTOR ROOT—is the higher of the two, and is separated from the larger root by some of the transverse fibres of the pons. The *deep origin* of this smaller or motor root is the MOTOR NUCLEUS lying just below the LATERAL ANGLE of the 4TH VENTRICLE (fig. 50, page 82). It is joined from the mid-brain by the superior or descending root of the 5th nerve, which comes from the accessory nucleus—a column of grey matter at the outer side of the grey matter of the aquæductus cerebri (Sylvius) (fig. 50, page 82). From this, the *deep origin*, the two parts of the motor root of the 5th nerve pass forwards and outwards to their *superficial origin* between the PONS and the BRACHIUM PONTIS.

The large or SENSORY ROOT.—The nucleus of this root is the Gasserian ganglion, situated on the front of the apex of the petrous part of the temporal bone. The unipolar nerve cells of this ganglion give off two branches, one of which passes into the peripheral nerve; the other enters the pons, and there divides into ascending and descending branches. The ascending branches end—*deep origin*—amongst the cells forming the sensory nucleus of the 5th nerve—a nucleus lying under cover of the overhanging lateral wall of the 4th ventricle close to the outer side of the motor nucleus (fig. 50, page 82; fig. 85, page 172). The descending branches form the descending, inferior, or spinal root of the 5th nerve. It can be traced down the spinal cord as far as the second cervical nerve (fig. 86, page 172).

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 Varolii (fig. 66, page 134). Their *deep origin* is situated underneath the outer part of the FASCICULUS or EMINENTIA TERES in the fore part of the floor of the 4th ventricle, in front of the striæ (acusticæ) medullares (fig. 50, page 82). From this origin the nerve bundles run forwards and outwards through the thickness of the pons to their *superficial origin*. The nucleus of the 6th nerve may be connected, by means of the posterior longitudinal bundle, with the 3rd nerve of the opposite side (fig. 84, page 172, and fig. 90, page 176). This connection is probably an indirect one through the nucleus of the opposite 3rd nerve; for there are no fibres directly from the 6th to the 3rd nerve.

The 7th Nerve consists of two parts—the FACIAL nerve proper or portio dura, and the PARS INTERMEDIA. The FACIAL nerve proper — 7th nerve — takes its *superficial origin* at the lower border of the pons, from the groove between the upper ends of the olivary and restiform bodies (fig. 66, page 134). Its *deep origin* is the facial nucleus in the formatio reticularis of the dorsal aspect of the pons, near the nucleus of the 6th nerve, but external and deeper in beneath the floor of the 4th ventricle (figs. 87, 88, page 176). This nucleus extends from the region of the nucleus of the 3rd nerve above to the nucleus of the 12th nerve below. The fibres, on leaving the nerve cells of the nucleus, are at first directed backwards and inwards towards the middle line, internal to the nucleus of the 6th nerve. They then ascend

FIG. 93.

Motor and Sensory Tracts.

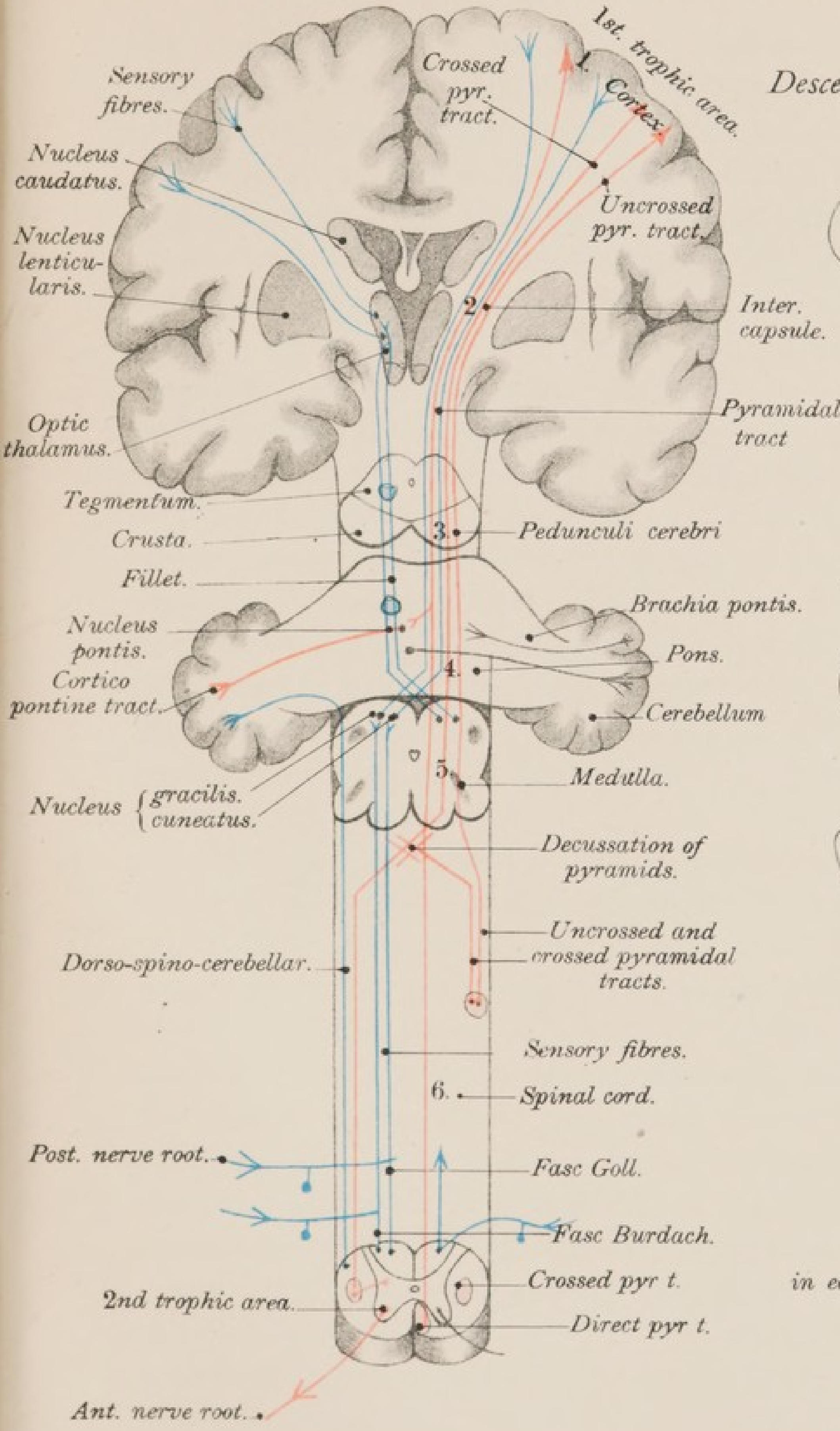
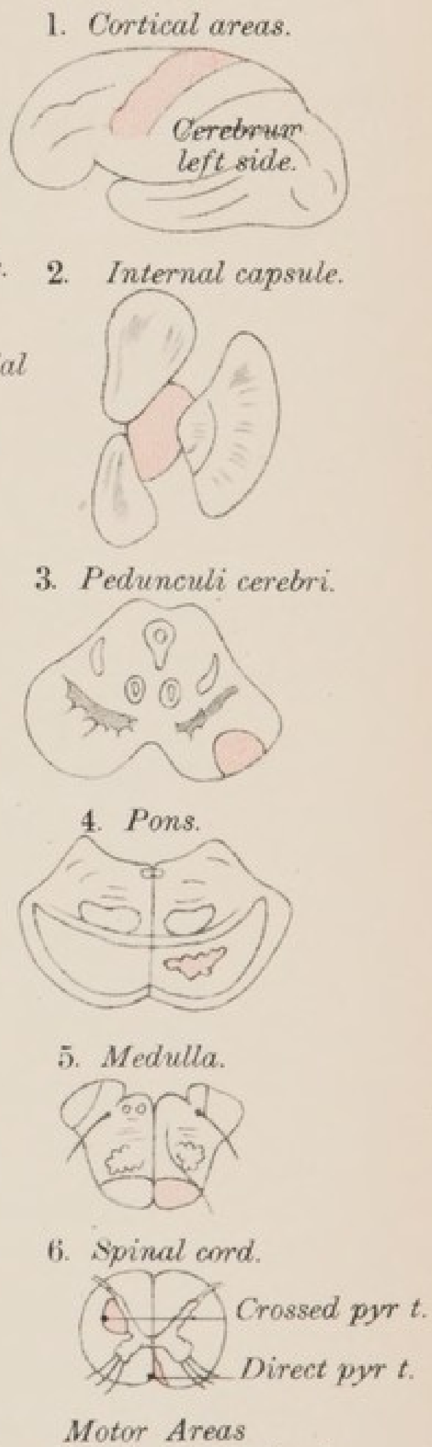


FIG. 94.

Descending degeneration.



Motor Areas in each case coloured red.

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for a short distance behind the nucleus of the 6th nerve, close to the floor of the 4th ventricle, forming part of the eminentia teres, and, bending down and out over the upper end of the nucleus of the 6th nerve (fig. 87, page 176), they run forwards, outwards, and downwards to the lower border of the pons—their *superficial origin.*

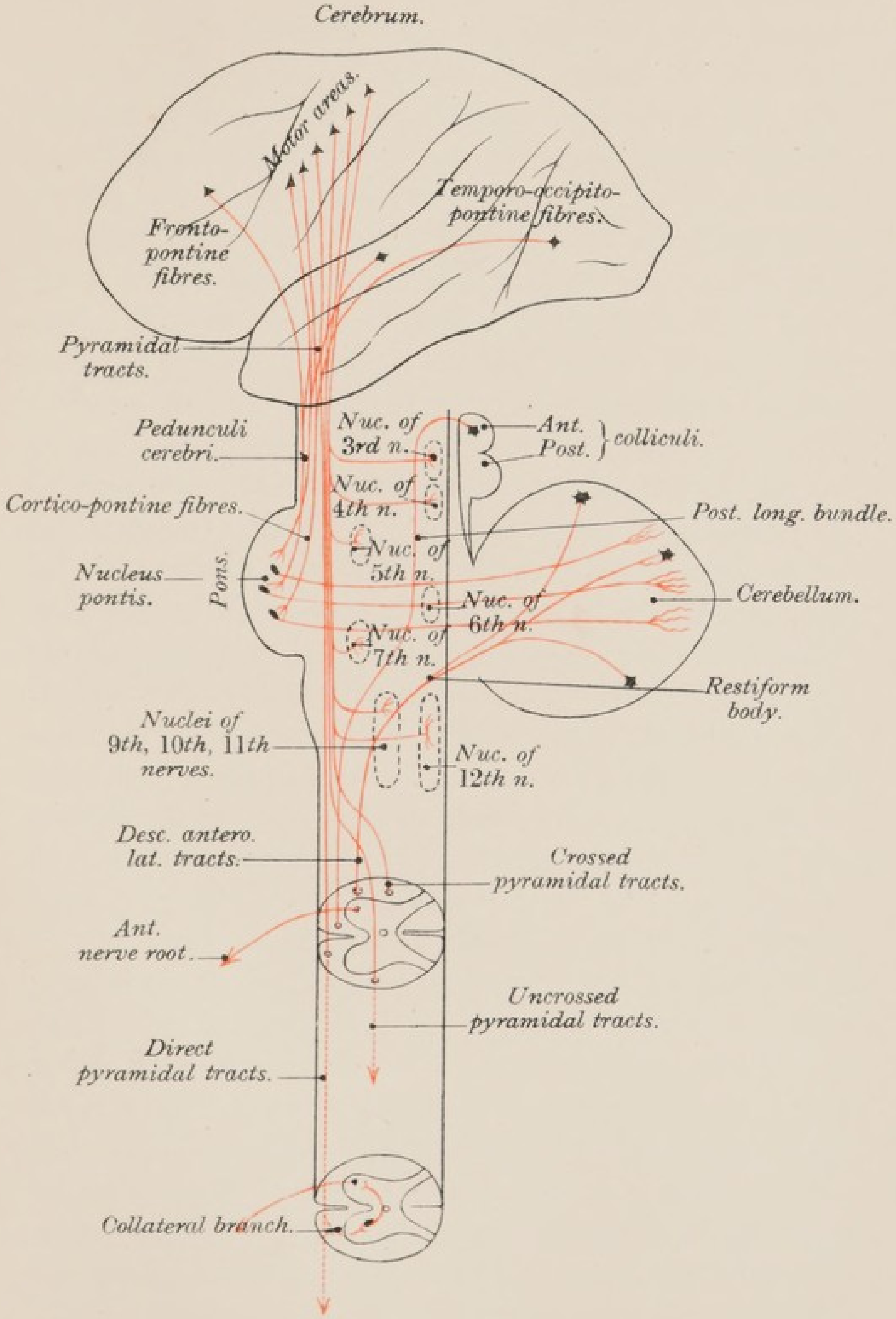
The facial nerve supplies all the muscles of expression, but the *corrugator supercilii* and *orbicularis palpebrarum* are supplied by fibres from the upper cells of this nucleus—those near the nucleus of the 3rd nerve; and the *orbicularis oris* by fibres from the lower set of cells—those near the nucleus of the hypoglossal nerve. Some hold, however, that those muscles are supplied from the nuclei of the 3rd and 12th nerves respectively (fig. 88, page 176), for in the pons the facial nerve is joined, through the posterior longitudinal bundle, by fibres from the nuclei of these nerves (3rd and 12th).

The PARS INTERMEDIA—the so-called sensory root of the facial nerve—is a small bundle of nerve fibres which lies between the facial and auditory nerves, and is connected with both. It carries taste fibres to the glosso-pharyngeal nucleus. As you no doubt already know, the cells of the geniculate ganglion of the facial nerve have, as usual, a *central* and a *peripheral* set of processes. The *central* processes form the *pars intermedia* of the facial nerve; the *peripheral* processes constitute the *chorda tympani* nerve. This nerve—the *chorda tympani*—starting in the anterior two-thirds of the tongue, at first travels with the lingual branch of the third division of the 5th nerve. It then joins the facial nerve in the aquæductus Fallopii, and thus reaches the geniculate ganglion. From the cells of this ganglion the taste fibres are conducted, through the pars intermedia, to the fasciculus solitarius and to the nucleus of the glosso-pharyngeal nerve. There is, however, another possible route for the taste fibres, viz. through the chorda tympani to the geniculate ganglion, thence through the great superficial petrosal nerve to Meckel's ganglion, to the superior maxillary division of the 5th nerve, through the Gasserian ganglion and 5th nerve to the cortical taste centres in the tip of the temporal lobe.

The Auditory Nerve—the 8th nerve—takes its *superficial origin* (fig. 66, page 134) in the same groove with, but behind, the facial from which it is separated by the *pars intermedia.* Its true origin, as with all sensory nerves, is the ganglia—*vestibular* and *spiral*—on the course of the nerve. Traced from these ganglia the axis-cylinder processes enter the medulla and divide into ascending and descending branches, which end in tufts at the *sub-cortical* or so-called deep origin of the nerve. The auditory nerve has two roots—a mesial and a lateral root (fig. 89, page 176).

(1) The *mesial root* — VESTIBULAR DIVISION — (anterior, ventral, upper root) is formed, as we have just seen, by the *central* processes of the bipolar nerve cells of the *vestibular ganglion*—ganglion of Scarpa —found on the auditory nerve within the internal auditory meatus. Passing backwards through the substance of the medulla and pons, *internal* to the *restiform body* (fig. 89, page 176), the fibres of this root divide into ascending and descending branches. The *former* end in the cells of the VESTIBULAR NUCLEUS (dorsal vestibular or principal vestibular nucleus),

FIG. 95.



Motor Tracts.

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beneath the AREA ACUSTICA — trigonum acusticum —of the 4th ventricle (fig. 50, page 82). By means of collaterals some of them are united to the two contiguous nuclei of Deiters and Bechterew (fig. 89, page 176); while others pass by these nuclei directly to the cerebellum (nuclei tecti). The *descending* branches form the descending root of the vestibular nerve, which ends in the NUCLEUS of the VESTIBULAR root. Some of these branches, along with fibres from the nucleus of Deiters, can be traced through the medulla to the spinal cord, as the vestibular spinal tract (Löwenthal). Other fibres from the nuclei of Deiters and Bechterew go to the nuclei fastigii of the opposite cerebellum, to the corpus dentatum, and to the vermis cerebelli; others join the posterior longitudinal bundle, and through it reach the nucleus of the 6th nerve of the same side, and the nuclei of the 3rd, 4th, and the motor nucleus of the 5th nerve of the opposite side. This root is concerned with the sense of equilibrium, and not with hearing. It is connected with the optic thalamus, hence the explanation of the fact that when we hear a sudden sound the head is turned to the direction from which it comes.

(2) The *lateral root*—COCHLEAR DIVISION—(lower or posterior root) is the true nerve of hearing, for it alone is connected with the organ of Corti. It arises as the *central* processes of the bipolar nerve cells in the *spiral ganglion* of the cochlea. Passing backwards into the medulla, on the *outer* side of the *restiform body*, as the lateral cochlear root (lower or posterior root) of the auditory nerve, its fibres divide into ascending and descending branches. The *ascending* branches end in the cells of the VENTRAL COCHLEAR NUCLEUS

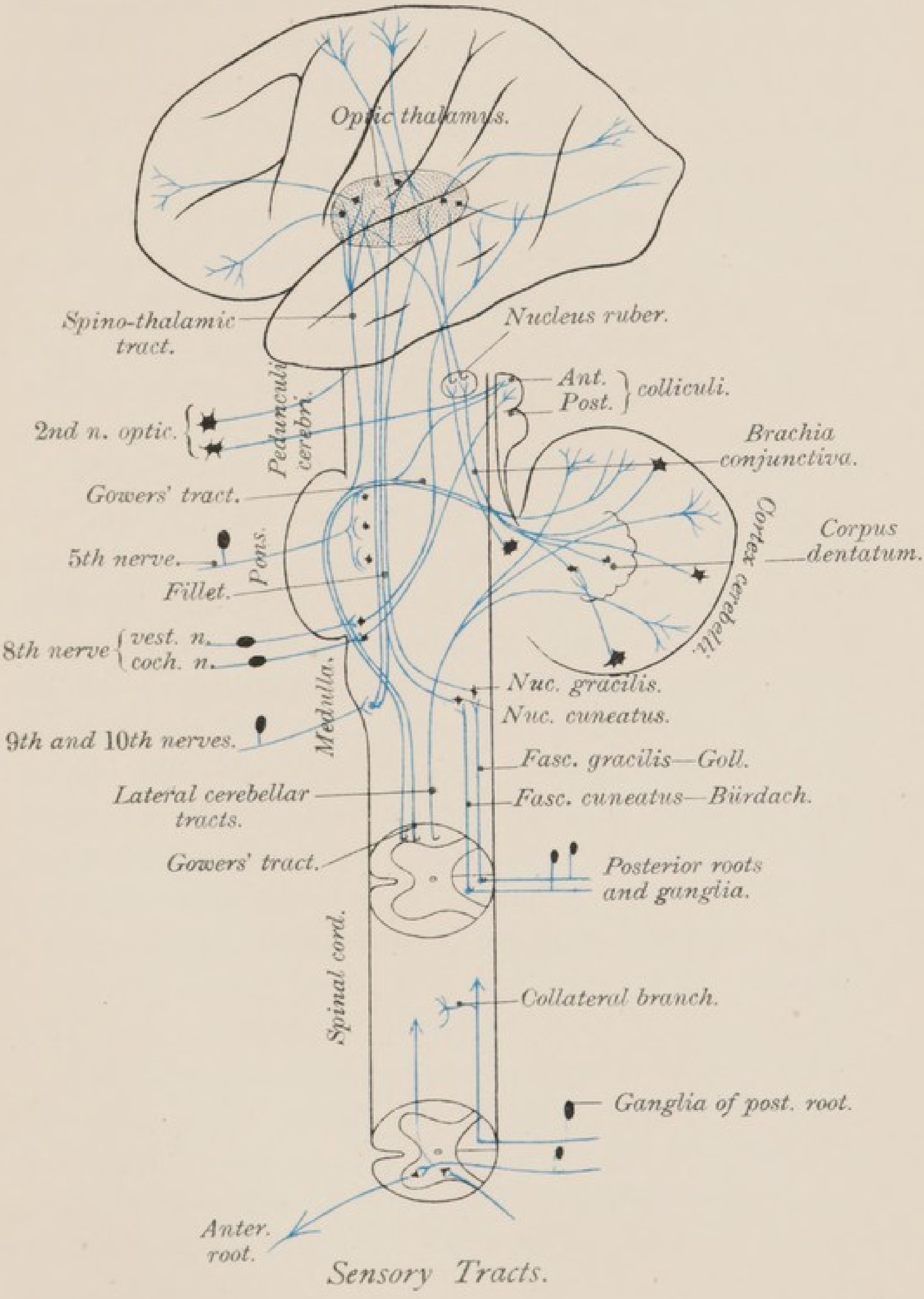
(accessory cochlear nucleus), placed in front of the restiform body, between the mesial and lateral roots of the auditory nerve (fig. 89, page 176). The *descending* branches end in the *ganglion* of the *lateral root* or DORSAL COCHLEAR NUCLEUS—a collection of cells amidst the fibres of the lateral root as they wind round the outer side of the restiform body (fig. 89, page 176). This nucleus will be found beneath the TUBERCULUM ACUSTICUM (fig. 44, page 66)—the elevation of the trigonum acusticum—beneath the striæ medullares, close to the lateral recess of the 4th ventricle.

The *central* connections of the cochlear division of the auditory nerve are as follow (fig. 89, page 176): (1) from the *ventral nucleus* through the corpus trapezoideum, and (2) from the *dorsal nucleus* through both the striæ medullares and corpus trapezoideum, to both superior olives, to the lateral fillet of the same side, but mostly of the opposite side, to the colliculi posteriores (posterior pair of corpora quadrigemina), to the corpora geniculata interna, and thence through the sub-lenticular part of the internal capsule to the CORTICAL AUDITORY CENTRES situated in the superior temporal convolution (fig. 39, page 60), and in the group of gyri on the UPPER ASPECT of the TEMPORAL LOBE, within the fissura cerebri lateralis (Sylvius).

These centres receive impulses from both ears, but mainly from the one of the opposite side.

The Glosso-pharyngeal—the 9th cranial nerve—has two parts: a motor, and a sensory. The motor part of this nerve takes its *deep origin* from the NUCLEUS AMBIGUUS or accessory vagal nucleus (fig. 50, page 82, and fig. 91, page 176). The sensory part

FIG. 96.



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starts in the ganglia on the nerve—the petrous and jugular ganglia. On entering the medulla its fibres divide into *descending* branches, which join the fasciculus solitarius; and *ascending* branches, which end in a special nucleus, common to this nerve and to the vagus. This nucleus lies beneath the inferior fovea of the lower half of the floor of the 4th ventricle (ala cinerea) (fig. 44, page 66). The *superficial origin* of the glosso-pharyngeal nerve is the groove between the olivary and restiform bodies (fig. 66, page 134). The glosso-pharyngeal nerve is probably a pure sensory nerve, its motor fibres being derived from the spinal accessory nerve.

The Vagus—the 10th cranial nerve. The *motor* portion of this nerve springs from the nucleus ambiguus or accessory vagal nucleus (fig. 92, page 176) of the same and of the opposite sides. The *sensory* fibres arise in the ganglia of the root and of the trunk of the vagus, and after entering the medulla divide into descending branches, which join the fasciculus solitarius (fig. 92, page 176), and ascending branches, which end in tufts in the vagal nucleus beneath the *ala cinerea*. The *superficial origin* of this nerve is the groove behind the olive.

The Spinal Accessory—the 11th cranial nerve—is a pure motor nerve. It has two parts: a spinal part, and an accessory part.

(1) The *spinal part* takes its *superficial origin* from the spinal cord behind the anterior roots of the upper five spinal nerves. Its *deep origin* is the column of cells in the spinal cord—the dorso-lateral group—which extends from the olive as far down as the 5th cervical nerve.

(2) The *accessory* or *bulbar part* has its *superficial* and its *deep origins* very similar to those of the vagus, viz. in the one case from the groove behind the olive; in the other, from the nucleus ambiguus, and from the column of cells lying beneath the ala cinerea of the 4th ventricle (fig. 44, page 66). This column of cells is common to the glosso-pharyngeal, to the vagus, and to the bulbar part of the spinal accessory. This last should really be regarded as part of the vagus, and not as a separate nerve.

The Hypoglossal—12th nerve—springs by several filaments—its *superficial origin*—from the groove between the anterior pyramids and the olives (fig. 66, page 134). Its fibres can be traced backwards through the formatio reticularis to its *deep origin*, a column of cells lying near the middle line, close to the surface of the lower half of the floor of the 4th ventricle, beneath the lower part of the fasciculus teres. This area is often called the TRIGONUM HYPOGLOSSI (figs. 50, 51, page 82, and fig. 91, page 176).

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 the motor tracts and nerves and their nuclei are anterior, and the sensory posterior.

GENERAL SUMMARY.

Having in the preceding sections described the several parts of the brain and spinal cord, we shall now take a general survey of both the grey and white substance of the whole Central Nervous System.

Grey Matter.—The grey matter of the cerebro-spinal nervous system consists of a countless number of superimposed neurones, with their *dendrites* or protoplasmic processes, and their *axones* or axis-cylinder processes. The former are centripetal, carrying impulses towards the cells; the latter are centrifugal, carrying impulses away from the cells. By means of these two sets of processes the different parts of the nerve axis are brought into relation with each other, and with every other part of the rest of the body. The neurones, though, according to some authorities, united with each other by delicate neuro-fribrillæ, may for all practical purposes be regarded as independent elements, their processes being contiguous only and not continuous. The cell bodies, supported by neuroglia and mainly nutritive in function, constitute the grey matter: their processes, especially their axis-cylinder process, form the various white strands.

A. In the CEREBRUM the grey matter forms the *cortical* and the *sub-cortical ganglia.*

1. The CORTICAL GANGLIA—CORTEX CEREBRI—can be mapped out into certain areas, which in many cases overlap each other, and which, for want of better names, are called the motor, the sensory, and the association areas.

(1) The MOTOR AREAS are placed in the anterior central gyrus—ascending frontal convolution. They occupy both the superficial and deep part of this gyrus, viz. that part which forms the anterior wall of the sulcus centralis (Rolando). They also extend into the paracentral lobule on the mesial aspect of the hemisphere.

(2) The SENSORIAL AREAS are not so well defined as are the motor areas.

(*a*) The centres for *common sensibility* reside in the post-central gyrus. It has quite a different structure from the anterior central gyrus. Some sensory fibres also end in the anterior central convolution, hence the name, *sensory-motor areas,* applied to these convolutions.

(*b*) The *centres for sight* are found in the cuneate lobe and in the outer aspect of the occipital pole (fig. 28, page 44). The centre for *visual memory* is located in the angular gyrus of the parietal lobe (fig. 28, page 44).

(*c*) The *sense of smell* and *of taste* are placed in the hippocampal and uncinate gyri, on the inner aspect of the hemisphere (fig. 42, page 60).

(*d*) The *sense of hearing* resides in the upper temporal gyrus and in the upper surface of the temporal lobe, that surface within the fissura cerebri lateralis (Sylvius).

(3) The ASSOCIATION AREAS constitute two-thirds of the entire cerebral cortex, occupying most of the frontal, temporal parietal, and occipital lobes. They cannot be stimulated from without.

2. The SUB-CORTICAL or BASAL GANGLIA are found in the interior of the cerebral hemispheres. Their functions are by no means decided. The optic thalami

are regarded as nuclei connected with sensation; the corpora striata, with motion. The pulvinar of the optic thalamus, the corpora geniculata externa, and the colliculi anteriores are the sub-cortical centres for sight; and by means of the optic radiation are united with the cortical centres located in the occipital lobes.

The *Colliculi posteriores*—posterior pair of corpora quadrigemina—and the corpora geniculata interna are the sub-cortical centres of hearing, and, through the auditory radiation, are connected with the cortical auditory centres in the temporal lobe.

The *Red Nucleus* is the primary termination of the brachia conjunctiva—superior peduncles of the cerebellum. New relays of fibres starting in these nuclei unite them with the optic thalamus, with the cerebral cortex, and with the grey matter of the anterior horns of the spinal cord.

B. The CEREBELLUM.—The grey matter of the cerebellum, like that of the cerebrum, is arranged in cortical and sub-cortical ganglia. By the three cerebellar peduncles they are brought into relation with the cerebrum, with the pons, with the medulla, with the spinal cord, and with the several cranial nerves. The chief sub-cortical ganglia of the cerebellum are the corpus dentatum in the lateral lobes, and the roof nuclei in the vermis cerebelli. Of the functions of the cerebellum, we as yet know little; it is associated with the co-ordination of muscular movements.

C. PEDUNCULI CEREBRI, PONS, and MEDULLA.—The rest of the grey matter of the central nervous system, extending from the aquæductus cerebri (Sylvius) to the filum terminale, is arranged in a dorsal part, behind the central canal—sensory in function; and a ventral part, in front of the central canal—motor in function. In the cerebral peduncles, pons, and medulla this grey matter forms the nuclei of origin or of termination of the several cranial nerves found in these regions. Thus, from the grey matter of the aquæductus cerebri (Sylvius) arise the 3rd, the 4th, and the upper root of the 5th cranial nerves; from the pons spring the 5th, the 6th, the 7th, and part of the 8th cranial nerves; and from the medulla we have the 8th, 9th, 10th, 11th, and 12th cranial nerves. Besides these nuclei of the cranial nerves, the only other sub-cortical ganglia in this region needing further notice are the nucleus of Deiters, and the nuclei of the fasciculus gracilis and of the fasciculus cuneatus. The nucleus of Deiters is connected (1) with the cells of the cortex cerebelli; (2) with the nuclei of the 3rd and 6th cranial nerves; and (3) with the cells of the anterior horn of the spinal cord (vestibulo-spinal tract). Finally, at the lower part of the medulla are the nuclei of the fasciculus gracilis and of the fasciculus cuneatus, which are the primary terminations of the long sensory strands—Goll and Bürdach—of the posterior columns of the spinal cord.

D. In the SPINAL CORD the grey matter is arranged in a series of columns—vesicular columns—which are the deep origins or terminations of the motor and sensory spinal nerves.

White Matter.—The white substance of the central nervous system consists principally of the axis-cylinder processes of the nerve cells which constitute the grey matter. It can be arranged in two distinct strands of fibres—short strands and long strands.

1. The SHORT STRANDS are those which unite different segments of the same divisions of the nerve axis. In the brain they comprise the various *Commissures*, connecting different hemispheres with each other; and the strands of *Association* fibres uniting different parts of the same hemispheres. In the spinal cord they join segments at one level with those at another, and occupy the regions of the cord known as the fasciculi propriï or mixed zones. Many of them are concerned with reflex acts.

To this group of short strands belong the *corpus callosum*, the *anterior* and *posterior commissures*, the *fornix*, the *anterior* and *posterior longitudinal bundles*, and the *cerebellar peduncles*.

(1) The corpus callosum, the fornix, and other minor commissures have already been sufficiently described on pages 158 and 161.

(2) The *anterior longitudinal bundle* starts at the nerve cells of the anterior colliculus. After decussating with its fellow in the middle line, it descends through the cerebral peduncles, through the pons, and through the medulla to the anterior funiculus of the spinal cord, where it lies close to the anterior mesial fissure (fig. 17, page 22). Its fibres end in the nuclei of motor cranial nerves and in the cells of the anterior horn of the spinal cord of both sides. They are concerned with ocular and pupillar reflexes.

(3) The *posterior longitudinal bundle* at first lies within the fasciculus proprius of the anterior column of the spinal cord; gradually, however, it is pushed backwards, by both the motor and sensory decussations, from the ventral aspect of the spinal cord to the dorsal aspect of the medulla, pons, and cerebral

peduncles. It contains both ascending and descending fibres. Both its origin and connections are much discussed. It probably carries fibres which, by means of terminals and collaterals, unite the nuclei of the several motor cranial nerves with each other, co-ordinating the nerves of the one side with those of the opposite side. It also receives fibres from the auditory tract, and from the cells of Deiters and other contiguous nuclei. The fibres from Deiters nuclei are by their ascending and descending branches connected, on the one hand, with the nuclei of the 3rd and 6th cranial nerves, and, on the other, with the cells of the anterior horn of the spinal cord. They, therefore, form a secondary vestibular tract, between the nuclei of the vestibular division of the auditory nerve and these cranial and spinal nerves respectively. The posterior longitudinal bundle, moreover, unites peripheral sensory nerves with the cells of origin of the motor cranial nerves, and the centres for the movements of the eyeballs with the visual centres.

(4) The *Peduncles of the Cerebellum* are three in number—the superior, the middle, and the inferior. They unite the cerebellum to the cerebrum, to the pons, and to the medulla and spinal cord.

(*a*) The *brachia conjunctiva*, or superior peduncles of the cerebellum, carry impulses from the corpus dentatum of the cerebellum to the red nucleus of the opposite side. Two new sets of fibres start in these nuclei: the one set ascends to the optic thalamus and through it to the cerebral cortex; the other set—rubo-spinal tract—travels from the red nucleus of the one side, through that of the opposite side, and thence to the lateral column of the spinal cord, where it lies, as we have seen, in front of the crossed pyramidal tract. Since the cortex cerebelli is, by means of the axones of Purkinjé's cells, joined with the cells of the corpus dentatum of the cerebellum of the same side, we can easily understand how it is that the cerebellar cortex of the one side is, through the red nucleus, brought into relation with the cerebral cortex of the opposite side, and with the spinal cord—rubo-spinal tract—of the same side.

(*b*) The *brachia pontis,* or middle peduncles of the cerebellum, carry fibres from the nucleus pontis to and from the cerebelli of both sides. This nucleus is also connected through the cortico-pontine fibres with the cortex of the frontal, temporal, and occipital lobes of the cerebrum.

(*c*) The *restiform body,* or inferior peduncle of the cerebellum, has a very complex constitution; see page 101. It is sufficient to state that it receives fibres from the lateral column of its own side, from the posterior columns of the medulla of both sides, and from the inferior olive of the opposite side.

Thus we see that the cerebellum is brought into relation with the opposite cerebral cortex, with both sides of the medulla, and with the same side of the spinal cord.

2. The LONG STRANDS—*projection fibres*—connect the motor-sensorial areas with lower centres. They are arranged in two groups: the one motor, the other sensory.

(1) The MOTOR STRANDS are twofold: the *principal motor strand*—cortico-spinal; and the *secondary motor strand*—the cortico-cerebellar-spinal. Both these motor strands consist of two sets of neurones:

the one *central—crossed*; the other *peripheral—uncrossed.*

(*a*) The *principal motor strand*, starting as the axis-cylinder processes of the nerve cells of the motor regions of the cerebral cortex—the first trophic realm,—descends through the corona radiata, through the knee-shaped bend, and through the anterior two-thirds of the posterior limb of the internal capsule, thence through the inner and middle portion of the crusta of the pedunculi cerebri to the pyramidal tracts of the pons and medulla of the same side. At the bottom of the anterior median fissure of the medulla, 90 per cent of the motor fibres decussate—decussation of the pyramids—with those of the opposite side, and then descend, as the crossed pyramidal tract, in the opposite half of the spinal cord to reach the peripheral neurones situated in the anterior horns—the second trophic realm. The rest—10 per cent—pass down the anterior column of the cord, of their own side, as the direct pyramidal tract, to cross over at lower levels, through the anterior commissure, to the grey matter of the opposite side of the spinal cord. The crossed pyramidal tracts, however, also receive a few fibres—the uncrossed lateral pyramidal tract — from the cerebrum of their own side, hence we find that, in cases of hemiplegia—one-sided paralysis—the sound side shows a certain degree of weakness, the injured side a certain amount of movement. In the cortex cerebri the motor centres are arranged from below upwards in the following order—(1) the face and neck; (2) the fingers, wrist, elbow, shoulder; (3) the trunk; (4) the hip, knee, ankle, toes: in the internal capsule the motor fibres are grouped, from before backwards, as follows—(1) in the genu we have fibres for the eyes, head, mouth, and tongue; (2) in the anterior two-thirds of the posterior limb we have, first, the fibres for the shoulder, then those for the elbow, wrist, fingers, thumb, trunk, hip, knee, ankle, and toes. Thus we see that the grouping of the fibres for the upper limb is different in the capsule from what it is in the cortex.

As they descend through the crura cerebri, pons, and medulla, on their way from the cerebral cortex, the axis-cylinder processes of the motor strands, which constitute the cranial nerves, cross over to the opposite side, and, by means of their collaterals and terminals, come into relation with the peripheral neurones of the several motor cranial nerves, just as at lower levels the fibres intended for the spinal nerves decussate in the pyramids (fig. 93, page 182). The central neurones therefore carry the impulses from the brain to the cranial and spinal peripheral motor neurones of the opposite side, which in turn transmit them to the muscles. Thus, for example, the *right* side of the face or arm is worked from the *right* facial or spinal nucleus—the sub-cortical origin; but from the *left* cerebral cortex—the cortical origin.

Hence it follows, as we have said, that all *peripheral* motor neurones are *uncrossed*, whereas the *central* ones are *crossed*.

The following cranial nerves are exceptions to this rule: the 3rd and the 12th nerves are partially crossed; the 4th nerves are totally crossed, decussating in the superior medullary velum.

(*b*) *Secondary Motor Strand.*—The cells of the central neurones of this strand are found in the same areas as the cells of the principal motor tracts, and their axis-cylinders descend mingled with those of the chief motor tract through the internal capsule and crura cerebri to the pons, where they leave that strand and end in branches amidst the nerve cells of the nucleus pontis. The axis-cylinders of the nerve cells of this nucleus (nucleus pontis) then cross over to the opposite half of the cerebellum, to terminate at the neurones of the cerebellar cortex, which transmit the impulses, probably through the cells of Deiters' nucleus, to the spinal cord, thence to the grey matter of the anterior cornu, and thus to the muscles. This, then, is also a crossed tract, the crossing taking place in the upper set of neurones (fig. 95, page 184).

(2) The SENSORY STRANDS conduct impulses from the periphery to the brain. They consist of a *peripheral* and of a *central* set of neurones.

The *peripheral neurones* are uncrossed and single. Their cells are situated outside the cerebro-spinal axis, in the spinal ganglia, for the spinal nerves, and in the ganglia of the sensory nerves, for the cranial nerves. The cells of these ganglia have a *peripheral process*—the protoplasmic process—which places the surface of the body and the various sense organs in communication with the cells of these ganglia; and a *central process*—the axis-cylinder process—connecting the cells of the ganglion with the central axis. They are, as we have said, uncrossed. The *central neurones* connect these peripheral neurones with the higher nerve centres. They are situated within the central nerve axis, and consist of at least two sets of superimposed neurones. They are crossed—the crossing taking place either in the spinal cord—

the inferior sensory decussation,—or in the medulla—the superior sensory decussation,—or in case of the cranial nerves, at higher levels.

In the spinal cord the chief sensory strands are the fasciculus of Goll and of Bürdach: the lateral cerebellar tract, and the fasciculus of Gowers.

a. The fasciculi of Goll and of Bürdach were traced into the medulla as the fasciculus gracilis and the fasciculus cuneatus. They end in the nuclei of these fasciculi. Thence second relays of cells carry the impulses one of two ways, either (1) through the inferior cerebellar peduncle to the cerebellum of the same side or opposite side, or (2) through the medulla—sensory decussation—through the pons and crura cerebri—*fillet*—and through the posterior part of the internal capsule to the opposite cerebral hemispheres. Some of these fibres go direct to the cerebral cortex; but most of them first pass through the optic thalamus (fig. 93, page 182).

The *fillet* is the strand of nerve fibres which conveys sensory impulses to the cerebral cortex from the posterior spinal nerve roots, from the auditory nuclei of the medulla and pons, and from the sensory nuclei of other cranial nerves. It is divided into two parts: the mesial or main fillet, and the lateral fillet.

(*a*) The *main* or *mesial fillet* is the continuation upwards of the posterior columns of the spinal cord through the nuclei of the fasciculus gracilis and the fasciculus cuneatus of the medulla. The former receives the fibres from the lower limbs, the latter from the upper limb. In the mesial line of the medulla, in the inter-olivary region, the fibres of the fillet decussate with those of the opposite side, constituting the superior sensory decussation or decussation of the fillet, as distinct from the inferior sensory decussation in the anterior commissure of the spinal cord. After decussating, the sensory fibres now form a distinct strand, the main or *mesial fillet*, which ascends through the dorsal part of the medulla, pons, and cerebral peduncles, and receiving fibres from the sensory nuclei of cranial nerves, ascends to the optic thalamus and to the region below it and to the anterior and posterior colliculi. Thence a new relay of fibres carries the impulses through the posterior limb of the internal capsule to the optic thalamus and to the cortical centres for sensation, chiefly situated in the post-central gyrus. The fillet is thus a crossed sensory tract, carrying tactile sensations and sensation from muscles, from bones, and from joints to the cortex cerebri. In the mid-brain the mesial fillet gives off a small bundle of fibres—the *superior fillet*—to the anterior pair of corpora quadrigemina—colliculi anteriores.

(*b*) The *lateral fillet* is the upward continuation of the central auditory tract. As you already know, the accessory and lateral auditory nuclei are the primary terminations of the cochlear division of the 8th cranial nerve. From these nuclei the auditory fibres travel either by way of the corpus trapezoid of the pons, or through the striæ medullares of the 4th ventricle, to the nucleus of the corpus trapezoid and to the superior olive of the *same*, but *mostly* of the *opposite* side. Thence, by new relays of fibres, they reach the nucleus of the lateral fillet, the posterior colliculi, a few only ending in the colliculi anteriores, and the corpora geniculata interna. From these nuclei the auditory tract travels to the cortical centres for hearing, situated, as we have seen, in the superior temporal gyrus and upper surface of the temporal lobe. Thus we see that each ear is connected with the cortical centres of both sides, but mainly with that of the opposite side. The lateral fillet is also connected with the lateral column of the spinal cord. The use of these fibres is, however, unknown.

b. The *ascending antero-lateral tract of Gowers,* lying, as you know, on the surface of the lateral aspect of the cord in front of the direct cerebellar tract, is a composite strand. One part of it, the *ventro-spino-cerebellar,* can be traced upwards to the pons, to the level of the 5th cranial nerve, where it turns downwards and backwards to enter the brachium conjunctivum. It ends in the lingual lobe of the superior vermis cerebelli of its own side. Another set of fibres—*spino-tectal*—reaches the pons and mid-brain. A third set—*spino-thalamic*—ascends, through the posterior limb of the internal capsule, to the optic thalamus and to the cerebral cortex, carrying sensations of touch, of temperature, and of pain from the posterior spinal nerve roots. It is a crossed tract through the cells of Clarke's column and through the anterior commissure of the spinal cord. Thus we see that sensations of touch, of temperature, and of pain cross in the spinal cord—inferior sensory decussation,—whereas sensations from muscles, from joints, and from bones cross in the medulla—superior sensory decussation.

c. The *dorso-spino-cerebellar* or *lateral cerebellar tract* ascends along the lateral margin of the spinal cord and medulla to the inferior peduncle of the cerebellum, thence to the upper part of the superior vermis. Most of its fibres end in the same side. This tract, which is associated with the co-ordination of muscular movements, is connected by means of the cells of Clarke's column with the posterior spinal nerve roots.

For the course followed by the several nerves of special sense, see Origins of Cranial Nerves, page 176.

SECTION III.

OUTLINE OF DEVELOPMENT.

In this section we shall give an outline of the development of the brain and spinal cord.

One of the earliest steps in the development of the human embryo is, as you know, the formation of the *blastoderm* or *germinal membrane.* This membrane is composed of three distinct superimposed layers of cells, the *ectoderm*, the *mesoderm*, and the *entoderm.* Of these, the ECTODERM is the one from which the central nervous system is developed.

NEURAL GROOVE.—On the dorsal aspect of the embryo, at a very early date, we find, in front of the primitive streak, two longitudinal ridges, separated from each other by an intervening furrow—the *primitive neural groove.* Gradually increasing in size, these two ridges grow backwards and ultimately meet in the middle line on the dorsal aspect of the embryo. Blending together in the middle line, they form a closed cylindrical longitudinal tube—the *primitive neural tube*—with walls composed of ectodermic cells (fig. 97, page 204). From this primitive tube the brain and spinal cord are formed; the *walls* giving rise to the *solid parts,* viz. to the neuroglia and to the nerve cells and their processes; the *cavity* remaining as the central canal of the spinal cord, and as the various *ventricles* of the brain. Along the line of junction of the two lateral walls, on the dorsal aspect of the neural tube, is a ridge of ectodermic cells, which unite the embedded with the surface ectoderm. This ridge is the *neural crest*, and from its cells are developed the ganglia of both the sympathetic system, and of the cranial and spinal nerves.

I. THE SPINAL CORD.

(Figs. 97, etc., Plate XXXVI. Page 204.)

The Spinal Cord is developed from the hinder part of the primitive neural tube. The lateral walls of this portion of the tube increase in thickness, so much so that the cavity of the tube is reduced to a mere longitudinal slit. Its roof and floor, however, remain thin, and form the mid-dorsal and mid-ventral laminæ. The walls are at first composed of columnar epithelial cells, their inner and outer free ends forming the inner and outer reticular basement membrane of the neural tube. Soon, however, this layer of cells differentiates, and gives rise to two different kinds of cells, known respectively as spongioblasts and germinal cells.

1. The SPONGIOBLASTS are long columnar cells, set at right angles to the long axis of the neural tube; their inner and outer ends form, as we have just seen, the inner and outer reticular basement membrane of the neural tube. At first the entire thickness of the wall of the tube is made up of these spongioblasts. Soon, however, the *outer ends* of the cells are transformed into a network of fibres—the *myelospongium*, which afterwards becomes the neuroglia or supporting con-

FIG. 97.

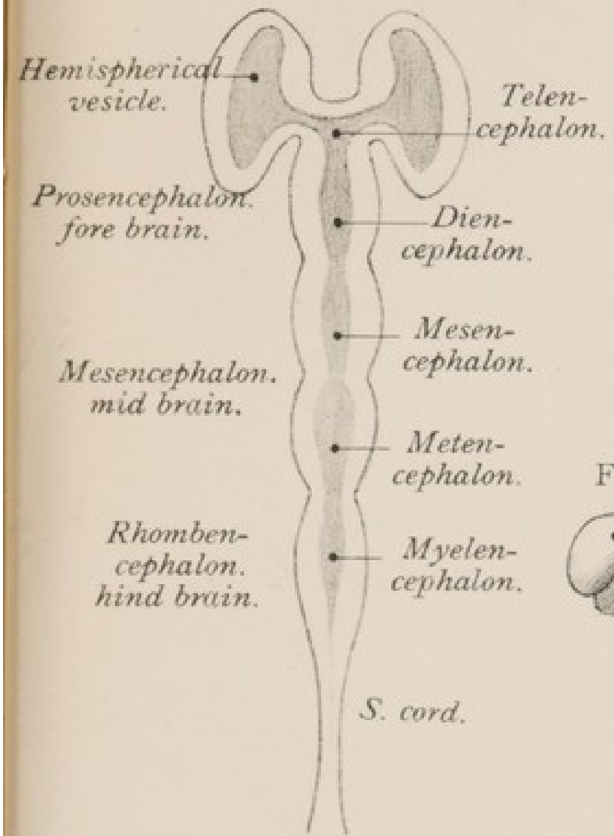


FIG. 98.

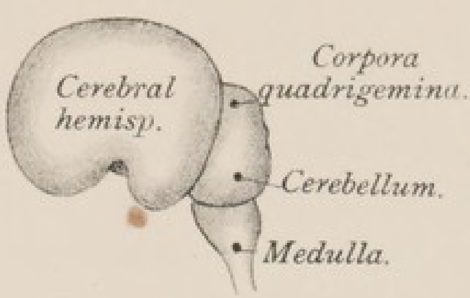


FIG. 99.

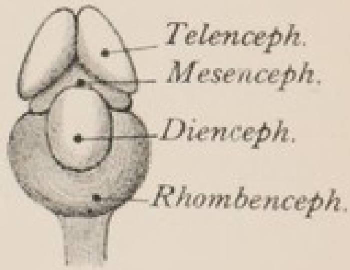


FIG. 100.

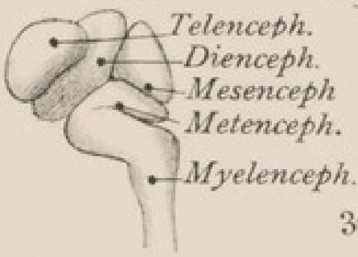


FIG. 101.

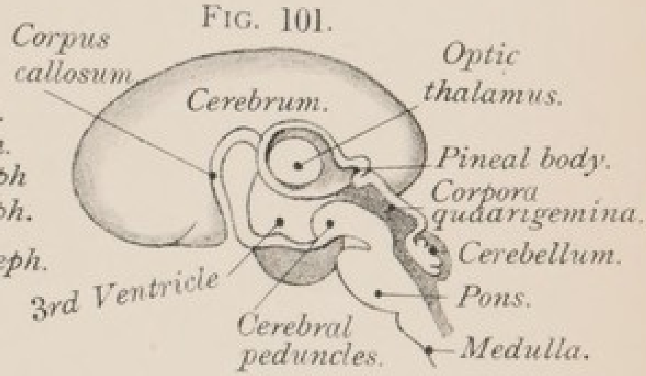


FIG. 102.

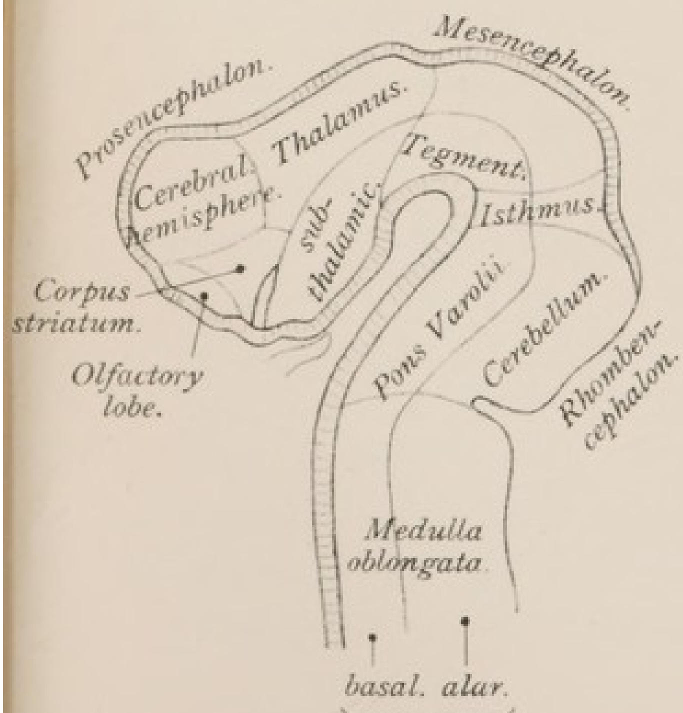
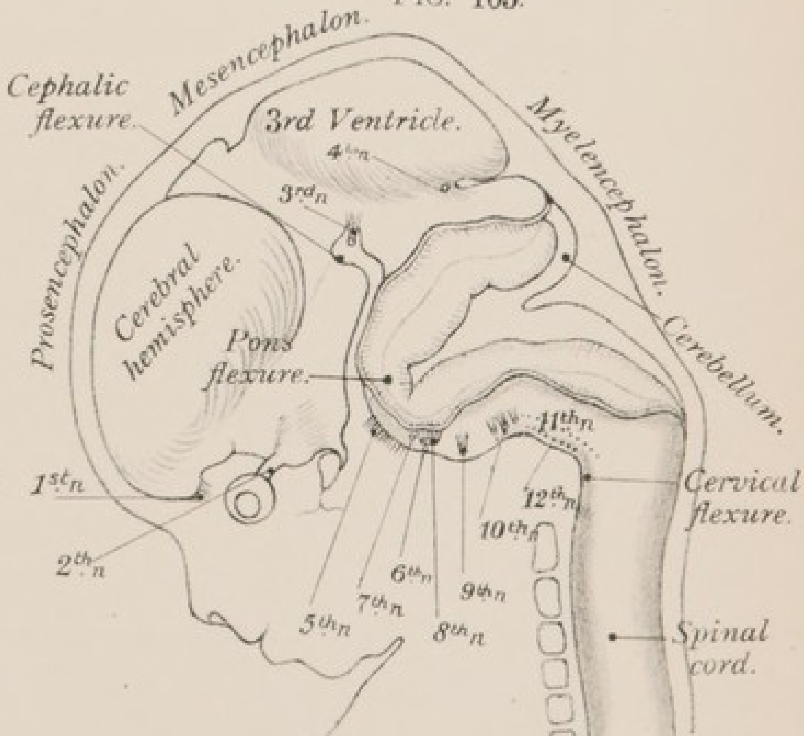


FIG. 103.



Mc Lagan & Cumming, Edinburgh.

nective tissue of the central nervous system. The *inner ends* of the cells, on the other hand, retain their columnar character, and, acquiring cilia, form the columnar ciliated epithelium — ependyma — which lines the central canal of the spinal cord and the various ventricles of the brain. Thus we see that the spongioblasts give rise to two distinct layers of cells: an *inner layer* of columnar epithelial cells—the *ependyma*; and an outer layer, spongy in character—the reticular layer or *myelospongium*.

2. GERMINAL CELLS.—Between the deep ends of the spongioblasts we find many rounded nucleated cells with clear protoplasm, and with their nuclei in some stage or other of division. Their origin is unknown. They, however, give rise to the next group of cells—the neuroblasts, the young nerve cells, hence the name germinal cell. It may be well to note that, though there are germinal cells in the lateral walls of the neural tube, there are none in the mid-dorsal and mid-ventral laminæ, these consisting of spongioblasts only.

3. NEUROBLASTS.—At first the germinal cells occupy the deeper part of the lateral wall of the neural tube, viz. that part next the inner basement membrane. Soon, however, they migrate to the interval between the reticular and columnar portions of the spongioblasts; in other words, they lie between the myelospongium and the ependyma. In this position they form a thick definite layer — the *mantle layer* —composed of large rounded cells, with little protoplasm in the body of the cells, but with distinct, large, oval nuclei. These cells are the NEUROBLASTS or young nerve cells. Though, at first, they are rounded,

they soon become pear-shaped; and the narrow end of the pear elongating, grows out as the axone or axis-cylinder process of the nerve cell. The body of the pear, on the other hand, becomes beset with numberless spinous processes, which finally break up into a reticulum of fine fibres. These fibres branch in all directions and constitute the dendrites or protoplasmic processes of the nerve cells.

BASAL and ALAR LAMINÆ (fig. 102, page 204).—Whereas the mid-dorsal and mid-ventral laminæ, which consist of spongioblasts only, undergo little change, the thickened lateral walls of the neural tube bulge out, on each side, giving rise to longitudinal grooves on the inside of the tube, and corresponding blunt, angular, longitudinal ridges on the outside. These longitudinal ridges and grooves are not confined to that portion of the tube which forms the spinal cord, but extend also to that part which forms the brain. They subdivide each lateral half of the wall of the neural tube into two longitudinal strips of nerve substance, one dorsal, the other ventral. The dorsal segment is known as the *alar lamina*, the ventral segment as the *basal lamina*. Into the former—the alar lamina—grow the axones from the ganglia of the posterior nerve roots: from the latter—the basal lamina—grow outwards the fasciculi which form the anterior nerve roots.

Our next step is to study the formation (1) of the grey matter, (2) of the white matter, and (3) of the fissures of the spinal cord.

I. THE GREY MATTER.—The ventral aspect of the mantle layer forms a longitudinal mass, which is rich in neuroblasts, and which occupies the site of the future *anterior cornua.* The neuroblasts, which form it, arrange themselves in definite groups, corresponding with the groups in the future anterior horns. Many of the cells send out their axis-cylinder process towards the surface of the neural tube, to the place of origin of the future anterior nerve roots. They constitute the fasciculi of these nerve roots. The *posterior horn* is a subsequent outgrowth from the thin dorsal part of the mantle layer. Its formation is coincident with the development of the posterior white columns of the spinal cord.

II. THE WHITE MATTER.—Externally, on the surface of the cord, in the region in which the future white columns of the cord are developed, we find no nuclei, this part of the embryonic cord being composed of the reticular part of the spongioblasts. Into this reticulum the young nerve cells—neuroblasts—send their axones. Of these, some grow outwards towards the points of exit of the future anterior nerve roots; others, becoming longitudinal, ascend and descend in the reticulum, and give rise to the anterior and lateral columns or funiculi of the spinal cord. The posterior columns have a different origin. They arise by the ingrowth of the axones of the nerve cells of the ganglia on the posterior nerve roots. These axones penetrate the cord from without, and, dividing into ascending and descending branches, constitute the chief part of the posterior columns. Thus we see that the anterior and lateral columns are the first to appear, then the posterior.

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 (see page 40).

III. FISSURES.—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 this fissure, thus separating it from the central canal of the cord. The posterior median fissure is not a real fissure, but is a mere septum consisting of neuroglia. The exact mode of its formation is much disputed.

At first the spinal cord fills the entire length of the spinal canal, so that there is no cauda equina; but, by the rapid growth of the canal as compared with the contained spinal marrow, the cord, at about the ninth month, reaches only as low as the 3rd lumbar vertebra. In the adult it usually reaches the 1st lumbar vertebra.

The membranes of the spinal cord are developed from the mesodermic tissue which grows round the original neural tube.

II. THE BRAIN.

(Plate XXXVI. Page 204.)

The Brain is formed from the fore part of the primitive neural tube. At the period of development, when the posterior part of this tube is as yet open, the anterior part dilates considerably, but at first remains single. Its walls thicken, and the cavity of the tube is subdivided by two constrictions into the three segments known as the *anterior*, the *middle*, and the *posterior primary cerebral vesicles*. The anterior and posterior primary vesicles soon divide into two, one behind the other, whereas the middle primary vesicle remains single. Thus we get *five secondary vesicles* (fig. 97, page 204) formed from the *three primary vesicles.*

The following table will give you, enumerated from before backwards, the names of these primary and secondary vesicles and the parts developed from each :—

TABLE OF THE CEREBRAL VESICLES AND THE PARTS DEVELOPED FROM EACH.

PRIMARY VESICLES.	SECONDARY VESICLES.	PARTS DEVELOPED FROM THE VARIOUS VESICLES.
1. Prosencephalon	1. Telencephalon	Cerebral Hemispheres. Corpora Striata. Corpus Callosum. Fornix. Lateral Ventricles. Olfactory Lobe. Fore part of 3rd Ventricle. Fore part of the Tuber Cinereum. Infundibulum. Posterior Lobe of Pituitary Body.
	2. Diencephalon	Optic Thalami. Corpora Geniculata. Pineal Body. Posterior part of the Tuber Cinereum. Posterior part of 3rd Ventricle. Corpora Mammillaria. Optic Nerve and Tracts.
2. Mesencephalon	3. Mesencephalon	Corpora Quadrigemina. Pedunculi Cerebri. Aquæductus Cerebri (Sylvius).

PRIMARY VESICLES.	SECONDARY VESICLES.	PARTS DEVELOPED FROM THE VARIOUS VESICLES.
3. Rhombencephalon	4. Isthmus Rhombencephali	The Superior Cerebellar Peduncles. Valve of Vieussens.
	5 Metencephalon	The Cerebellum. Pons Varolii. Anterior part of the 4th Ventricle.
	6. Myelencephalon	Medulla Oblongata. Posterior part of 4th Ventricle.

Thus we get six rings, with ectodermic walls, composed of histological elements similar to those which give origin to the spinal cord. By subsequent changes in these rings the brain and its subdivisions are built up.

1. **The Rhombencephalon**—POSTERIOR CEREBRAL VESICLE—gives origin to the medulla oblongata, to the pons Varolii, and to the cerebellum. Bending forwards at the upper or anterior end of the primitive spinal cord—the cervical flexure (fig. 103, page 204), the posterior vesicle makes a second bend, a knee-shaped bend, backwards on itself. At first single, it soon becomes divided by a constriction into two parts, a posterior division—the *Myelencephalon,* and an anterior division—the *Metencephalon.*

The hinder division of the vesicle—the *Myelencephalon,* forming the forward bend, becomes developed into the MEDULLA, and the lower part of the 4TH VENTRICLE.

The backward fold forming the fore part of the original vesicle—the *Metencephalon*—becomes the CEREBELLUM and the upper part of the 4TH VENTRICLE;

and the knee-shaped bend gives rise to the PONS VAROLII; hence it is often called the pons curvature.

The *isthmus rhombencephali*—the constricted part between the posterior and middle cerebral vesicles—becomes the superior cerebellar peduncles and the valve of Vieussens (fig. 102, page 204).

2. **The Mesencephalon**—MIDDLE CEREBRAL VESICLE—likewise bends forwards on the posterior vesicle, but, unlike the other primary vesicles, does not divide, but remains single. Its *roof*—alar lamina—becomes thickened, and in it are formed the CORPORA QUADRIGEMINA. Its *floor* and sides—basal lamina—give rise to the PEDUNCULI CEREBRI, while the original CENTRAL CANAL, much narrowed by the growth of these parts, remains as the AQUÆDUCTUS CEREBRI (Sylvius)—iter a tertio ad quartum ventriculum.

3. **The Prosencephalon**—ANTERIOR CEREBRAL VESICLE, like the posterior, becomes subdivided into two portions—a posterior, the *Diencephalon*, and an anterior, the *Telencephalon*. The entire vesicle, at first single and straight, bends forwards on the middle vesicle—the cephalic flexure—which now forms the most prominent part of the head (fig. 103, page 204). From its sides, before it divides into its two segments, grow out two hollow club-shaped diverticula, the OPTIC VESICLES and OPTIC STALKS, which ultimately become the retina and the optic nerves (fig. 103, page 204).

Diencephalon.—In the lateral walls of this segment—the *diencephalon*—are developed the two OPTIC THALAMI, separated from each other by a median cleft—the 3RD VENTRICLE. Across this cavity is subsequently formed the massa intermedia, the middle or grey commissure. In the floor of the ventricle are formed the CORPORA MAMMILLARIA and the posterior part of the TUBER CINEREUM — all of which are structures to be seen in the interpeduncular space. At the back, the cavity communicates with the 4th ventricle through a narrow channel, the continuation backwards of the original cavity—the AQUÆDUCTUS CEREBRI (Sylvius); in front, through the interventricular foramina, it communicates with the lateral ventricles.

The roof of the vesicle rapidly becomes thinner, and is reduced to a mere lamina of epithelium connected with the pia mater and with the choroid plexus in the roof 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 forwards, then backwards as a hollow process—the PINEAL BODY—epiphysis cerebri—which is regarded as a rudimentary third eye.

Telencephalon.—The *fore* part of the original anterior cerebral vesicle—*telencephalon*—bulges forward as a median mass, which is at first single, but soon becomes divided by a longitudinal cleft into two lateral segments, united by a thin *mesial* part at the bottom of the cleft. The wall of the *mesial segment*, in other words, the bottom of the cleft, remains thin and stationary, and forms the *lamina terminalis*. The cavity of the mesial segment becomes the fore part of the 3RD VENTRICLE, and in its floor are formed the anterior part of the TUBER CINEREUM, the INFUNDIBULUM, and the posterior lobe of the PITUITARY BODY. The *lateral segments*, on the other hand, grow rapidly and form the hemispherical vesicles, which become the CEREBRAL HEMISPHERES (fig. 103, page 204). As we saw on page 115, these cerebral hemispheres can each be subdivided into two parts, the Rhinencephalon and the Pallium. This subdivision is recognisable at a very early date, the line of demarcation being a slight lateral furrow on the surface of the hemispheres. In the human brain the Rhinencephalon is very rudimentary and the Pallium enormously developed. The cavities within them remain as the LATERAL VENTRICLES. These are connected with the 3rd ventricle, and, through it, with each other, by a constantly narrowing neck, the FORAMEN INTERVENTRICULARE (Monro) (fig. 97, page 204). 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 this grey mass we find the grey and white matter of the island of Reil. The OLFACTORY LOBES are hollow outgrowths of the lower and lateral parts of the hemispherical vesicles.

The *roof* and *walls* of the hemispherical vesicles are, at first, 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. Of these fissures, some are infoldings of the entire wall, and cause corresponding elevations in the interior of the vesicle; these are the primary fissures: the sulci or secondary fissures are mere grooves, and do not give rise to corresponding elevations in the interior. Increasing rapidly in size these hemispheres grow backwards, and, finally, completely overlap and hide the other subdivisions of the brain.

The Fornix, the Corpus Callosum, and the anterior commissure appear to take their origin in connection with the lamina terminalis; but their exact mode of development is still very doubtful. However, in front, and for some distance backwards, the mesial surfaces of the cerebral hemispheres come in contact, and at certain places partly grow together. From these united parts of the mesial aspect of the hemispherical vesicles are developed the CORPUS CALLOSUM and the FORNIX. 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 the first developed, its growth extending backwards with the growth of the hemispheres. Those portions of the mesial walls of the hemispherical vesicles, which lie between the fore part of the corpus callosum and the fornix, form, as they unite, two areas called from their shape the *trapezoid plates*, and from their position, the *areæ paraterminales* (Elliot-Smith). These plates or laminæ form the septum lucidum, the vertical partition separating the lateral ventricles. Between the two layers of which this septum is composed, 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.

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