4. The Brain or Encephalon

General Considerations and Divisions.—The brain, is contained within the cranium, and constitutes the upper, greatly expanded part of the central nervous system. In its early embryonic condition it consists of three hollow vesicles, termed the hind-brain or rhombencephalon, the mid-brain or mesencephalon, and the fore-brain or prosencephalon; and the parts derived from each of these can be recognized in the adult (Fig. 677). Thus in the process of development the wall of the hind-brain undergoes modification to form the medulla oblongata, the pons, and cerebellum, while its cavity is expanded to form the fourth ventricle. The mid-brain forms only a small part of the adult brain; its cavity becomes the cerebral aqueduct (aqueduct of Sylvius), which serves as a tubular communication between the third and fourth ventricles; while its walls are thickened to form the corpora quadrigemina and cerebral peduncles. The fore-brain undergoes great modification: its anterior part or telencephalon expands laterally in the form of two hollow vesicles, the cavities of which become the lateral ventricles, while the surrounding walls form the cerebral hemispheres and their commissures; the cavity of the posterior part diencephalon forms the greater part of the third ventricle, and from its walls are developed most of the structures which bound that cavity.

Fig. 677–Scheme showing the connections of the several parts of the brain. (After Schwalbe.) (See enlarged image)
e hind-brain or rhombencephalon occupies the posterior fossa of the cranial cavity and lies below a fold of dura mater, the tentorium cerebelli. It consists of (a) the myelencephalon, comprising the medulla oblongata and the lower part of the fourth ventricle; (b) the metencephalon, consisting of the pons, cerebellum, and the intermediate part of the fourth ventricle; and (c) the isthmus rhombencephali, a constricted portion immediately adjoining the mid-brain and including the superior peduncles of the cerebellum, the terior medullary velum, and the upper part of the fourth ventricle.

The Medulla Oblongata (spinal bulb).—The medulla oblongata extends from the lower margin of the pons to a plane passing transversely low the pyramidal decussation and above the first pair of cervical nerves; this plane corresponds with the upper border of the atlas behind, d the middle of the odontoid process of the axis in front; at this level the medulla oblongata is continuous with the medulla spinalis. Its terior surface is separated from the basilar part of the occipital bone and the upper part of the odontoid process by the membranes of the brain d the occipitomental ligaments. Its posterior surface is received into the fossa between the hemispheres of the cerebellum, and the upper portion it forms the lower part of the floor of the fourth ventricle.

The medulla oblongata is pyramidal in shape, its broad extremity being directed upward toward the pons, while its narrow, lower end is tinuous with the medulla spinalis. It measures about 3 cm. in length, about 2 cm. in breadth at its widest part, and about 1.25 cm. in ckeness. The central canal of the medulla spinalis is prolonged into its lower half, and then opens into the cavity of the fourth ventricle; the dulla oblongata may therefore be divided into a lower closed part containing the central canal, and an upper open part corresponding with the ver portion of the fourth ventricle.

The Anterior Median Fissure (fissura mediana anterior; ventral or ventromedian fissure) contains a fold of pia mater, and extends along the ire length of the medulla oblongata: it ends at the lower border of the pons in a small triangular expansion, termed the foramen cecum. Its ver part is interrupted by bundles of fibers which cross obliquely from one side to the other, and constitute the pyramidal decussation. Some ers, termed the anterior external arcuate fibers, emerge from the fissure above this decussation and curve lateralward and upward over the face of the medulla oblongata to join the inferior peduncle.

The Posterior Median Fissure (fissura mediana posterior; dorsal or dorsomedian fissure) is a narrow groove; and exists only in the closed rt of the medulla oblongata; it becomes gradually shallower from below upward, and finally ends about the middle of the medulla oblongata, ere the central canal expands into the cavity of the fourth ventricle.
These two fissures divide the closed part of the medulla oblongata into symmetrical halves, each presenting elongated eminences which, on surface view, are continuous with the funiculi of the medulla spinalis. In the open part the halves are separated by the anterior median fissure, and by a median raphé which extends from the bottom of the fissure to the floor of the fourth ventricle. Further, certain of the cranial nerves pass through the substance of the medulla oblongata, and are attached to its surface in series with the roots of the spinal nerves; thus, the fibers of the hypoglossal nerve represent the upward continuation of the anterior nerve roots, and emerge in linear series from a furrow termed \textit{antero-lateral sulcus}. Similarly, the accessory, vagus, and glossopharyngeal nerves correspond with the posterior nerve roots, and are attached to the bottom of a sulcus named the \textit{postero-lateral sulcus}. Advantage is taken of this arrangement to subdivide each half of the medulla oblongata into three districts, \textit{anterior, middle}, and \textit{posterior}. Although these three districts appear to be directly continuous with the corresponding funiculi of the medulla spinalis, they do not necessarily contain the same fibers, since some of the fasciculi of the medulla spinalis end in the medulla oblongata, while others alter their course in passing through it. The \textit{anterior district} (Fig. 679) is named the \textit{pyramid} (\textit{pyramis medullæ oblongata}) and lies between the anterior median fissure and the \textit{antero-lateral sulcus}. Its upper end is slightly constricted, and between it and the pons the fibers of the abducent nerve emerge; a little below the pons it becomes enlarged and prominent, and finally tapers into the anterior funiculus of the medulla spinalis, with which, at first sight, it appears to be directly continuous.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure679.png}
\caption{Medulla oblongata and pons. Anterior surface. (See enlarged image)}
\end{figure}

The two pyramids contain the motor fibers which pass from the brain to the medulla oblongata and medulla spinalis, corticobulbar and corticospinal fibers. When these pyramidal fibers are traced downward it is found that some two-thirds or more of them leave the pyramids in successive bundles, and decussate in the anterior median fissure, forming what is termed the **pyramidal decussation**. Having crossed the midline, they pass down in the posterior part of the lateral funiculus as the lateral cerebrospinal fasciculus. The remaining fibers—*i.e.*, those which occupy the lateral part of the pyramid—do not cross the middle line, but are carried downward as the anterior cerebrospinal fasciculus (*Fig. 680*) into the anterior funiculus of the same side.

The greater part of the anterior proper fasciculus of the medulla spinalis is continued upward through the medulla oblongata under the name of the **medial longitudinal fasciculus**.
The lateral district (Fig. 681) is limited in front by the antero-lateral sulcus and the roots of the hypoglossal nerve, and behind by the postero-lateral sulcus and the roots of the accessory, vagus, and glossopharyngeal nerves. Its upper part consists of a prominent oval mass which is named the olive, while its lower part is of the same width as the lateral funiculus of the medulla spinalis, and appears on the surface to be a direct continuation of it. As a matter of fact, only a portion of the lateral funiculus is continued upward into this district, for the lateral cerebospinal fasciculus passes into the pyramid of the opposite side, and the dorsal spinocerebellar fasciculus is carried into the inferior dentice in the posterior district. The ventral spinocerebellar fasciculus is continued upward on the lateral surface of the medulla oblongata in the same relative position it occupies in the spinal cord until it passes under cover of the external arcuate fibers. It passes beneath these fibers dorsal to the olive and ventral to the roots of the vagus and glossopharyngeal nerves; it continues upward through the pons along the dorsal edge of the lateral lemniscus. The remainder of the lateral funiculus consists chiefly of the lateral proper fasciculus. Most of these fibers beneath the olive and disappear from the surface; but a small strand remains superficial to the olive. In a depression at the upper end of this and is the acoustic nerve.
Fig. 682 – Superficial dissection of brain-stem. Lateral view. (See enlarged image)
Fig. 683– Dissection of brain-stem. Lateral view. (See enlarged image)
FIG. 684–Deep dissection of brain-stem. Lateral view. (See enlarged image)
The olive (oliva; olivary body) is situated lateral to the pyramid, from which it is separated by the antero-lateral sulcus, and the fibers of the pogoSSal nerve. Behind, it is separated from the posterolateral sulcus by the ventral spinocerebellar fasciculus. In the depression between the upper end of the olive and the pons lies the acoustic nerve. It measures about 1.25 cm. in length, and between its upper end and the pons there is a slight depression to which the roots of the facial nerve are attached. The external arcuate fibers wind across the lower part of the ramid and olive and enter the inferior peduncle.

The posterior district (Fig. 686) lies behind the posterolateral sulcus and the roots of the accessory, vagus, and the glosopharyngeal nerves, and, like the lateral district, is divisible into a lower and an upper portion.
The lower part is limited behind by the posterior median fissure, and consists of the fasciculus gracilis and the fasciculus cuneatus. The fasciculus gracilis is placed parallel to and along the side of the posterior median fissure, and separated from the fasciculus cuneatus by the stero-intermediate sulcus and septum. The gracile and cuneate fasciculi are at first vertical in direction; but at the lower part of the rhomboid fossa they diverge from the middle line in a V-shaped manner, and each presents an elongated swelling. That on the fasciculus gracilis is named the clava, and is produced by a subjacent nucleus of gray matter, the nucleus gracilis; that on the fasciculus cuneatus is termed the cuneate bercle, and is likewise caused by a gray nucleus, named the nucleus cuneatus. The fibers of these fasciculi terminate by arborizing around cells in their respective nuclei. A third elevation, produced by the substantia gelatinosa of Rolando, is present in the lower part of the stierior district of the medulla oblongata. It lies on the lateral aspect of the fasciculus cuneatus, and is separated from the surface of the medulla oblongata by a band of nerve fibers which form the spinal tract (spinal root) of the trigeminal nerve. Narrow below, this elevation gradually expands above, and ends, about 1.25 cm. below the pons, in a tubercle, the tubercle of Rolando (tuber cinereum).

The upper part of the posterior district of the medulla oblongata is occupied by the inferior peduncle, a thick rope-like strand situated between the lower part of the fourth ventricle and the roots of the glosopharyngeal and vagus nerves. The inferior peduncles connect the medulla spinalis and medulla oblongata with the cerebellum, and are sometimes named the restiform bodies. As they pass upward, they converge from each other, and assist in forming the lower part of the lateral boundaries of the fourth ventricle; higher up, they are directed onward, each passing to the corresponding cerebellar hemisphere. Near their entrance, into the cerebellum they are crossed by several strands fibers, which run to the median sulcus of the rhomboid fossa, and are named the striæ medullares. The inferior peduncle appears to be the upward continuation of the fasciculus gracilis and fasciculus cuneatus; this, however, is not so, as the fibers of these fasciculi end in the gracile and cuneate nuclei. The constitution of the inferior peduncle will be subsequently discussed.

Caudal to the striæ medullares the inferior peduncle is partly covered by the corpus pontobulbare (Essick 120), a thin mass of cells and fibers tending from the pons between the origin of the VII and VIII cranial nerves.
the medulla oblongata and pass to different parts of the brain; (4) the gray substance, which in the medulla spinalis forms a continuous H-shaped column, becomes greatly modified and subdivided in the medulla oblongata, where also new masses of gray substance are added; (5) on account of the opening out of the central canal of the medulla spinalis, certain parts of the gray substance, which in the medulla spinalis were more or less centrally situated, are displayed in the rhomboid fossa; (6) the medulla oblongata is intimately associated with many of the cranial nerves, some arising form, and others ending in, nuclei within its substance.

The Cerebrospinal Fasciculi.—The downward course of these fasciculi from the pyramids of the medulla oblongata and their partial decussation have already been described (page 761). In crossing to reach the lateral funiculus of the opposite side, the fibers of the lateral cerebrospinal fasciculi extend backward through the anterior columns, and separate the head of each of these columns from its base (Figs. 7, 688). The base retains its position in relation to the ventral aspect of the central canal, and, when the latter opens into the fourth ventricle, pears in the rhomboid fossa close to the middle line, where it forms the nuclei of the hypoglossal and abducent nerves; while above the level the ventricle it exists as the nuclei of the trochlear and oculomotor nerves in relation to the floor of the cerebral aqueduct. The head of the lumn is pushed lateralward and forms the nucleus ambiguus, which gives origin from below upward to the cranial part of the accessory and motor fibers of the vagus and glossopharyngeal, and still higher to the motor fibers of the facial and trigeminal nerves.

The fasciculus gracilis and fasciculus cuneatus constitute the posterior sensory fasciculi of the medulla spinalis; they are prolonged upward to the lower part of the medulla oblongata, where they end respectively in the nucleus gracilis and nucleus cuneatus. These two nuclei are continuous with the central gray substance of the medulla spinalis, and may be regarded as dorsal projections of this, each being covered superficially by the fibers of the corresponding fasciculus. On transverse section (Fig. 694) the nucleus gracilis appears as a single, more or less quadrangular mass, while the nucleus cuneatus consists of two parts: a larger, somewhat triangular, medial nucleus, composed of small or medium-sized cells, and a smaller lateral nucleus containing large cells.
Fig. 688—Section of the medulla oblongata at the level of the decussation of the pyramids. (Testut.) 1. Anterior median fissure. 2. Posterior median sulcus. 3. Motor roots. 4. Sensory roots. 5. Base of the anterior column, from which the head (5') has been detached by the lateral cerebrospinal fasciculus. 6. Decussation of the lateral cerebrospinal fasciculus. 7. Posterior columns (in blue). 8. Gracile nucleus. (See enlarged image)
The fibers of the fasciculus gracilis and fasciculus cuneatus end by arborizing around the cells of these nuclei (Fig. 692). From the cells of the new fibers arise; some of these are continued as the posterior external arcuate fibers into the inferior peduncle, and through it to the cerebellum, but most of them pass forward through the neck of the posterior column, thus cutting off its head from its base (Fig. 693). Curving forward, they decussate in the middle line with the corresponding fibers of the opposite side, and run upward immediately behind the cerebrospinal fibers, as a flattened band, named the lemniscus or fillet. The decussation of these sensory fibers is situated above that of the motor fibers, and is named the [decussation of the lemniscus](https://www.nlm.nih.gov/medlineplus/images/decussationoflemniscus.html) or [sensory decussation](https://www.nlm.nih.gov/medlineplus/images/sensorydecussation.html). The lemniscus is joined by the spinothalamic fasciculus (page 792), the fibers of which are derived from the cells of the gray substance of the opposite side of the medulla spinalis.

The base of the posterior column at first lies on the dorsal aspect of the central canal, but when the latter opens into the fourth ventricle, it pears in the lateral part of the rhomboid fossa. It forms the terminal nuclei of the sensory fibers of the vagus and glossopharyngeal nerves, d is associated with the vestibular part of the acoustic nerve and the sensory root of the facial nerve. Still higher, it forms a mass of pigmented cells—the [locus caeruleus](https://www.nlm.nih.gov/medlineplus/images/locuscaeruleus.html)—in which some of the sensory fibers of the trigeminal nerve appear to end. The head of the posterior column forms ang nucleus, in which the fibers of the spinal tract of the trigeminal nerve largely end.
The dorsal spinocerebellar fasciculus (fasciculus cerebellospinalis; direct cerebellar tract) leaves the lateral district of the medulla oblongata; most of its fibers are carried backward into the inferior peduncle of the same side, and through it are conveyed to the cerebellum; but some run upward with the fibers of the lemniscus, and, reaching the inferior colliculus, undergo decussation, and are carried to the cerebellum through the superior peduncle.

The proper fasciculi (basis bundles) of the anterior and lateral funiculi largely consist of intersegmental fibers, which link together the different segments of the medulla spinalis; they assist in the production of the formatio reticularis of the medulla oblongata, and many of them are accumulated into a fasciculus which runs up close to the median raphé between the lemniscus and the rhomboid fossa; this strand is named the medial longitudinal fasciculus, and will be again referred to.

Gray Substance of the Medulla Oblongata (Figs. 694, 695).—In addition to the gracile and cuneate nuclei, there are several other nuclei to be considered. Some of these are traceable from the gray substance of the medulla spinalis, while others are unrepresented in it.

The hypoglossal nucleus is derived from the base of the anterior column; in the lower closed part of the medulla oblongata it is situated on the ventrolateral aspect of the central canal; but in the upper part it approaches the rhomboid fossa, where it lies close to the middle line, under an eminence named the trigonum hypoglossi (Fig. 709). Numerous fibers connect the two nuclei, both nuclei send long dendrons across the middle line, commissure fibers also connect them. The nucleus measures about 2 cm. in length, and consists of large multipolar nerve cells, similar to those in the anterior column of the spinal cord, whose axons constitute the roots of the hypoglossal nerve. These nerve roots leave the ventral side of the nucleus, pass forward between the white reticular formation and the gray reticular formation, between the inferior olivary nucleus and the medial accessory olivary nucleus, and emerge from the antero-lateral sulcus.

2. The nucleus ambiguus (Figs. 696, 697), the somatic motor nucleus of the glossopharyngeal, vagus and cranial portion of the accessory nerves, is the continuation into the medulla oblongata of the dorso-lateral cell group of the anterior column of the spinal cord. Its large multipolar cells are like those in the anterior column of the cord; they form a slender column in the deep part of the formatio reticularis grisea about midway between the dorsal accessory olive and the nucleus of the spinal tract of the trigeminal. It extends from the level of the decussation of the median fillet to the upper end of the medulla oblongata. Its fibers first pass backward toward the floor of the fourth ventricle d then curve rather abruptly lateralward and ventrally to join the fibers from the dorsal nucleus.

25. The dorsal nucleus (Figs. 696, 698), nucleus ala cinerea, often called the sensory nucleus or the terminal nucleus of the sensory fibers of the glossopharyngeal and vagus nerves, is probably a mixed nucleus and contains not only the terminations of the sympathetic afferent or

sensory fibers and the cells connected with them but contains also cells which give rise to sympathetic efferent or preganglionic fibers. These preganglionic fibers terminate in sympathetic ganglia from which the impulses are carried by other neurons. The cells of the dorsal nucleus are spindle-shaped, like those of the posterior column of the spinal cord, and the nucleus is usually considered as representing the base of the spinal cord. It measures about 2 cm. in length, and in the lower, closed part of the medulla oblongata is situated behind the hypoglossal nucleus; whereas in the upper, open part it lies lateral to that nucleus, and corresponds to an eminence, named the **ala cinerea** (**trigonum vagi**), the rhomboid fossa.

![Diagram of the medulla oblongata](See enlarged image)

**Fig. 694**– Section of the medulla oblongata at about the middle of the olive. (Schwalbe.)

**Fig. 695**– Transverse section of medulla oblongata below the middle of the olive. (See enlarged image)

The **nuclei of the cochlear and vestibular nerves** are described on page 788.
The cranial nerve nuclei schematically represented; dorsal view. Motor nuclei in red; sensory in blue. (The olfactory and optic centers are not represented.) (See enlarged image)

5. The olivary nuclei (Fig. 694) are three in number on either side of the middle line, viz., the inferior olivary nucleus, and the medial and dorsal accessory olivary nuclei; they consist of small, round, yellowish cells and numerous fine nerve fibers. (a) The inferior olivary nucleus is the largest, and is situated within the olive. It consists of a gray folded lamina arranged in the form of an incomplete capsule, opening medially by an aperture called the hilum emerging from the hilum are numerous fibers which collectively constitute the peduncle of the olive. The axons, olivocerebellar fibers, which leave the olivary nucleus pass out through the hilum and decussate with those from the opposite olive in the raphé, then as internal arcuate fibers they pass partly through and partly around the opposite olive and enter the inferior peduncle to be distributed to the cerebellar hemisphere of the opposite side from which they arise. The fibers are smaller than the internal arcuate fibers connected with the median lemniscus. Fibers passing in the opposite direction from the cerebellum to the olivary nucleus are often described as their existence is doubtful. Much uncertainty also exists in regard to the connections of the olive and the spinal cord. Important connections between the cerebrum and the olive of the same side exist but the exact pathway is unknown. Many collaterals from the reticular formation and in the pyramids enter the inferior olivary nucleus. Removal of one cerebellar hemisphere is followed by atrophy of the opposite olivary nucleus. (b) The medial accessory olivary nucleus lies between the inferior olivary nucleus and the pyramid, and forms a curved lamina, the concavity of which is directed laterally. The fibers of the hypoglossal nerve, as they traverse the medulla, pass between the medial accessory and the inferior olivary nuclei. (c) The dorsal accessory olivary nucleus is the smallest, and appears on transverse section as a curved lamina behind the inferior olivary nucleus.

The nucleus arcuatus is described below with the anterior external arcuate fibers.

Inferior Peduncle (restiform body).—The position of the inferior peduncles has already been described (page 775). Each comprises:

1) Fibers from the dorsal spinocebellar fasciculus, which ascends from the lateral funiculus of the medulla spinalis.

2) The olivocerebellar fibers from the opposite olivary nucleus.

3) Internal arcuate fibers from the gracile and cuneate nuclei of the opposite side; these fibers form the deeper and larger part of the inferior peduncle.

See enlarged image
The anterior external arcuate fibers vary as to their prominence in different cases: in some they form an almost continuous layer covering the pyramid and olive, while in others they are barely visible on the surface. They arise from the cells of the gracile and cuneate nuclei, and passing forward through the formatio reticularis, decussate in the middle line. Most of them reach the surface by way of the anterior median fissure, and arch backward over the pyramid. Reinforced by others which emerge between the pyramid and olive, they pass backward over the olive and lateral district of the medulla oblongata, and enter the inferior peduncle. They thus connect the cerebellum with the gracile and cuneate nuclei of the opposite side. As the fibers arch across the pyramid, they enclose a small nucleus which lies in front of and medial to the pyramid. This is named the nucleus arcuatus, and is serially continuous above with the nuclei pontis in the pons; it contains small fusiform cells, around which some of the arcuate fibers end, and from which others arise.
Fig. 698– Primary terminal nuclei of the afferent (sensory) cranial nerves schematically represented; lateral view. The olfactory and optic centers are not represented. (See enlarged image)

Fig. 699– Diagram showing the course of the arcuate fibers. (Testut.) 1. Medulla oblongata anterior surface. 2. Anterior median fissure. 3. Fourth ventricle. 4. Inferior olivary nucleus, with the accessory olivary nuclei. 5. Gracile nucleus. 6. Cuneate nucleus. 7. Trigeminal. 8. Inferior peduncles, seen from in front. 9. Posterior external arcuate fibers. 10. Anterior external arcuate fibers. 11. Internal arcuate fibers. 12. Peduncle of inferior olivary nucleus. 13. Nucleus arcuatus. 14. Vagus. 15. Hypoglossal. (See enlarged image)

5) The posterior external arcuate fibers also take origin in the gracile and cuneate nuclei; they pass to the inferior peduncle of the same side. It is uncertain whether fibers are continued directly from the gracile and cuneate fasciculi into the inferior peduncle.

5) Fibers from the terminal sensory nuclei of the cranial nerves, especially the vestibular. Some of the fibers of the vestibular nerve are thought to continue directly into the cerebellum.

7) Fibers from the ventral spinocerebellar fasciculus.

8) The existence of fibers from the cerebellum (cerebellobulbar, cerebello-olivary, and cerebello-spinal) to the medulla and spinal cord is very certain.

Fig. 700– The formatio reticularis of the medulla oblongata, shown by a transverse section passing through the middle of the olive. (Testut.) 1. Anterior median fissure. 2. Fourth ventricle. 3. Formatio reticularis, with 3′, its internal part (reticularis alba), and 3″, its external part (reticularis grisea). 4. Raphé. 5. Pyramid. 6. Lemniscus. 7. Inferior olivary nucleus with the two accessory olivary nuclei. 8. Hypoglossal nerve,

**Formatio Reticularis (Fig. 700).**—This term is applied to the coarse reticulum which occupies the anterior and lateral districts of the medulla longata. It is situated behind the pyramid and olive, extending laterally as far as the inferior peduncles, and dorsally to within a short distance the rhomboid fossa. The reticulum is caused by the intersection of bundles of fibers running at right angles to each other, some being longitudinal, others more or less transverse in direction. The formatio reticularis presents a different appearance in the anterior district from that it does in the lateral; in the former, there is an almost entire absence of nerve cells, and hence this part is known as the *reticularis alba*; whereas in the lateral district nerve cells are numerous, and as a consequence it presents a gray appearance, and is termed the *reticularis isea*.

1 the substance of the formatio reticularis are two small nuclei of gray matter: one, the *inferior central nucleus* (*nucleus of Roller*), near the sral aspect of the hilus of the inferior olivary nucleus; the other, the *nucleus lateralis*, between the olive and the spinal tract of the trigeminal rve.

\[\text{In the reticularis alba the longitudinal fibers form two well-defined fasciculi, viz.: (1) thelemniscus, which lies close to the raphé, immediately hind the fibers of the pyramid; and (2) the medial longitudinal fasciculus, which is continued upward from the anterior and lateral proper culated of the medulla spinalis, and, in the upper part of the medulla oblongata, lies between the lemniscus and the gray substance of the omboid fossa. The longitudinal fibers in the reticularis grisea are derived from the lateral funiculus of the medulla spinalis after the lateral ÿospinal fasciculus has passed over to the opposite side, and the dorsal spinocerebellar fasciculus has entered the inferior peduncle. They m indeterminate fibers, with the exception of a bundle named the fasciculus solitarius, which is made up of descending fibers of the vagus ÿospopharyngeal nerves. The transverse fibers of the formatio reticularis are the arcuate fibers already described (page 782).}\]

**Pons (pons Varoli).**—The pons or forepart of the hind-brain is situated in front of the cerebellum. From its superior surface the cerebral duncles emerge, one on either side of the middle line. Curving around each peduncle, close to the upper surface of the pons, a thin white nd, the *tamina pontis*, is frequently seen; it enters the cerebellum between the middle and superior peduncles. Behind and below, the pons is niusulous with the medulla oblongata, but is separated from it in front by a furrow in which the abducent, facial, and acoustic nerves appear.

\[s \text{ventral or anterior surface (pars basilaris pontis) is very prominent, markedly convex from side to side, less so from above downward. It consists of transverse fibers arched like a bridge across the middle line, and gathered on either side into a compact mass which forms \text{middle peduncle}. It rests upon the clivus of the sphenoidal bone, and is limited above and below by well-defined borders. In the middle line the sulcus basilaris for the lodgement of the basilar artery; this sulcus is bounded on either side by an eminence caused by the descent of the ÿospinal fibers through the substance of the pons. Outside these eminences, near the upper border of the pons, the trigeminal nerves make \text{their exit}, each consisting of a smaller, medial, motor root, and a larger, lateral, sensory root; vertical lines drawn immediately beyond the genial nerves, may be taken as the boundaries between the ventral surface of the pons and the middle cerebellar peduncle.}\]

\[s \text{dorsal or posterior surface (pars dorsalis pontis), triangular in shape, is hidden by the cerebellum, and is bounded laterally by the superior duncle; it forms the upper part of the rhomboid fossa, with which it will be described.}\]

\[\text{ructure (Fig. 701).—Transverse sections of the pons show it to be composed of two parts which differ in appearance and structure: thus, the silar or ventral portion consists for the most part of fibers arranged in transverse and longitudinal bundles, together with a small amount of \text{sub substance}; while the dorsal tegmental portion is a continuation of the reticular formation of the medulla oblongata, and most of its stituents are continued into the tegmenata of the cerebral peduncles.}\]

\[\text{he basilar part of the pons consists of —(a) superficial and deep transverse fibers, (b) longitudinal fasciculi, and (c) some small nuclei of \text{sub substance}, termed the nuclei pontis which give rise to the transverse fibers.}\]

\[\text{he superficial transverse fibers (fibrae pontis superficiales) constitute a rather thick layer on the ventral surface of the pons, and are lected into a large rounded bundle on either side of the middle line. This bundle, with the addition of some transverse fibers from the deeper t of the pons, forms the greater part of the brachium pontis.}\]

\[\text{he deep transverse fibers (fibrae pontis profunde) partly intersect and partly lie on the dorsal aspect of the cerebrospinal fibers. They course the lateral border of the pons, and form part of the middle peduncle; the further connections of this brachium will be discussed with theatomy of the cerebellum.}\]

\[\text{he longitudinal fasciculi (fasciculi longitudinales) are derived from the cerebral peduncles, and enter the upper surface of the pons. They eam downward on either side of the middle line in larger or smaller bundles, separated from each other by the deep transverse fibers; these gitudinal bundles cause a forward projection of the superficial transverse fibers, and thus give rise to the eminences on the anterior surface.}\]
Some of these fibers end in, or give off collateral to, the nuclei pontis. An important pathway is thus formed between the cerebral cortex and the cerebellum, the first neuron having its cell body in the cortex and sending its axon through the internal capsule and cerebral peduncle to form synapses either by terminals or collaterals with cell bodies situated in the nuclei pontis. Axons from these cells form the transverse fibers which pass through the middle peduncle into the cerebellum. Others after decussating, terminate either directly or indirectly in the motor nuclei of the spinal and cranial nerves; but most of them are carried through the pons, and at its lower surface are collected into the pyramids of the medulla. The fibers which end in the motor nuclei of the cranial nerves are derived from the cells of the cerebral cortex, and at the same relation to the motor cells of the cranial nerves that the cerebrospinal fibers bear to the motor cells in the anterior column of the spinal cord. Probably none of the collaterals or terminals of the cerebrospinal and cerebrobulbar fibers end directly in the motor nuclei of the spinal and cranial nerves, one or more association neurons are probably interpolated in the pathway.

Fig. 701–Coronal section of the pons, at its upper part. (See enlarged image)

The nuclei pontis are serially continuous with the arcuate nuclei in the medulla, and consist of small groups of multipolar nerve cells which are scattered between the bundles of transverse fibers. The dorsal or tegmental part of the pons is chiefly composed of an upward continuation of the reticular formation and gray substance of the medulla oblongata. It consists of transverse and longitudinal fibers and also contains important gray nuclei, and is subdivided by a median rhé, which, however, does not extend into the basilar part, being obliterated by the transverse fibers. The transverse fibers in the lower part of the pons are collected into a distinct strand, named the trapezoid body. This consists of fibers which arise from the cells of the cochlear nucleus, and will be referred to in connection with the cochlear division of the acoustic nerve. In the substance of the trapezoid body is a collection of nerve cells, which constitutes the trapezoid nucleus. The longitudinal fibers, which are continuous with those of the medulla oblongata, are mostly collected into two fasciculi on either side. One of these lies between the trapezoid body and the reticular formation, and the upward prolongation of the lemniscus; the second is situated near the floor of the fourth ventricle, and is the medial longitudinal fasciculus. Other longitudinal fibers, more diffusely distributed, arise from the cells of the gray substance of the pons.

The rest of the dorsal part of the pons is a continuation upward of the formatio reticularis of the medulla oblongata, and, like it, presents the appearance of a network, in the meshes of which are numerous nerve cells. Besides these scattered nerve cells, there are some larger masses of gray substance, viz., the superior olivary nucleus and the nuclei of the trigeminal, abducent, facial, and acoustic nerves (Fig. 696). The superior olivary nucleus (nucleus olivaris superior) is a small mass of gray substance situated on the dorsal surface of the lateral part of the trapezoid body. Rudimentary in man, but well developed in certain animals, it exhibits the same structure as the inferior olivary nucleus, is situated immediately above it. Some of the fibers of the trapezoid body end by arborizing around the cells of this nucleus, while others se from these cells.

The nuclei of the trigeminal nerve (nuclei n. trigemini) in the pons are two in number: a motor and a sensory. The motor nucleus is situated in the upper part of the pons, close to its posterior surface and along the line of the lateral margin of the fourth ventricle. It is serially analogous with the nucleus ambiguus and the dorso-lateral cell group of the anterior column of the spinal cord. The axis-cylinder processes of cells form the motor root of the trigeminal nerve. The mesencephalic root arises from the gray substance of the floor of the cerebral
The cerebellum constitutes the largest part of the hindbrain. It lies behind the pons and medulla oblongata; between its lateral portion and these structures is the cavity of the fourth ventricle. It rests on the inferior occipital fossae, while above it is the tentorium cerebelli, a fold of dura mater which separates it from the tentorial surface of the cerebrum. It is somewhat oval in form, but constricted anterioiy and flattened from above downward, its greatest diameter being from side to side. Its surface is not convoluted like that of the cerebrum, but traversed by numerous curved furrows or sulci, which vary in depth at different parts, and separate the laminae of which it is composed. Its average weight in the male is about 150 gms. In the adult the proportion between the cerebellum and cerebrum is about 1 to 8, in the infant about 1 to 20.

Lobes of the Cerebellum.—The cerebellum consists of three parts, a median and two lateral, which are continuous with each other, and are essentially the same in structure. The median portion is constricted, and is called the vermis, from its annulated appearance which it owes to transverse ridges and furrows upon it; the lateral expanded portions are named the hemispheres. On the upper surface of the cerebellum the vermis is elevated above the level of the hemispheres, but on the under surface it is sunk almost out of sight in the bottom of a deep depression between them; this depression is called the vallecula cerebelli, and lodges the posterior part of the medulla oblongata. The part of the vermis on the upper surface of the cerebellum is named the superior vermis; that on the lower surface, the inferior vermis. The hemispheres are separated below and behind by a deep notch, the posterior cerebellar notch, and in front by a broader shallower notch, the anterior cerebellar notch. The anterior notch lies close to the pons and upper part of the medullae, and its superior edge encircles the inferior colliculi and the posterior cerebellar peduncle. The posterior notch contains the upper part of the falx cerebelli, a fold of dura mater.

The cerebellum is characterized by a laminated or foliated appearance; it is marked by deep, somewhat curved fissures, which extend for a considerable distance into its substance, and divide it into a series of layers or leaves. The largest and deepest fissure is named the horizontal fissure. It commences in front of the pons, and passes horizontally around the free margin of the hemisphere to the middle line behind, and divides the cerebellum into an upper and a lower portion. Several secondary but deep fissures separate the cerebellum into lobes, and these are either subdivided by shallower sulci, which separate the individual folia or laminae from each other. Sections across the laminae show that the...
ia, though differing in appearance from the convolutions of the cerebrum, are analogous to them, inasmuch as they consist of central white substance covered by gray substance.

The cerebellum is connected to the cerebrum, pons, and medulla oblongata; to the cerebrum by the superior peduncle, to the pons by the middle peduncle, and to the medulla oblongata by the inferior peduncles.

**Fig. 702—Upper surface of the cerebellum. (Schäfer.) (See enlarged image)**

The upper surface of the cerebellum (*Fig. 702*) is elevated in the middle and sloped toward the circumference, the hemispheres being connected together by the superior vermis, which assumes the form of a raised median ridge, most prominent in front, but not sharply defined on the hemispheres. The superior vermis is subdivided from before backward into the lingula, the lobulus centralis, the monticulus and the ium vermis, and each of these, with the exception of the lingula, is continuous with the corresponding parts of the hemispheres—the lobulus atralis with the alæ, the monticulus with the quadrangular lobules, and the folium vermis with the superior semilunar lobules.

The lingula (*lingula cerebelli*) is a small tongue-shaped process, consisting of four or five folia; it lies in front of the lobulus centralis, and is concealed by it. Anteriorly, it rests on the dorsal surface of the anterior medullary velum, and its white substance is continuous with that of the um.

The Lobulus Centralis and Alæ.—The lobulus centralis is a small square lobule, situated in the anterior cerebellar notch. It overlaps the gula, from which it is separated by the precentral fissure; laterally, it extends along the upper and anterior part of each hemisphere, where it forms a wing-like prolongation, the alæ lobuli centralis.

The Monticulus and Quadrangular Lobules.—The monticulus is the largest part of the superior vermis. Anteriorly, it overlaps the lobulus atralis, from which it is separated by the postcentral fissure; laterally, it is continuous with the quadrangular lobule in the hemispheres. It divided by the preclival fissure into an anterior, raised part, the culmenor summit, and a posterior sloped part, the clivus; the quadrangular sulcule is similarly divided. The culmen and the anterior parts of the quadrangular lobules form the lobus culminis; the clivus and the posterior urs, the lobus clivi.

The Folium Vermis and Superior Semilunar Lobule.—The folium vermis (*folium cacuminis; cacuminal lobe*) is a short, narrow, concealed and at the posterior extremity of the vermis, consisting apparently of a single folium, but in reality marked on its upper and under surfaces by secondary fissures. Laterally, it expands in either hemisphere into a considerable lobule, the superior semilunar lobule (*lobulus semilunaris perior; postero-superior lobules*), which occupies the posterior third of the upper surface of the hemisphere, and is bounded below by the horizontal sulcus. The superior semilunar lobules and the folium vermis form the lobus semilunaris.
The under surface of the cerebellum (Fig. 703) presents, in the middle line, the inferior vermis, buried in the vallecula, and separated from the hemisphere on either side by a deep groove, the sulcus valleculæ. Here, as on the upper surface, there are deep fissures, dividing it into narrow segments or lobules; but the arrangement is more complicated, and the relation of the segments of the vermis to those of the hemispheres is less clearly marked. The inferior vermis is subdivided from before backward, into (1) the nodule, (2) the uvula, (3) the pyramid, and (4) the tuber vermis; the corresponding parts on the hemispheres are (1) the flocculus, (2) the tonsilla cerebelli, (3) the biventral lobule, and (4) the inferior semilunar lobule. The three main fissures are (1) the postnodular fissure, which runs transversely across the vermis, between the nodule and the uvula. In the hemispheres this fissure passes in front of the tonsil, crosses between the flocculus and the biventral lobule behind, and joins the anterior end of the horizontal sulcus. (2) The prepyramidal fissure crosses the vermis between the uvula in front and the pyramid behind, then curves forward between the tonsil and the biventral lobe, to join the postnodular fissure. (3) The postpyramidal fissure passes across the vermis between the pyramid and the tuber vermis, and, in the hemispheres, courses hind the tonsil and biventral lobules, and then along the lateral border of the biventral lobule to the postnodular sulcus; in the hemisphere it forms the anterior boundary of the inferior semilunar lobule.

The Nodule and Flocculus.—The nodule (nodulus vermis; nodular lobe), or anterior end of the inferior vermis, abuts against the roof of the fourth ventricle, and can only be distinctly seen after the cerebellum has been separated from the medulla oblongata and pons. On either side of the nodule is a thin layer of white substance, named the posterior medullary velum. It is semilunar in form, its convex border being continuous with the white substance of the cerebellum; it extends on either side as far as the flocculus. The flocculus is a prominent, irregular lobule, situated in front of the biventral lobule, between it and the middle cerebellar peduncle. It is subdivided into a few small laminæ, and is connected to the inferior medullary velum by its central white core. The flocculi, together with the posterior medullary velum and nodule, constitute the lobus noduli.

The Uvula and Tonsilla.—The uvula (uvula vermis; uvular lobe) forms a considerable portion of the inferior vermis; it is separated on either side from the tonsil by the sulcus valleculæ, at the bottom of which it is connected to the tonsil by a ridge of gray matter, indented on its face by shallow furrows, and hence called the furrowed band. The tonsilla (tonsilla cerebelli; amygdaline nucleus) is a rounded mass, situated in front of the biventral lobule, between it and the middle cerebellar peduncle. It is subdivided into a few small laminae, and is connected to the inferior medullary velum by its central white core. The flocculi, together with the posterior medullary velum and nodule, constitute the lobus uvulae.

The Pyramid and Biventral lobules constitute the lobus pyramidis. The pyramid is a conical projection, forming the largest prominence of inferior vermis. It is separated from the hemispheres by the sulcus valleculæ, across which it is connected to the biventral lobule by an distinct gray band, analogous to the furrowed band already described. The biventral lobule is triangular in shape; its apex points backward, and is joined by the gray band to the pyramid. The lateral border is separated from the inferior semilunar lobule by the postpyramidal fissure. The base is directed forward, and is on a line with the anterior border of the tonsil, and is separated from the flocculus by the postnodular fissure.

The Tuber Vermis (tuber valvulae) and the Inferior Semilunar Lobule (lobulus semilunaris inferior; postero-superior lobule) collectively form the lobus tuberis (tuberal lobule). The tuber vermis, the most posterior division of the inferior vermis, is of small size, and laterally leads out into the large inferior semilunar lobules, which comprise at least two-thirds of the inferior surface of the hemisphere.
Internal Structure of the Cerebellum.—The cerebellum consists of white and gray substance.

White Substance.—If a sagittal section (Fig. 704) be made through either hemisphere, the interior will be found to consist of a central stem of white substance, in the middle of which is a gray mass, the dentate nucleus. From the surface of this central white stem a series of plates is prolonged; these are covered with gray substance and form the laminae. In consequence of the main branches from the central stem dividing and subdividing, a characteristic appearance, named the arbor vitae, is presented. If the sagittal section be made through the middle of the vermis, it will be found that the central stem divides into a vertical and a horizontal branch. The vertical branch passes upward to the culmen monticuli, where it subdivides freely, one of its ramifications passing forward and upward to the central lobule. The horizontal branch passes backward to the folium vermis, greatly diminished in size in consequence of having given off large secondary branches; one, from its upper surface, ascends the clivus monticuli; the others descend, and enter the lobes in the inferior vermis, viz., the tuber vermis, the pyramid, the uvula, and the nodule.

The white substance of the cerebellum includes two sets of nerve fibers: (1) projection fibers, (2) fibrae propriæ.

Projection Fibers.—The cerebellum is connected to the other parts of the brain by three large bundles of projection fibers, viz., to the cerebrum the superior peduncles, to the pons by the middle peduncle, and to the medulla oblongata by the inferior peduncles (Fig. 705). The superior cerebellar peduncles (brachia conjunctiva), two in number, emerge from the upper and medial part of the white substance of the hemispheres and are placed under cover of the upper part of the cerebellum. They are joined to each other across the middle line by the posterior medullary velum, and can be followed upward as far as the inferior colliculi, under which they disappear. Below, they form the upper lateral boundaries of the fourth ventricle, but as they ascend they converge on the dorsal aspect of the ventricle and thus assist in roofing it in.

Fig. 704—Sagittal section of the cerebellum, near the junction of the vermis with the hemisphere. (Schäfer.) (See enlarged image)
The fibers of the superior peduncle are mainly derived from the cells of the dentate nucleus of the cerebellum and emerge from the hilus of this nucleus; a few arise from the cells of the smaller gray nuclei in the cerebellar white substance, and others from the cells of the cerebellar cortex. They are continued upward beneath the corpora quadrigemina, and the fibers of the two peduncles undergo a complete decussation ventral to the Sylvian aqueduct. Having crossed the middle line they divide into ascending and descending groups of fibers, the former ending in the red nucleus, the thalamus, and the nucleus of the oculomotor nerve, while the descending fibers can be traced as far as the dorsal part of the pons; Cajal believes them to be continued into the anterior funiculus of the medulla spinalis.

As already stated (page 762), the majority of the fibers of the ventral spinocerebellar fasciculus of the medulla spinalis pass to the cerebellum, which they reach by way of the superior peduncle.

The middle cerebellar peduncles (brachia pontis) (Fig. 705) are composed entirely of centripetal fibers, which arise from the cells of the nuclei pontis of the opposite side and end in the cerebellar cortex; the fibers are arranged in three fasciculi, superior, inferior, and deep. The superior fasciculus, the most superficial, is derived from the upper transverse fibers of the pons; it is directed backward and lateralward superficial to the other two fasciculi, and is distributed mainly to the lobules on the inferior surface of the cerebellar hemisphere and to the parts of the superior surface adjoining the posterior and lateral margins. The inferior fasciculus is formed by the lowest transverse fibers of the pons; it passes under cover of the superior fasciculus and is continued downward and backward more or less parallel with it, to be distributed to the upper anterior cerebellar folia. The fibers of this fasciculus cover those of the restiform body.

The inferior cerebellar peduncles (restiform bodies) pass at first upward and lateralward, forming part of the lateral walls of the fourth ventricle, and then bend abruptly backward to enter the cerebellum between the superior and middle peduncles. Each contains the following fasciculi: (1) the dorsal spinocerebellar fasciculus of the medulla spinalis, which ends mainly in the superior vermis; (2) fibers from the gracile and cuneate nuclei of the same and of the opposite sides; (3) fibers from the opposite olivary nuclei; (4) crossed and uncrossed fibers from the reticular formation of the medulla oblongata; (5) vestibular fibers, derived partly from the vestibular division of the acoustic nerve and partly from the nuclei in which this division ends—these fibers occupy the medial segment of the inferior peduncle and divide into ascending and descending groups of fibers, the ascending fibers partly end in the roof nuclei of the opposite side of the cerebellum; (6) cerebellobulbar fibers which come from the opposite roof nucleus and probably from the dentate nucleus, and are said to end in the nuclei of Deiters and in the formatio reticularis of the medulla oblongata; (7) some fibers from the ventral spinocerebellar fasciculus are said to join the dorsal spinocerebellar fasciculus.

The anterior medullary velum (velum medullare anterius; valve of Vieussens; superior medullary velum) is a thin, transparent lamina of white substance, which stretches between the superior peduncle; on the dorsal surface of its lower half the folia and lingula are prolonged. It tms, together with the superior peduncle, the roof of the upper part of the fourth ventricle; it is narrow above, where it passes beneath the thalamus, and broader below, where it is continuous with the white substance of the superior vermis. A slightly elevated ridge, the frænulum veli, descends upon its upper part from between the inferior colliculi, and on either side of this the trochlear nerve emerges.

The posterior medullary velum (velum medullare posterius; inferior medullary velum) is a thin layer of white substance, prolonged from the site of the cerebellum, above and on either side of the nodule; it forms a part of the roof of the fourth ventricle. Somewhat semilunar in shape, it is thickened at the posterior angles, the ends of the tentorium cerebelli; it is continued below into the tela choroidea of the fourth ventricle and forms the roof of the fourth ventricle posteriorly and widely scattered around the posterior part of the fourth ventricle.
ape, its convex edge is continuous with the white substance of the cerebellum, while its thin concave margin is apparently free; in reality, however, it is continuous with the epithelium of the ventricle, which is prolonged downward from the posterior medullary velum to the ligulæ. The two medullary vela are in contact with each other along their line of emergence from the white substance of the cerebellum; and this line contact forms the summit of the roof of the fourth ventricle, which, in a vertical section through the cavity, appears as a pointed angle.

The Fibrae Propriae of the cerebellum are of two kinds: (1) **commissural fibers**, which cross the middle line at the anterior and posterior parts the vermis and connect the opposite halves of the cerebellum; (2) **arcuate or association fibers**, which connect adjacent laminae with each other.

Gray Substance.—The gray substance of the cerebellum is found in two situations: (1) on the surface, forming the cortex; (2) as independent masses in the interior.

1) The gray substance of the cortex presents a characteristic foliated appearance, due to the series of laminae which are given off from the outer white substance; these in turn give off secondary laminae, which are covered by gray substance. Externally, the cortex is covered by pia mater; internally is the medullary center, consisting mainly of nerve fibers.

Microscopic Appearance of the Cortex (Fig. 706).—The cortex consists of two layers, viz., an external gray molecular layer, and an internal gray-colored nuclear layer; between these is an incomplete stratum of cells which are characteristic of the cerebellum, viz., the cells of Purkinje.

The external gray or molecular layer consists of fibers and cells. The nerve fibers are delicate fibrillæ, and are derived from the following sources: (a) the dendrites and axon collaterals of Purkinje’s cells; (b) fibers from cells in the nuclear layer; (c) fibers from the central white substance of the cerebellum; (d) fibers derived from cells in the molecular layer itself. In addition to these are other fibers, which have a vertical direction, and are the processes of large neuroglia cells, situated in the nuclear layer. They pass outward to the periphery of the gray matter, where they expand into little conical enlargements which form a sort of limiting membrane beneath the pia mater, analogous to the membrana limitans interna in the retina, formed by the sustentacular fibers of Müller.

The cells of the molecular layer are small, and are arranged in two strata, an outer and an inner. They all possess branched axons; those of the outer layer are termed basket cells; they run for some distance parallel with the surface of the folium—giving off collaterals which pass in a radial direction toward the bodies of Purkinje’s cells, around which they become enlarged, and form basket-like net-works.

The cells of Purkinje form a single stratum of large, flask-shaped cells at the junction of the molecular and nuclear layers, their bases resting against the latter; in fishes and reptiles they are arranged in several layers. The cells are flattened in a direction transverse to the long axis of the folium, and thus appear broad in sections carried across the folium, and fusiform in sections parallel to the long axis of the folium. From the neck of the flask one or more dendrites arise and pass into the molecular layer, where they subdivide and form an extremely rich arborescence, the various subdivisions of the dendrites being covered by lateral spinelike processes. This arborescence is not circular, but, like the cell, is flattened at right angles to the long axis of the folium; in other words, it does not resemble a round bush, but has been aptly compared by Obersteiner to the branches of a fruit tree trained against a trellis or a wall. Hence, in sections carried across the folium the arborescence is wide and expanded; whereas in those which are parallel to the long axis of the folium, the arborescence, like the cell itself, is seen in profile, and is limited to a narrow area.

From the bottom of the flask-shaped cell the axon arises; this passes through the nuclear layer, and, becoming medullated, is continued as a nerve fiber in the subjacent white substance. As this axon traverses the granular layer it gives off fine collaterals, some of which run back into the molecular layer.
The internal rust-colored or nuclear layer (Fig. 706) is characterized by containing numerous small nerve cells of a reddish-brown color, together with many nerve fibrils. Most of the cells are nearly spherical and provided with short dendrites which spread out in a spider-like manner in the nuclear layer. Their axons pass outward into the molecular layer, and, bifurcating at right angles, run for some distance parallel to the surface. In the outer part of the nuclear layer are some larger cells, of the type II of Golgi. Their axons undergo frequent division as soon as they leave the nerve cells, and pass into the nuclear layer; while their dendrites ramify chiefly in the molecular layer.

Finally, in the gray substance of the cerebellar cortex there are fibers which come from the white center and penetrate the cortex. The cell-origin of these fibers is unknown, though it is believed that it is probably in the gray substance of the medulla spinalis. Some of these fibers end in the nuclear layer by dividing into numerous branches, on which are to be seen peculiar moss-like appendages; hence they have been termed by Ramón y Cajal the moss fibers; they form an arborescence around the cells of the nuclear layer and are said to come from fibers in the inferior peduncle. Other fibers, the clinging or tendril fibers, derived from the medullary center can be traced into the molecular layer, where their branches cling around the dendrites of Purkinje’s cells. They are said to come from fibers of the middle peduncle.

The independent centers of gray substance in the cerebellum are four in number on either side: one is of large size, and is known as the nucleus dentatus; the other three, much smaller, are situated near the middle of the cerebellum, and are known as the nucleus emboliformis, nucleus globosus, and nucleus fastigii.
The nucleus dentatus (Fig. 707) is situated a little to the medial side of the center of the stem of the white substance of the hemisphere. It consists of an irregularly folded lamina, of a grayish-yellow color, containing white fibers, and presenting on its antero-medial aspect an opening, the hilus, from which most of the fibers of the superior peduncle emerge (page 792).

The nucleus emboliformis lies immediately to the medial side of the nucleus dentatus, and partly covering its hilus. The nucleus globosus is elongated mass, directed antero-posteriorly, and placed medial to preceding. The nucleus fastigii is somewhat larger than the other two, and situated close to the middle line at the anterior end of the superior vermis, and immediately over the roof of the fourth ventricle, from which it separated by a thin layer of white substance.

The cerebellum is concerned with the coördination of movements necessary in equilibration, locomotion and prehension. In it terminate pathways conducting impulses of muscle sense, tendon sense, joint sense and equilibratory disturbances. With the exception of the ventral spinocerebellar fasciculus these impulses enter through the inferior peduncle. The reflex arc is completed by fibers in the superior peduncle which pass to the red nucleus and the thalamus and thence by additional neurons (rubrospinal tract) to the motor centers. The exact functions of different parts are still quite uncertain, owing to the contradictory nature of the evidence furnished by (1) ablation experiments upon animals, and (2) clinical observations in man of the effects produced by abscesses or tumors affecting different portions of the organ.

The Fourth Ventricle (ventriculus quartus).—The fourth ventricle, or cavity of the hind-brain, is situated in front of the cerebellum and hind the pons and upper half of the medulla oblongata. Developmentally considered, the fourth ventricle consists of three parts: the superior belonging to the isthmus rhombencephali, an intermediate, to the metencephalon, and an inferior, to the myelencephalon. It is lined by ciliated epithelium, and is continuous below with the central canal of the medulla oblongata; above, it communicates, by means of a passage termed the cerebral aqueduct, with the cavity of the third ventricle. It presents four angles, and possesses a roof or dorsal wall, floor or ventral wall, and lateral boundaries.

Angles. — The superior angle is on a level with the upper border of the pons, and is continuous with the lower end of the cerebral aqueduct. The inferior angle is on a level with the lower end of the olive, and opens into the central canal of the medulla oblongata. Each lateral angle corresponds with the point of meeting of the brachia and inferior peduncle. A little below the lateral angles, on a level with the striae ofyllares, the ventricular cavity is prolonged outward in the form of two narrow lateral recesses, one on either side; these are situated between the inferior peduncles and the flocculi, and reach as far as the attachments of the glossopharyngeal and vagus nerves.

Lateral Boundaries. — The lower part of each lateral boundary is constituted by the clava, the fasciculus cuneatus, and the inferior peduncle; upper part by the middle and the superior peduncle.

Roof or Dorsal Wall (Fig. 708).—The upper portion of the roof is formed by the superior peduncle and the anterior medullary velum; the ver, by the posterior medullary velum, the epithelial lining of the ventricle covered by the tela chorioidea inferior, the tænæ of the uth ventricle, and the obex.

The superior peduncle (page 792), on emerging from the central white substance of the cerebellum, pass upward and forward, forming at first lateral boundaries of the upper part of the cavity; on approaching the inferior colliculi, they converge, and their medial portions overlap the cavity and form part of its roof.
The anterior medullary velum (page 793) fills in the angular interval between the superior peduncle, and is continuous behind with the white substance of the cerebellum; it is covered on its dorsal surface by the lingula of the superior vermis.

The posterior medullary velum (page 794) is continued downward and forward from the central white substance of the cerebellum in front of the nodule and tonsils, and ends inferiorly in a thin, concave, somewhat ragged margin. Below this margin the roof is devoid of nervous matter except in the immediate vicinity of the lower lateral boundaries of the ventricle, where two narrow white bands, the tæniae of the fourth ventricle (ligulae), appear; these bands meet over the inferior angle of the ventricle in a thin triangular lamina, the obex. The non-nervous part of the roof is formed by the epithelial lining of the ventricle, which is prolonged downward as a thin membrane, from the deep surface of the posterior medullary velum to the corresponding surface of the obex and tæniae, and thence on to the floor of the ventricular cavity; it is strengthened by a portion of the pia mater, which is named the tela chorioidea of the fourth ventricle.

The tæniae of the fourth ventricle (tænia ventriculi quarti; ligula) are two narrow bands of white matter, one on either side, which complete the lower part of the roof of the cavity. Each consists of a vertical and a horizontal part. The vertical part is continuous below the obex with the clava, to which it is adherent by its lateral border. The horizontal portion extends transversely across the inferior peduncle, below the striæ medullares, and roofs in the lower and posterior part of the lateral recess; it is attached by its lower margin to the inferior peduncle, and partly closes the choroid plexus, which, however, projects beyond it like a cluster of grapes; and hence this part of the tænia has been termed cornucopia (Bochdalek). The obex is a thin, triangular, gray lamina, which roofs in the lower angle of the ventricle and is attached by its eral margins to the clavæ. The tela chorioidea of the fourth ventricle is the name applied to the triangular fold of pia mater which is carried upward between the cerebellum and the medulla oblongata. It consists of two layers, which are continuous with each other in front, and are more or less adherent throughout. The posterior layer covers the antero-inferior surface of the cerebellum, while the anterior is applied to the structures which form the lower part of the roof of the ventricle, and is continuous inferiorly with the pia mater on the inferior peduncles and medulla.

![Diagram of the roof of the fourth ventricle](See enlarged image)

Rhomboid Plexuses.—These consist of two highly vascular inflexions of the tela chorioidea, which invaginate the lower part of the roof of the ventricle and are everywhere covered by the epithelial lining of the cavity. Each consists of a vertical and a horizontal portion: the former lies close to the middle line, and the latter passes into the lateral recess and projects beyond its apex. The vertical parts of the plexuses are distinct from each other, but the horizontal portions are joined in the middle line; and hence the entire structure presents the form of the letter T, the rical limb of which, however, is double.

Openings in the Roof.—In the roof of the fourth ventricle there are three openings, a medial and two lateral: the medial aperture (foramen of Majendie), is situated immediately above the inferior angle of the ventricle; the lateral apertures, (foramina of Luschka) are found at the extremities of the lateral recesses. By means of these three openings the ventricle communicates with the subarachnoid cavity, and the cerebrospinal fluid can circulate from the one to the other.

Rhomboid Fossa (fossa rhomboidea; “floor” of the fourth ventricle) (Fig. 709).—The anterior part of the fourth ventricle is named, from its...
ape, the rhomboid fossa, and its anterior wall, formed by the back of the pons and medulla oblongata, constitutes the floor of the fourth ventricle. It is covered by a thin layer of gray substance continuous with that of the medulla spinalis; superficial to this is a thin lamina of uroglia which constitutes the ependyma of the ventricle and supports a layer of ciliated epithelium. The fossa consists of three parts, superior, intermediate, and inferior. The superior part is triangular in shape and limited laterally by the superior cerebellar peduncle; its apex, directed upward, is continuous with the cerebral aqueduct; its base it represented by an imaginary line at the level of the upper ends of the superior foveæ. The intermediate part extends from this level to that of the horizontal portions of the tæniae of the ventricle; it is narrow above where it is limited laterally by the middle peduncle, but widens below and is prolonged into the lateral recesses of the ventricle. The inferior part is triangular, and its downwardly directed apex, named the calamus scriptorius, is continuous with the central canal of the closed part of the medulla oblongata.

Fig. 709—Rhomboid fossa. (See enlarged image)

The rhomboid fossa is divided into symmetrical halves by a median sulcus which reaches from the upper to the lower angles of the fossa and deeper below than above. On either side of this sulcus is an elevation, the medial eminence, bounded laterally by a sulcus, the sulcus limitans. In the superior part of the fossa the medial eminence has a width equal to that of the corresponding half of the fossa, but opposite the superior fovea it forms an elongated swelling, the colliculus facialis, which overlies the nucleus of the abducent nerve, and is, in part at least, produced by the ascending portion of the root of the facial nerve. In the inferior part of the fossa the medial eminence assumes the form of a triangular area, the trigonum hypoglossi. When examined under water with a lens this trigone is seen to consist of a medial and a lateral area separated by a series of oblique furrows; the medial area corresponds with the upper part of the nucleus of the hypoglossal nerve, the lateral th a small nucleus, the nucleus intercalatus.

The sulcus limitans forms the lateral boundary of the medial eminence. In the superior part of the rhomboid fossa it corresponds with the eural limit of the fossa and presents a bluish-gray area, the locus caeruleus, which owes its color to an underlying patch of deeply pigmented nerve cells, termed the substantia ferruginea. At the level of the colliculus facialis the sulcus limitans widens into a flattened depression, the superior fovea, and in the inferior part of the fossa appears as a distinct dimple, the inferior fovea. Lateral to the foveæ is a rounded elevation named the area acustica, which extends into the lateral recess and there forms a feebly marked swelling, the tuberculum acusticum. Winding around the inferior peduncle and crossing the area acustica and the medial eminence are a number of white strands, the striæ medullares, which form a portion of the cochlear division of the acoustic nerve and disappear into the median sulcus. Below the superior fovea, and between the trigonum hypoglossi and the lower part of the area acustica is a triangular dark field, the ala cinerea, which responds to the sensory nucleus of the vagus and glossopharyngeal nerves. The lower end of the ala cinerea is crossed by a narrow translucent ridge, the funiculus separans, and between this funiculus and the clava, is a small tongue-shaped area, the area postrema. On section it is seen that the funiculus separans is formed by a strip of thickened ependyma, and the area postrema by loose, highly vascular, uroglial tissue containing nerve cells of moderate size.

Note 120. Essick, Am. Jour. Anat., 1907. [back]
**Note 121.** See article by E. B. Jamieson, Journal of Anatomy and Physiology, vol. xlv. [back]

**Note 122.** J. T. Wilson (Journal of Anatomy and Physiology, vol. xl) has pointed out that the central canal of the medulla oblongata, immediately below its entrance into the fourth ventricle, retains the cleft-like form presented by the fetal medulla spinalis, and that it is marked by dorso- and ventro-lateral sulci. [back]

### 4b. The Mid-brain or Mesencephalon

The mid-brain or mesencephalon ([Fig. 681](#)) is the short, constricted portion which connects the pons and cerebellum with the diencephalon and cerebral hemispheres. It is directed upward and forward, and consists of (1) a ventrolateral portion, composed of a pair of lindrical bodies, named the cerebral peduncles; (2) a dorsal portion, consisting of four rounded eminences, named the corpora adrigemina; and (3) an intervening passage or tunnel, the cerebral aqueduct, which represents the original cavity of the mid-brain and inects the third with the fourth ventricle ([Fig. 710](#)).

![Coronal section through mid-brain](#)

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The cerebral peduncles (pedunculus cerebri; crus cerebri) are two cylindrical masses situated at the base of the brain, and largely hidden by the temporal lobes of the cerebrum, which must be drawn aside or removed in order to expose them. They emerge from the upper surface of the pons, one on either side of the middle line, and, diverging as they pass upward and forward, disappear into the substance of the cerebral hemispheres. The depressed area between the crura is termed the interpeduncular fossa, and consists of a layer of grayish substance, the posterior perforated substance, which is pierced by small apertures for the transmission of bloodvessels; its lower part lies on the ventral aspect of the medial portions of the tegmenta, and contains a nucleus named the interpeduncular ganglion (page 802); its upper part assists in forming the floor of the third ventricle. The ventral surface of each peduncle is crossed from the medial to the lateral side by the superior cerebellar and posterior cerebral arteries; its lateral surface is in relation to the gyrus hippocampi of the cerebral hemisphere and is crossed from hind forward by the trochlear nerve. Close to the point of disappearance of the peduncle into the cerebral hemisphere, the optic tract winds around its ventro-lateral surface. The medial surface of the peduncle forms the lateral boundary of the interpeduncular fossa, and is urked by a longitudinal furrow, the oculomotor sulcus, from which the roots of the oculomotor nerve emerge. On the lateral surface of each peduncle there is a second longitudinal furrow, termed the lateral sulcus; the fibers of the lateral lemniscus come to the surface in this sulcus, pass backward and upward, to disappear under the inferior colliculus.
Structure of the Cerebral Peduncles (Figs. 711, 712).—On transverse section, each peduncle is seen to consist of a dorsal and a ventral part, separated by a deeply pigmented lamina of gray substance, termed the substantia nigra. The dorsal part is named the tegmentum; the ventral, or base or crusta; the two bases are separated from each other, but the tegmenta are joined in the median plane by a forward prolongation of the nē of the pons. Laterally, the tegmenta are free; dorsally, they blend with the corpora quadrigemina.

The base (basis pedunculi; crusta or pes) is semilunar on transverse section, and consists almost entirely of longitudinal bundles of efferent fibers, which arise from the cells of the cerebral cortex and are grouped into three principal sets, viz., cerebrospinal, frontopontine, and temporopontine (Fig. 710). The cerebrospinal fibers, derived from the cells of the motor area of the cerebral cortex, occupy the middle thirds of the base; they are continued partly to the nuclei of the motor cranial nerves, but mainly into the pyramids of the medulla oblongata. The frontopontine fibers are situated in the medial fifth of the base; they arise from the cells of the frontal lobe and end in the nuclei of the pons. The temporopontine fibers are lateral to the cerebrospinal fibers; they originate in the temporal lobe and end in the nuclei pontis. The substantia nigra (intercalatum) is a layer of gray substance containing numerous deeply pigmented, multipolar nerve cells. It is semilunar transverse section, its concavity being directed toward the tegmentum; from its convexity, prolongations extend between the fibers of the base the peduncle. Thicker medially than laterally, it reaches from the oculomotor sulcus to the lateral sulcus, and extends from the upper surface the pons to the subthalamic region; its medial part is traversed by the fibers of the oculomotor nerve as these stream forward to reach the oculomotor sulcus. The connections of the cells of the substantia nigra have not been definitely established. It receives collaterals from the spinothalamic and the pyramidal bundles. Bechterew is of the opinion that the fibers from the motor area of the cerebral cortex form synapses
th cells whose axons pass to the motor nucleus of the trigeminal nerve and serve for the coordination of the muscles of mastication.  

The **tegmentum** is continuous below with the reticular formation of the pons, and, like it, consists of longitudinal and transverse fibers, 

†eter with a considerable amount of gray substance. The principal gray masses of the tegmentum are the red nucleus and the intermediolateral nglion; of its fibers the chief longitudinal tracts are the superior peduncle, the medial longitudinal fasciculus, and the lemniscus.  

**iRAY SUBSTANCE.**—The **red nucleus** is situated in the anterior part of the tegmentum, and is continued upward into the posterior part of subthalamic region. In sections at the level of the superior colliculus it appears as a circular mass which is traversed by the fibers of the olomotor nerve. It receives many terminals and collaterals from the superior cerebellar peduncle also collaterals from the ventral longitudinal ndle, from Gudden’s bundle and the median lemniscus. The axons of its larger cells cross the middle line and are continued downward into the eral funiculus of the medulla spinalis as the rubrospinal tract (page 761); those of its smaller cells end mainly in the thalamus. The rubrospinal ct forms an important part of the pathway from the cerebellum to the lower motor centers.  

The **interpeduncular ganglion** is a median collection of nerve cells situated in the ventral part of the tegmentum. The fibers of the fasciculus reflexus of Meynert, which have their origin in the cells of the ganglion habenulae (page 812), end in it.  

Besides the two nuclei mentioned, there are small collections of cells which form the dorsal and ventral nuclei and the central nucleus of the raphé.  

**WHITE SUBSTANCE.**—(1) The origin and course of the **superior peduncle** have already been described (page 792).  

? The **medial (posterior) longitudinal fasciculus** is continuous below with the proper fasciculi of the anterior and lateral funiculi of the dulla spinalis. In the medulla oblongata and pons it runs close to the middle line, near the floor of the fourth ventricle; in the mid-brain it is situated on the ventral aspect of the cerebral aqueduct, below the nuclei of the oculomotor and trochlear nerves. Its connections are imperfectly own, but it consists largely of ascending and descending intersegmental or association fibers, which connect the nuclei of the hind-brain and d-brain to each other. Many of the fibers arise in Deiters’s nucleus (lateral vestibular nucleus) and divide into ascending and descending bunches which send terminals and collaterals to the motor nuclei of the cranial and spinal nerves. Its spinal portion is located in the anterior nuncus and is known as the **vestibulospinal fasciculus.** Other fibers pass to the median longitudinal bundle from cells in the reticular  

†ation of the medulla, pons and mid-brain and also from certain large cells in the terminal nucleus of the trigeminal nerve. According to ingev it extends to the so-called nucleus of the posterior longitudinal bundle in the hypothalamic region, but this is uncertain and the fibers  

†e nucleus of the oculomotor are smaller in diameter than the rest of the bundle. According to Held fibers from the posterior commissure be traced into the posterior longitudinal bundle, and according to the same author many of the descending fibers arise in the superior llicus, and, after decussating in the middle line, end in the motor nuclei of the pons and medulla oblongata. These fibers from the superior llicus probably pass into the ventral longitudinal bundle. Fibers are said to pass through the medial longitudinal fasciculus from the nucleus the abducens nerve into the oculomotor nerve of the opposite side, and through this nerve to the Rectus medialis oculi. Fraser, however, denies  

†existence of such fibers. Again, fibers are said to be prolonged through this fasciculus from the nucleus of the oculomotor nerve into the  

†al nerve, and are distributed to the Orbicularis oculi, the Corrugator, and the Frontalis.  

The **ventral longitudinal bundle** consists for the most part of the **tectospinal fasciculus,** and arises from the superior colliculus, the fibers arch  

†erally around the central gray matter and cross the midline in the fountain-decussation of Meynert. They then descend in the tegmentum, part  

†em passing through the red nucleus ventral to the medial longitudinal bundle. In the medulla oblongata and spinal cord its fibers are more or s intermingled with the medial longitudinal bundle and the rubrospinal tract. It descends in the adjoining region of the ventral and lateral nunci. Collaterals and terminals are given off to the red nucleus and probably other nuclei of the brain stem and to the anterior column of the nul cord. It is probably concerned in optic reflexes.  

? The **medial lemniscus** or **medial filament** (Fig. 713).—The fibers of the medial lemniscus take origin in the gracile and cuneate nuclei of the dulla oblongata, and as internal arcuate fibers they cross to the opposite side in the sensory deccussation (page 777). They then pass in the erolivary stratum upward through the medulla oblongata, in which they are situated behind the cerebrosensory fibers and between the olives. In  

†ons and lower part of the mid-brain it occupies the ventral part of the reticular formation and tegmentum close to the raphé, while above it  

†ually shifts to the dorso-lateral part of the tegmentum in the angle between the red nucleus and the substantia nigra. In the pons it assumes a  

†ened ribbon-like appearance, and is placed dorsal to the trapezium. As the lemniscus ascends, it receives additional fibers from the terminal  

†ory nuclei of the cranial nerves of the opposite side. Many of the fibers which arise from the terminal sensory nuclei of the cranial nerves  

† upward in the formatio reticularis as a separate bundle, known as the **central tract of the cranial nerves,** to the thalamus.  

†any fibers either terminate in or send off collaterals to the gray matter of the medulla, the pons, and the mid-brain. Large numbers of fibers ss to or from the substantia nigra. Many collaterals enter the red nucleus and other fibers are said to run to the superior colliculus. The great  

† of the fibers, however, enter the ventro-lateral portion of the thalamus, give off collaterals to the posterior semilunar nucleus and then minate in the principal sensory nucleus of the thalamus.
In the cerebral peduncle, a few of its fibers pass upward in the lateral part of the base of the peduncle, on the dorsal aspect of the tempopontine fibers, and reach the lentiform nucleus and the insula. The greater part of the medial lemniscus, on the other hand, is prolonged through the tegmentum, and most of its fibers end in the thalamus; probably some are continued directly through the occipital part of the internal capsule to the cerebral cortex. From the cells of the thalamus a relay of fibers is prolonged to the cerebral cortex.

The medial lemniscus may be considered as the upward continuation of the posterior funiculus of the spinal cord and to convey conscious impulses of muscle sense and tactile discrimination.

The central or thalamic tract of the cranial nerves is closely associated with the medial lemniscus. The fibers of the spinothalamic fasciculi continued from the spinal cord into this tract which passes upward in the reticular formation and the tegmentum to the thalamus along the rsal side of the median lemniscus. It receives fibers from the opposite terminal sensory nuclei of the vagus, glossopharyngeal, facial, trigeminal and probably the vestibular nerves. Many of the secondary sensory fibers of the trigeminal cross the raphé from its terminal nucleus and pass upward to the thalamus by a more or less separate but closely associated pathway known as the central tract of the trigeminal nerve which also lies on the dorsal aspect of the lemniscus. These two tracts give off collaterals to the posterior semilunar nucleus of the thalamus and terminate in the anterior semilunar nucleus of the ventro-lateral region of the thalamus sending collaterals into the zona incerta.
Fig. 714--Transverse section passing through the sensory decussation. Schematic. (Testut.) 1. Anterior median fissure. 2. Posterior median sulcus. 3, 3'. Head and base of anterior column (in red). 4. Hypoglossal nerve. 5. Bases of posterior column. 6. Gracile nucleus. 7. Cuneate nucleus. 8, 8. Lemniscus. 9. Sensory decussation. 10. Cerebospinal fasciculus. (See enlarged image)

The fibers of the rubrospinal tract (bundle of Monakow) arise in the red nucleus, cross the midline in the decussation of Forel and pass downward in the formatio reticularis of the brainstem into the lateral funiculus of the spinal cord ventral to the crossed pyramidal tract.

The lateral lemniscus (lemniscus lateralis) comes to the surface of the mid-brain along its lateral sulcus, and disappears under the inferior lenticulopeduncular fissure. It consists of fibers from the terminal nuclei of the cochlear division of the acoustic nerve, together with others from the superior and inferior colliculi. Most of these fibers are crossed, but some are uncrossed. Many of them pass to the inferior colliculus of the same side, but others are prolonged to the thalamus, and thence through the occipital part of the internal capsule to the middle and superior temporal gyri.

The corpora quadrigemina (Fig. 720) are four rounded eminences which form the dorsal part of the mid-brain. They are situated above and in front of the anterior medullary velum and superior peduncle, and below and behind the third ventricle and posterior commissure. They are covered by the splenium of the corpus callosum, and are partly overlapped on either side by the medial angle, or pulvinar, of the posterior end of the thalamus; on the lateral aspect, under cover of the pulvinar, is an oval eminence, named the medial geniculate body. The corpora adrigemina are arranged in pairs (superior and inferior colliculi), and are separated from one another by a crucial sulcus. The longitudinal ramus of this sulcus extends superiorly to form a slight depression which supports the pineal body, a cone-like structure which projects backward on the thalamencephalon and partly obscures the superior colliculi. From the inferior end of the longitudinal sulcus, a white band, termed the frenulum veli, is prolonged downward to the anterior medullary velum; on either side of this band the trochlear nerve emerges, and passes toward the lateral aspect of the cerebral peduncle to reach the base of the brain. The superior colliculi are larger and darker in color than the inferior ones, and are oval in shape. The inferior colliculi are hemispherical, and somewhat more prominent than the superior. The superior colliculi are associated with the sense of sight, the inferior with that of hearing.

From the lateral aspect of each colliculus a white band, termed the brachium, is prolonged upward and forward. The superior brachium extends lateralward from the superior colliculus, and, passing between the pulvinar and medial geniculate body, is partly continued to an eminence called the lateral geniculate body, and partly into the optic tract. The inferior brachium passes forward and upward from the inferior colliculus and disappears under cover of the medial geniculate body.

A close relationship with the corpora quadrigemina is the superior peduncles, which emerge from the upper and medial parts of the cerebellar mesoparychae. They run upward and forward, and, passing under the inferior colliculi, enter the tegmenta as already described (page 792).

Structure of the Corpora Quadrigemina.—The inferior colliculus (colliculus inferior; inferior quadrigeminal body; postgemina) consists of a compact nucleus of gray substance containing large and small multipolar nerve cells, and more or less completely surrounded by white fibers rived from the lateral lemniscus. Most of these fibers end in the gray nucleus of the same side, but some cross the middle line and end in that of the opposite side. From the cells of the gray nucleus, fibers are prolonged through the inferior brachium into the tegmentum of the cerebral duncle, and are carried to the thalamus and the cortex of the temporal lobe; other fibers cross the middle line and end in the opposite lenticulopeduncular sulcus. The corpora quadrigemina are larger in the lower animals than in man. In fishes, reptiles, and birds they are hollow, and only two in number (orpis bigemina); they represent the superior colliculi of mammals, and are therefore termed the optic lobes, because of their intimate connection with the optic tracts.

The cerebral aqueduct (aqueductus cerebri; aqueduct of Sylvius) is a narrow canal, about 15 mm. long, situated between the corpora adrigemina and tegmenta, and connecting the third with the fourth ventricle. Its shape, as seen in transverse section, varies at different levels,
being T-shaped, triangular above, and oval in the middle; the central part is slightly dilated, and was named by Retzius the ventricle of the midbrain. It is lined by ciliated columnar epithelium, and is surrounded by a layer of gray substance named the central gray stratum: this is continuous below with the gray substance in the rhomboid fossa, and above with that of the third ventricle. Dorsally, it is partly separated from gray substance of the quadrigeminal bodies by the fibers of the lemniscus; ventral to it are the medial longitudinal fasciculus, and the tractus reticularis of the tegmentum. Scattered throughout the central gray stratum are numerous nerve cells of various sizes, interlaced, by a tangle of fine fibers. Besides these scattered cells it contains three groups which constitute the nuclei of the oculomotor and trochlear nerves, and the nucleus of the mesencephalic root of the trigeminal nerve. The nucleus of the trigeminal nerve extends along the entire length of the nerve and occupies the lateral part of the gray stratum, while the nuclei of the oculomotor and trochlear nerves are situated in its ventral part. The nucleus of the oculomotor nerve is about 10 cm. long, and lies under the superior colliculus, beyond which, however, it extends for a short distance into the gray substance of the third ventricle. The nucleus of the trochlear nerve is small and nearly circular, and is on a level with a plane carried transversely through the upper part of the inferior colliculus.

**Note 123.** A band of fibers, the tractus peduncularis transversus, is sometimes seen emerging from in front of the superior colliculus; it passes around the ventral aspect of the peduncle about midway between the pons and the optic tract, and dips into the oculomotor sulcus. This band is a constant structure in many mammals, but is only present in about 30 per cent. of human brains. Since it undergoes atrophy after enucleation of the eyeballs, it may be considered as forming a path for visual sensations. [back]

**Note 124.** A. Bruce and J. H. Harvey Pirrie, “On the Origin of the Facial Nerve,” Review of Neurology and Psychiatry, December, 1908, No. 12, vol. vi, produce weighty evidence against the view that the facial nerve derives fibers from the nucleus of the oculomotor nerve. [back]

### 4c. The Fore-brain or Prosencephalon

The fore-brain or prosencephalon consists of: (1) the diencephalon, corresponding in a large measure to the third ventricle and the structures which bound it; and (2) the telencephalon, comprising the largest part of the brain, viz., the cerebral hemispheres; these hemispheres are intimately connected with each other across the middle line, and each contains a large cavity, named the lateral ventricle. The lateral ventricles communicate through the interventricular foramen with the third ventricle, but are separated from each other by a medial septum, the septum lucidum; this contains a slit-like cavity, which does not communicate with the ventricles.

![Fig. 715– Mesal aspect of a brain sectioned in the median sagittal plane.](enlarged image)
The diencephalon comprises: (1) the thalamencephalon; (2) the pars mammilarishypothalami; and (3) the posterior part of the third ventricle. For descriptive purposes, however, it is more convenient to consider the whole of the third ventricle and its boundaries together; this cessitates the inclusion, under this heading, of the pars optica hypothalami and the corresponding part of the third ventricle—structures which properly belong to the telencephalon.

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The thalamencephalon comprises: (1) the thalamus; (2) the metathalamus or corpora geniculata; and (3) epithalamus, consisting of the trigonum habenulæ, the pineal body, and the posterior commissure.

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**Fig. 716—Dissection showing the ventricles of the brain.** (See enlarged image)

The thalami (optic thalamus) (Figs. 716, 717) are two large ovoid masses, situated one on either side of the third ventricle and reaching for some distance behind that cavity. Each measures about 4 cm. in length, and presents two extremities, an anterior and a posterior, and four faces, superior, inferior, medial, and lateral.

The anterior extremity is narrow; it lies close to the middle line and forms the posterior boundary of the interventricular foramen. The posterior extremity is expanded, directed backward and lateralward, and overlaps the superior colliculus. Medially it presents an angular prominence, the pulvinar, which is continued laterally into an oval swelling, the lateral geniculate body, while beneath the pulvinar, but separated from it by the superior brachium, is a second oval swelling, the medial geniculate body.

The superior surface is free, slightly convex, and covered by a layer of white substance, termed the stratum zonale. It is separated laterally on the caudate nucleus by a white band, the stria terminalis, and by the terminal vein. It is divided into a medial and a lateral portion by an lique shallow furrow which runs from behind forward and medialward and corresponds with the lateral margin of the fornix; the lateral part forms a portion of the floor of the lateral ventricle, and is covered by the epithelial lining of this cavity; the medial part is covered by the tela choroidea of the third ventricle, and is destitute of an epithelial covering. In front, the superior is separated from the medial surface by a salient margin, the tænia thalami, along which the epithelial lining of the third ventricle is reflected on to the under surface of the tela choroidea. Hind, it is limited medially by a groove, the sulcus habenulae, which intervenes between it and a small triangular area, termed the trigonum habenulae.

The inferior surface rests upon and is continuous with the upward prolongation of the tegmentum (subthalamic tegmental region), in front of which it is related to the substantia innominata of Meynert.
The medial surface constitutes the upper part of the lateral wall of the third ventricle, and is connected to the corresponding surface of the opposite thalamus by a flattened gray band, the massa intermedia (middle or gray commissure). This mass averages about 1 cm. in its anteroposterior diameter: it sometimes consists of two parts and occasionally is absent. It contains nerve cells and nerve fibers; a few of the latter may cross the middle line, but most of them pass toward the middle line and then curve lateralward on the same side.

The lateral surface is in contact with a thick band of white substance which forms the occipital part of the internal capsule and separates the thalamus from the lentiform nucleus of the corpus striatum.

The thalamus consists chiefly of gray substance, but its upper surface is covered by a layer of white substance, named the stratum nacel, and its lateral surface by a similar layer termed the lateral medullary lamina. Its gray substance is incompletely subdivided into three parts—anterior, medial, and lateral—by a white layer, the medial medullary lamina. The anterior part comprises the anterior tubercle, the lateral part lies next the lateral wall of the third ventricle while the lateral and largest part is interposed between the medullary laminae and includes the pulvinar. The lateral part is traversed by numerous fibers which radiate from the thalamus into the internal capsule, and pass through the latter to the cerebral cortex. These three parts are built up of numerous nuclei, the connections of many of which are imperfectly own.
Connections.—The thalamus may be regarded as a large ganglionic mass in which the ascending tracts of the tegmentum and a considerable portion of the fibers of the optic tract end, and from the cells of which numerous fibers (thalamocortical) take origin, and radiate to almost every part of the cerebral cortex. The lemniscus, together with the other longitudinal strands of the tegmentum, enters its ventral part: the thalamomammillary fasciculus (bundle of Vicq d’Azyr), from the corpus mammillare, enters in its anterior tubercle, while many of the fibers of the optic tract terminate in its posterior end. The thalamus also receives numerous fibers (corticothalamic) from the cells of the cerebral cortex. The fibers that arise from the cells of the thalamus form four principal groups or stalks: (a) those of the anterior stalk pass through the frontal part of the internal capsule to the frontal lobe; (b) the fibers of the posterior stalk (optic radiations) arise in the pulvinar and are conveyed through the occipital part of the internal capsule to the occipital lobe; (c) the fibers of the inferior stalk leave the under and medial surfaces of the thalamus, and pass beneath the lentiform nucleus to the temporal lobe and insula; (d) those of the parietal stalk pass from the lateral nucleus of the thalamus to the parietal lobe. Fibers also extend from the thalamus into the corpus striatum—those destined for the caudate nucleus leave the lateral surface, and those for the lentiform nucleus, the inferior surface of the thalamus.
The Metathalamus (Fig. 719) comprises the geniculate bodies, which are two in number—a medial and a lateral—on each side.

The medial geniculate body (corpus geniculatum mediale; internal geniculate body; postgeniculatum) lies under cover of the pulvinar of the thalamus and on the lateral aspect of the corpora quadrigemina. Oval in shape, with its long axis directed forward and lateralward, it is lighter in color and smaller in size than the lateral. The inferior brachium from the inferior colliculus disappears under cover of it while from its lateral extremity a strand of fibers passes to join the optic tract. Entering it are many acoustic fibers from the lateral lemniscus. The medial geniculate bodies are connected with one another by the commissure of Gudden, which passes through the posterior part of the optic chiasma.

The lateral geniculate body (corpus geniculatum laterale; external geniculate body; pregeniculatum) is an oval elevation on the lateral part of the posterior end of the thalamus, and is connected with the superior colliculus by the superior brachium. It is of a dark color, and presents a laminated arrangement consisting of alternate layers of gray and white substance. It receives numerous fibers from the optic tract, while other fibers of this tract pass over or through it into the pulvinar. Its cells are large and pigmented; their axons pass to the visual area in the occipital part of the cerebral cortex.

The superior colliculus, the pulvinar, and the lateral geniculate body receive many fibers from the optic tracts, and are therefore intimately connected with sight, constituting what are termed the lower visual centers. Extirpation of the eyes in a newly born animal entails an arrest of development of these centers, but has no effect on the medial geniculate bodies or on the inferior colliculi. Moreover, the latter are well-developed in the mole, an animal in which the superior colliculi are rudimentary.

The Epithalamus comprises the trigonum habenulæ, the pineal body, and the posterior commissure.

The trigonum habenulæ is a small depressed triangular area situated in front of the superior colliculus and on the lateral aspect of the sterior part of the thalami. It contains a group of nerve cells termed the ganglion habenulæ. Fibers enter it from the stalk of the pineal body, and others, forming what is termed the habenular commissure, pass across the middle line to the corresponding ganglion of the opposite side. Most of its fibers are, however, directed downward and form a bundle, the fasciculus retroflexus of Meynert, which passes medial to the red nucleus, and, after decussating with the corresponding fasciculus of the opposite side, ends in the interpeduncular ganglion.

The pineal body (corpus pineale; epiphysis) is a small, conical, reddish-gray body which lies in the depression between the superior colliculi. It is placed beneath the splenium of the corpus callosum, but is separated from this by the tela chorioidea of the third ventricle, the lower layer of which envelops it. It measures about 8 mm. in length, and its base, directed forward, is attached by a stalk or peduncle of white substance. The stalk of the pineal body divides anteriorly into two laminae, a dorsal and a ventral, separated from one another by the pineal recess of the ventricle. The ventral lamina is continuous with the posterior commissure; the dorsal lamina is continuous with the habenular commissure and divides into two strands the medullary striae, which run forward, one on either side, along the junction of the medial and upper surfaces of thalamus to blend in front with the columns of the fornix.

The posterior commissure is a rounded band of white fibers crossing the middle line on the dorsal aspect of the upper end of the cerebral
The fibers of the aqueduct. Its fibers acquire their medullary sheaths early, but their connections have not been definitely determined. Most of them have their origin in a nucleus, the **nucleus of the posterior commissure** (nucleus of Darkschewitsch), which lies in the central gray substance of the upper end of the cerebral aqueduct, in front of the nucleus of the oculomotor nerve. Some are probably derived from the posterior part of the thalamus and from the superior colliculus, while others are believed to be continued downward into the medial longitudinal fasciculus.

The **Hypothalamus** (Fig. 720) includes the **subthalamic tegmental region** and the structures forming the greater part of the floor of the third ventricle, viz., the **corpora mammillaria, tuber cinereum, infundibulum, hypophysis,** and **optic chiasma.**

The **subthalamic tegmental region** consists of the upward continuation of the tegmentum; it lies on the ventro-lateral aspect of the thalamus and separates it from the fibers of the internal capsule. The red nucleus and the substantia nigra are prolonged into its lower part; in front it is continuous with the substantia innominata of Meynert, medially with the gray substance of the floor of the third ventricle.

From above downward of three strata: (1) **stratum dorsale,** directly applied to the under surface of the thalamus and consisting of longitudinal fibers; (2) **zona incerta,** a continuation forward of the formatio reticularis of the tegmentum; and (3) the **corpus subthalamicum** (nucleus of Luys), a brownish mass presenting a lenticular shape on transverse section, and situated on the dorsal aspect of the base of the cerebral peduncle; it is encapsuled by a lamina of nerve fibers and contains numerous medium-sized nerve cells, the connections of which are as yet not fully determined.

The **corpora mammillaria** (corpus albicantia) are two round white masses, each about the size of a small pea, placed side by side below the gray substance of the floor of the third ventricle in front of the posterior perforated substance. They consist of white substance externally and of gray substance internally, the cells of the latter forming two nuclei, a **medial** of smaller and a **lateral** of larger cells. The white substance is mainly formed by the fibers of the columns of the fornix, which descend to the base of the brain and end partly in the corpora mammillaria. From the cells of the gray substance of each mammillary body two fasciculi arise: one, the **thalamomammillary fasciculus** (bundle of Vicq d'Azyr), passes upward into the anterior nucleus of the thalamus; the other is directed downward into the tegmentum. Afferent fibers are relayed to reach the corpus mammillare from the medial lemniscus and from the tegmentum.

The **tuber cinereum** is a hollow eminence of gray substance situated between the corpora mammillaria behind, and the optic chiasma in front. Laterally it is continuous with the anterior perforated substances and anteriorly with a thin lamina, the **lamina terminalis.** From the under surface of the tuber cinereum a hollow conical process, the **infundibulum,** projects downward and forward and is attached to the posterior lobe of the hypophysis.

The lateral part of the tuber cinereum is a nucleus of nerve cells, the **basal optic nucleus of Meynert,** while close to the cavity of the third ventricle are three additional nuclei. Between the tuber cinereum and the corpora mammillaria a small elevation, with a corresponding
pression in the third ventricle, is sometimes seen. Retzius has named it the **eminentia saccularis**, and regards it as a representative of the saccus vasculosus found in this situation in some of the lower vertebrates.

The **hypophysis** (pituitary body) (Fig. 721) is a reddish-gray, somewhat oval mass, measuring about 12.5 mm. in its transverse, and about 8 n. in its antero-posterior diameter. It is attached to the end of the infundibulum, and is situated in the fossa hypophyseos of the sphenoidal ne, where it is retained by a circular fold of dura mater, the **diaphragma sella**; this fold almost completely roofs in the fossa, leaving only a small central aperture through which the infundibulum passes.

**Optic Chiasma** (chiasma opticum; optic commissure).—The optic chiasma is a flattened, somewhat quadrilateral band of fibers, situated at the action of the floor and anterior wall of the third ventricle. Most of its fibers have their origins in the retina, and reach the chiasma through the optic nerves, which are continuous with its antero-lateral angles. In the chiasma, they undergo a partial decussation (Fig. 722); the fibers from the nasal half of the retina decussate and enter the optic tract of the opposite side, while the fibers from the temporal half of the retina do not dergo decussation, but pass back into the optic tract of the same side. Occupying the posterior part of the commissure, however, is a strand of fibers, the **commissure of Gudden**, which is not derived from the optic nerves; it forms a connecting link between the medial geniculate bodies.

**Optic Tracts.**—The optic tracts are continued backward and lateralward from the postero-lateral angles of the optic chiasma. Each passes between the anterior perforated substance and the tuber cinereum, and, winding around the ventrolateral aspect of the cerebral peduncle, divides into a medial and a lateral root. The former comprises the fibers of Gudden’s commissure. The lateral root consists mainly of afferent fibers which arise in the retina and undergo partial decussation in the optic chiasma, as described; but it also contains a few fine efferent fibers which ve their origins in the brain and their terminations in the retina. When traced backward, the afferent fibers of the lateral root are found to end the lateral geniculate body and pulvinar of the thalamus, and in the superior colliculus; and these three structures constitute the **lower visual centers**. Fibers arise from the nerve cells in these centers and pass through the occipital part of the internal capsule, under the name of the **optic diations**, to the cortex of the occipital lobe of the cerebrum, where the **higher or cortical visual center** is situated. Some of the fibers of the optic radiations take an opposite course, arising from the cells of the occipital cortex and passing to the lower visual centers. Some fibers are detached from the optic tract, and pass through the cerebral peduncle to the nucleus of the oculomotor nerve. These may be regarded as the efferent branches for the Sphincter pupillae and Ciliaris muscles. Other fibers have been described as reaching the cerebellum through the perior peduncle; while others, are lost in the pons.

**Third Ventricle** (ventriculus tertius) (Figs. 716, 720).—The third ventricle is a median cleft between the two thalami. Behind, it communicates with the fourth ventricle through the cerebral aqueduct, and in front with the lateral ventricles through the interventricular ‘amen. Somewhat triangular in shape, with the apex directed backward, it has a **roof**, a **floor**, an **anterior** and a **posterior boundary** and a pair of lateral walls.
The roof (Fig. 723) is formed by a layer of epithelium, which stretches between the upper edges of the lateral walls of the cavity and is continuous with the epithelial lining of the ventricle. It is covered by and adherent to a fold of pia mater, named the tela chorioidea of the third ventricle, from the under surface of which a pair of vascular fringed processes, the choroid plexuses of the third ventricle, project downward, one on either side of the middle line, and invaginate the epithelial roof into the ventricular cavity.

The floor slopes downward and forward and is formed mainly by the structures which constitute the hypothalamus: from before backward these are: the optic chiasma, the tuber cinereum and infundibulum, and the corpora mammillaria. Behind the last, the floor is formed by the epeduncular fossa and the tegmenta of the cerebral peduncles. The ventricle is prolonged downward as a funnel-shaped recess, the recessus infundibuli, into the infundibulum, and to the apex of the latter the hypophysis is attached.

The anterior boundary is constituted below by the lamina terminalis, a thin layer of gray substance stretching from the upper surface of the optic chiasma to the rostrum of the corpus callosum; above by the columns of the fornix and the anterior commissure. At the junction of the floor and anterior wall, immediately above the optic chiasma, the ventricle presents a small angular recess or diverticulum, the optic recess. Between the columns of the fornix, and above the anterior commissure, is a second recess termed the vulva. At the junction of the roof and anterior wall of the ventricle, and situated between the thalami behind and the columns of the fornix in front, is the interventricular foramen (foramen of Monro) through which the third communicates with the lateral ventricles.
The posterior boundary is constituted by the pineal body, the posterior commissure and the cerebral aqueduct. A small recess, the recessus pinealis, projects into the stalk of the pineal body, while in front of and above the pineal body is a second recess, the recessus suprapinealis, consisting of a diverticulum of the epithelium which forms the ventricular roof.

The lateral wall consists of an upper portion formed by the medial surface of the anterior two-thirds of the thalamus, and a lower consisting an upward continuation of the gray substance of the ventricular floor. These two parts correspond to the alar and basal laminae respectively of the lateral wall of the fore-brain vesicle and are separated from each other by a furrow, the sulcus of Monro, which extends from the interventricular foramen to the cerebral aqueduct (pages 741 and 742). The lateral wall is limited above by the tænia thalami. The columns of the fornix curve downward in front of the interventricular foramen, and then run in the lateral walls of the ventricle, where, at first, they form distinct prominences, but subsequently are lost to sight. The lateral walls are joined to each other across the cavity of the ventricle by a band of gray matter, the massa intermedia (page 809).

Interpeduncular Fossa (Fig. 724).—This is a somewhat lozenge-shaped area of the base of the brain, limited in front by the optic chiasma, hind by the antero-superior surface of the pons, antero-laterally by the converging optic tracts, and postero-laterally by the diverging cerebral peduncles. The structures contained in it have already been described; from behind forward, they are the posterior perforated substance, corpora mamillaria, tuber cinereum, infundibulum, and hypophysis.

Telencephalon.—The telencephalon includes: (1) the cerebral hemispheres with their cavities, the lateral ventricles; and (2) the pars optica hypothalami and the anterior portion of the third ventricle (already described under the diencephalon). As previously stated (see page 4), each cerebral hemisphere may be divided into three fundamental parts, viz., the rhinencephalon, the corpus striatum, and the neopallium. The rhinencephalon, associated with the sense of smell, is the oldest part of the telencephalon, and forms almost the whole of the hemisphere in the lower animals, e.g., fishes, amphibians, and reptiles. In man it is rudimentary, whereas the neopallium undergoes great development and forms the chief part of the hemisphere.
The Cerebral Hemispheres.—The cerebral hemispheres constitute the largest part of the brain, and, when viewed together from above, assume a form of an ovoid mass broader behind than in front, the greatest transverse diameter corresponding with a line connecting the two parietal eminences. The hemispheres are separated medially by a deep cleft, named the longitudinal cerebral fissure, and each possesses a central cavity, the lateral ventricle.

The Longitudinal Cerebral Fissure (fissura cerebri longitudinalis; great longitudinal fissure) contains a sickle-shaped process of dura mater, the falx cerebri. It front and behind, the fissure extends from the upper to the under surfaces of the hemispheres and completely separates them, but its middle portion separates them for only about one-half of their vertical extent; for at this part they are connected across the middle line by the great central white commissure, the corpus callosum.

In a median sagittal section (Fig. 720) the cut corpus callosum presents the appearance of a broad, arched band. Its thick posterior end, termed the splenium, overlaps the mid-brain, but is separated from it by the tela chorioidea of the third ventricle and the pineal body. Its anterior end, termed the genu, gradually tapers into a thinner portion, the rostrum, which is continued downward and backward in front of the anterior commissure to join the lamina terminalis. Arching backward from immediately behind the anterior commissure to the under surface of the splenium is a second white band named the fornix: between this and the corpus callosum are the laminae and cavity of the septum lucidum.

Surfaces of the Cerebral Hemispheres.—Each hemisphere presents three surfaces: lateral, medial, and inferior.

The lateral surface is convex in adaptation to the concavity of the corresponding half of the vault of the cranium. The medial surface is flat and vertical, and is separated from that of the opposite hemisphere by the great longitudinal fissure and the falx cerebri. The inferior surface is an irregular form, and may be divided into three areas: anterior, middle, and posterior. The anterior area, formed by the orbital surface of the frontal lobe, is concave, and rests on the roof of the orbit and nose; the middle area is convex, and consists of the under surface of the temporal lobe: it is adapted to the corresponding half of the middle cranial fossa. The posterior area is concave, directed medialward as well as downward, and is named the tentorial surface, since it rests upon the tentorium cerebelli, which intervenes between it and the upper surface of the cerebellum.

Fig. 725–Lateral surface of left cerebral hemisphere, viewed from above. (See enlarged image)

These three surfaces are separated from each other by the following borders: (a) supero-medial, between the lateral and medial surfaces;
infero-lateral, between the lateral and inferior surfaces; the anterior part of this border separating the lateral from the orbital surface, is
own as the superciliary border; (c) medial occipital, separating the medial and tentorial surfaces; and (d) medial orbital, separating the
oral from the medial surface. The anterior end of the hemisphere is named the frontal pole; the posterior, the occipital pole; and the anterior
do the temporal lobe, the temporal pole. About 5 cm. in front of the occipital pole on the infero-lateral border is an indentation or notch, med the preoccipital notch.

he surfaces of the hemispheres are moulded into a number of irregular eminences, named gyri or convolutions, and separated by furrows
med fissures and sulci. The furrows are of two kinds, complete and incomplete. The former appear early in fetal life, are few in number, and
 Produced by infoldings of the entire thickness of the brain wall, and give rise to corresponding elevations in the interior of the ventricle. ey comprise the hippocampal fissure, and parts of the calcarine and collateral fissures. The incomplete furrows are very numerous, and only
ent the subjacent white substance, without producing any corresponding elevations in the ventricular cavity.

he gyri and their intervening fissures and the sulci are fairly constant in their arrangement; at the same time they vary within certain limits,
t only in different individuals, but on the two hemispheres of the same brain. The convoluted condition of the surface permits of a great
seas of the gray matter without the sacrifice of much additional space. The number and extent of the gyri, as well as the depth of the
vening furrows, appear to bear a direct relation to the intellectual powers of the individual.

tertain of the fissures and sulci are utilized for the purpose of dividing the hemisphere into lobes, and are therefore
med interlobular; included under this category are the lateral cerebral, parieto-occipital, calcarine, and collateral fissures, the central and
ulate sulci, and the sulcus circularis.

Fig. 726–Lateral surface of left cerebral hemisphere, viewed from the side. (See enlarged image)

he Lateral Cerebral Fissure (fissura cerebri lateralis [Sylvii]; fissure of Sylvius) (Fig. 726) is a well-marked cleft on the inferior and lateral
aces of the hemisphere, and consists of a short stem which divides into three rami. The stem is situated on the base of the brain, and
mences in a depression at the lateral angle of the anterior perforated substance. From this point it extends between the anterior part of
poral lobe and the orbital surface of the frontal lobe, and reaches the lateral surface of the hemisphere. Here it divides into three rami: an
erior horizontal, an anterior ascending, and a posterior. The anterior horizontal ramus passes forward for about 2.5 cm. into the inferior
ral gyrus, while the anterior ascending ramus extends upward into the same convolution for about an equal distance. The posterior
us is the longest; it runs backward and slightly upward for about 7 cm., and ends by an upward inflexion in the parietal lobe.

he Central Sulcus (sulcus centralis [Rolandi]; fissure of Rolando; central fissure) (Figs. 725, 726) is situated about the middle of the lateral
ace of the hemisphere, and begins in or near the longitudinal cerebral fissure, a little behind its mid-point. It runs sinuously downward and
ward, and ends a little above the posterior ramus of the lateral fissure, and about 2.5 cm. behind the anterior ascending ramus of the same
ure. It described two chief curves: a superior genu with its concavity directed forward, and an inferior genu with its concavity directed
ward. The central sulcus forms an angle opening forward of about 70° with the median plane.

he Parieto-occipital Fissure (fissura parieto-occipitalis).—Only a small part of this fissure is seen on the lateral surface of the hemisphere, its
ef part being on the medial surface.
The lateral part of the parietoöccipital fissure (Fig. 726) is situated about 5 cm. in front of the occipital pole of the hemisphere, and measures out 1.25 cm. in length.

The medial part of the parietoöccipital fissure (Fig. 727) runs downward and forward as a deep cleft on the medial surface of the hemisphere, and joins the calcarine fissure below and behind the posterior end of the corpus callosum. In most cases it contains a submerged gyrus.

The Calcarine Fissure (fissura calcarina) (Fig. 727) is on the medial surface of the hemisphere. It begins near the occipital pole in two converging rami, and runs forward to a point a little below the splenium of the corpus callosum, where it is joined at an acute angle by the medial part of the parietoöccipital fissure. The anterior part of this fissure gives rise to the prominence of the calcar avis in the posterior cornu the lateral ventricle.

The Cingulate Sulcus (sulcus cinguli; callosomarginal fissure) (Fig. 727) is on the medial surface of the hemisphere; it begins below the anterior end of the corpus callosum and runs upward and forward nearly parallel to the rostrum of this body and, curving in front of the genu, is continued backward above the corpus callosum, and finally ascends to the supero-medial border of the hemisphere a short distance behind the per end of the central sulcus. It separates the superior frontal from the cingulate gyrus.

The Collateral Fissure (fissura collateralis) (Fig. 727) is on the tentorial surface of the hemisphere and extends from near the occipital pole to within a short distance of the temporal pole. Behind, it lies below and lateral to the calcarine fissure, from which it is separated by the lingual gyrus; in front, it is situated between the hippocampal gyrus and the anterior part of the fusiform gyrus.

The Sulcus Circularis (circuminsular fissure) (Fig. 731) is on the lower and lateral surfaces of the hemisphere: it surrounds the insula and separates it from the frontal, parietal, and temporal lobes.

Lobes of the Hemispheres.—By means of these fissures and sulci, assisted by certain arbitrary lines, each hemisphere is divided into the following lobes: the frontal, the parietal, the temporal, the occipital, the limbic, and the insula.

Ontal Lobe (lobus frontalis).—On the lateral surface of the hemisphere this lobe extends from the frontal pole to the central sulcus, the latter separating it from the parietal lobe. Below, it is limited by the posterior ramus of the lateral fissure, which intervenes between it and the central sulcus. On the medial surface, it is separated from the cingulate gyrus by the cingulate sulcus; and on the inferior surface, it is bounded behind by the stem of the lateral fissure.
The lateral surface of the frontal lobe (Fig. 726) is tranversed by three sulci which divide it into four gyri: the sulci are named the precentral, superior and inferior frontal; the gyri are the anterior central, and the superior, middle, and inferior frontal. The precentral sulcus runs parallel to the central sulcus, and is usually divided into an upper and a lower part; between it and the central sulcus is the anterior central gyrus. From the precentral sulcus, the superior and inferior frontal sulci run forward and downward, and divide the remainder of the lateral face of the lobe into three parallel gyri, named, respectively the superior, middle, and inferior frontal gyri.

The anterior central gyrus (gyrus centralis anterior; ascending frontal convolution; precentral gyre) is bounded in front by the precentral sulcus, behind by the central sulcus; it extends from the supero-medial border of the hemisphere to the posterior ramus of the lateral fissure.

The superior frontal gyrus (gyrus frontalis superior; superfrontal gyre) is situated above the superior frontal sulcus and is continued on to the medial surface of the hemisphere. The portion on the lateral surface of the hemisphere is usually more or less completely subdivided into an upper and a lower part by an antero-posterior sulcus, the paramedial sulcus, which, however, is frequently interrupted by bridging gyri.

The middle frontal gyrus (gyrus frontalis medius; medifrontal gyre), between the superior and inferior frontal sulci, is continuous with the anterior orbital gyrus on the inferior surface of the hemisphere; it is frequently subdivided into two by a horizontal sulcus, the medial frontal sulcus of Eberstaller, which ends anteriorly in a wide bifurcation.

The inferior frontal gyrus (gyrus frontalis inferior; subfrontal gyre) lies below the inferior frontal sulcus, and extends forward from the lower part of the precentral sulcus; it is continuous with the lateral and posterior orbital gyri on the under surface of the lobe. It is subdivided by the terior horizontal and ascending rami of the lateral fissure into three parts, viz., (1) the orbital part, below the anterior horizontal ramus of the sulcus; (2) the triangular part (cap of Broca), between the ascending and horizontal rami; and (3) the basilar part, behind the anterior ending ramus. The left inferior frontal gyrus is, as a rule, more highly developed than the right, and is named the gyrus of Broca, from the fact that Broca described it as the center for articulate speech.

The inferior or orbital surface of the frontal lobe is concave, and rests on the orbital plate of the frontal bone (Fig. 729). It is divided into four orbital gyri by a well-marked H-shaped orbital sulcus. These are named, from their position, the medial, anterior, lateral, and posterior orbital gyri. The medial orbital gyrus presents a well-marked antero-posterior sulcus, the olfactory sulcus, for the olfactory tract; the portion of this is named the straight gyrus, and is continuous with the superior frontal gyrus on the medial surface.

The medial surface of the frontal lobe is occupied by the medial part of the superior frontal gyrus (marginal gyrus) (Fig. 727). It lies between the cingulate sulcus and the supero-medial margin of the hemisphere. The posterior part of this gyrus is sometimes marked off by a vertical sulcus, and is distinguished as the paracentral lobule, because it is continuous with the anterior and posterior central gyri.

The parietal lobe (lobus parietalis).—The parietal lobe is separated from the frontal lobe by the central sulcus, but its boundaries below and behind are not so definite. Posteriorly, it is limited by the parieto-occipital fissure, and by a line carried across the hemisphere from the end of the fissure toward the preoccipital notch. Below, it is separated from the temporal lobe by the posterior ramus of the lateral fissure, and by a line carried backward from it to meet the line passing downward to the preoccipital notch.
The lateral surface of the parietal lobe (Fig. 726) is cleft by a well-marked furrow, the intraparietal sulcus of Turner, which consists of an oblique and a horizontal portion. The oblique part is named the postcentral sulcus, and commences below, about midway between the lower end of the central sulcus and the upturned end of the lateral fissure. It runs upward and backward, parallel to the central sulcus, and is metimes divided into an upper and a lower ramus. It forms the hinder limit of the posterior central gyrus.

From about the middle of the postcentral sulcus, or from the upper end of its inferior ramus, the horizontal portion of the intraparietal sulcus carried backward and slightly upward on the parietal lobe, and is prolonged, under the name of the occipital ramus, on to the occipital lobe, where it divides into two parts, which form nearly a right angle with the main stem and constitute the transverse occipital sulcus. The part of the parietal lobe above the horizontal portion of the intraparietal sulcus is named the superior parietal lobule; the part below, the inferior parietal lobule.

The posterior central gyrus ( gyrus centralis posterior; ascending parietal convolution; postcentral gyre) extends from the longitudinal fissure above to the posterior ramus of the lateral fissure below. It lies parallel with the anterior central gyrus, with which it is connected below, and also, sometimes, above, the central sulcus.

The superior parietal lobule ( lobulus parietalis superior) is bounded in front by the upper part of the postcentral sulcus, but is usually connected with the posterior central gyrus above the end of the sulcus; behind it is the lateral part of the parieto-occipital fissure, around the end which it is joined to the occipital lobe by a curved gyrus, the arcus parieto-occipitalis; below, it is separated from the inferior parietal lobule the horizontal portion of the intraparietal sulcus.

The inferior parietal lobule ( lobulus parietalis inferior; subparietal district or lobule) lies below the horizontal portion of the intraparietal sulcus, and behind the lower part of the postcentral sulcus. It is divided from before backward into two gyri. One, the supramarginal, arches over the upturned end of the lateral fissure; it is continuous in front with the postcentral gyrus, and behind with the superior temporal gyrus. The second, the angular, arches over the posterior end of the superior temporal sulcus, behind which it is continuous with the middle temporal gyrus.

The medial surface of the parietal lobe (Fig. 727) is bounded behind by the medial part of the parieto-occipital fissure; in front, by the sterior end of the cingulate sulcus; and below, it is separated from the cingulate gyrus by the subparietal sulcus. It is of small size, and consists of a square-shaped convolution, which is termed the precuneus or quadrate lobe.

Occipital Lobe ( lobus occipitalis).—The occipital lobe is small and pyramidal in shape; it presents three surfaces: lateral, medial, and tentorial.

The lateral surface is limited in front by the lateral part of the parieto-occipital fissure, and by a line carried from the end of this fissure to the occipital notch; it is traversed by the transverse occipital and the lateral occipital sulci. The transverse occipital sulcus is continuous with the posterior end of the occipital ramus of the intraparietal sulcus, and runs across the upper part of the lobe, a short distance behind the rieito-occipital fissure. The lateral occipital sulcus extends from behind forward, and divides the lateral surface of the occipital lobe into superior and an inferior gyrus, which are continuous in front with the parietal and temporal lobes. 125

The medial surface of the occipital lobe is bounded in front by the medial part of the parieto-occipital fissure, and is traversed by the calcarine sure, which subdivides it into the cuneus and the lingual gyrus. The cuneus is a wedge-shaped area between the calcarine fissure and the
The lingual gyrus lies between the calcarine fissure and the posterior part of the collateral fissure; hind, it reaches the occipital pole; in front, it is continued on to the tentorial surface of the temporal lobe, and joins the hippocampal gyrus. The tentorial surface of the occipital lobe is limited in front by an imaginary transverse line through the preoccipital notch, and consists of the sterior part of the fusiform gyrus (occipitotemporal convolution) and the lower part of the lingual gyrus, which are separated from each other the posterior segment of the collateral fissure.

Temporal Lobe (lobus temporalis).—The temporal lobe presents superior, lateral, and inferior surfaces.

The superior surface forms the lower limit of the lateral fissure and overlaps the insula. On opening out the lateral fissure, three or four gyri I'll be seen springing from the depth of the hinder end of the fissure, and running obliquely forward and outward on the posterior part of the per surface of the superior temporal gyrus; these are named the transverse temporal gyri (Heschl) (Fig. 730).

The lateral surface (Fig. 726) is bounded above by the posterior ramus of the lateral fissure, and by the imaginary line continued backward on it; below, it is limited by the infero-lateral border of the hemisphere. It is divided into superior, middle, and inferior gyri by the superior and middle temporal sulci. The superior temporal sulcus runs from before backward across the temporal lobe, some little distance below, but parallel with, the posterior ramus of the lateral fissure; and hence it is often termed the parallel sulcus. The middle temporal sulcus takes the same direction as the superior, but is situated at a lower level, and is usually subdivided into two or more parts. The superior temporal gyrus lies between the posterior ramus of the lateral fissure and the superior temporal sulcus, and is continuous behind with the supramarginal and angular gyri. The middle temporal gyrus is placed between the superior and middle temporal sulci, and is joined posteriorly with the angular gyrus. The inferior temporal gyrus is placed below the middle temporal sulcus, and is connected behind with the inferior occipital gyrus; it also extends around the infero-lateral border on to the inferior surface of the temporal lobe, where it is limited by the inferior sulcus.

The inferior surface is concave, and is continuous posteriorly with the tentorial surface of the occipital lobe. It is traversed by the inferior temporal sulcus, which extends from near the occipital pole behind, to within a short distance of the temporal pole in front, but is frequently divided by bridging gyri. Lateral to this fissure is the narrow tentorial part of the inferior temporal gyrus, and medial to it the fusiform gyrus, which extends from the occipital to the temporal pole; this gyrus is limited medially by the collateral fissure, which separates it from the gual gyrus behind and from the hippocampal gyrus in front.

The Insula (island of Reil; central lobe) (Fig. 731) lies deeply in the lateral or Sylvian fissure, and can only be seen when the lips of that sure are widely separated, since it is overlapped and hidden by the gyri which bound the fissure. These gyri are termed the opercula of the aula; they are separated from each other by the three rami of the lateral fissure, and are named the orbital, frontal, frontoparietal, and temporal ercula. The orbital operculum lies below the anterior horizontal ramus of the fissure, the frontal between this and the anterior ascending nus, the parietal between the anterior ascending ramus and the upturned end of the posterior ramus, and the temporal below the posterior nus. The frontal operculum is of small size in those cases where the anterior horizontal and ascending rami of the lateral fissure arise from a mon stem. The insula is surrounded by a deep circular sulcus which separates it from the frontal, parietal, and temporal lobes. When the ercula have been removed, the insula is seen as a triangular eminence, the apex of which is directed toward the anterior perforated substance. s divided into a larger anterior and a smaller posterior part by a deep sulcus, which runs backward and upward from the apex of the insula.
The anterior part is subdivided by shallow sulci into three or four **short gyri**, while the posterior part is formed by one **long gyrus**, which is often bifurcated at its upper end. The cortical gray substance of the insula is continuous with that of the different opercula, while its deep face corresponds with the lentiform nucleus of the corpus striatum.

**Fig. 731**—The insula of the left side, exposed by removing the opercula. (See enlarged image)

**Limbic Lobe** (Fig. 727).—The term limbic lobe was introduced by Broca, and under it he included the cingulate and hippocampal gyri, which together arch around the corpus callosum and the hippocampal fissure. These he separated on the morphological ground that they are well-developed in animals possessing a keen sense of smell (osmatic animals), such as the dog and fox. They were thus regarded as a part of the nencephalon, but it is now recognized that they belong to the neopallium; the cingulate gyrus is therefore sometimes described as a part of the frontal lobe, and the hippocampal as a part of the temporal lobe.

The **cingulate gyrus** (*gyrus cinguli; callosal convolution*) is an arch-shaped convolution, lying in close relation to the superficial surface of the corpus callosum, from which it is separated by a slit-like fissure, the **callosal fissure**. It commences below the rostrum of the corpus callosum, curves around in front of the genu, extends along the upper surface of the body, and finally turns downward behind the splenium, where it is connected by a narrow **isthmus** with the hippocampal gyrus. It is separated from the medial part of the superior frontal gyrus by the cingulate sulcus, and from the precuneus by the subparietal sulcus.

The **hippocampal gyrus** (*gyrus hippocampi*) is bounded above by the hippocampal fissure, and below by the anterior part of the collateral sulcus. Behind, it is continuous superiority with the isthmus, with the cingulate gyrus and inferiorly with the lingual gyrus. Running in the substance of the cingulate and hippocampal gyri, and connecting them together, is a tract of arched fibers, named the **cingulum** (page 843). The anterior extremity of the hippocampal gyrus is recurved in the form of a hook (**uncus**), which is separated from the apex of the temporal lobe by light fissure, the **incisura temporalis**. Although superficially continuous with the hippocampal gyrus, the uncus forms morphologically a part of the rhinencephalon.

The **Hippocampal Fissure** (*fissura hippocampi; dentate fissure*) begins immediately behind the splenium of the corpus callosum, and runs forward between the hippocampal and dentate gyri to end in the uncus. It is a complete fissure (page 819), and gives rise to the prominence of the hippocampus in the inferior horn of the lateral ventricle.
Rhinencephalon (Fig. 732).—The rhinencephalon comprises the olfactory lobe, the uncus, the subcallosal and supracallosal gyri, the fascia dentata hippocampi, the septum pellucidum, the fornix, and the hippocampus.

. The Olfactory Lobe (lobus olfactorius) is situated under the inferior or orbital surface of the frontal lobe. In many vertebrates it constitutes a well-marked portion of the hemisphere and contains an extension of the lateral ventricle; but in man and some other mammals it is limentary. It consists of the olfactory bulb and tract, the olfactory trigone, the parolfactory area of Broca, and the anterior perforated substance.

1) The olfactory bulb (bulbus olfactorius) is an oval, reddish-gray mass which rests on the cribriform plate of the ethmoid and forms the anterior expanded extremity of the olfactory tract. Its under surface receives the olfactory nerves, which pass upward through the cribiform plate from the olfactory region of the nasal cavity. Its minute structure is described on page 848.

2) The olfactory tract (tractus olfactorius) is a narrow white band, triangular on coronal section, the apex being directed upward. It lies in the olfactory sulcus on the inferior surface of the frontal lobe, and divides posteriorly into two striae, a medial and a lateral. The lateral stria is directed across the lateral part of the anterior perforated substance and then bends abruptly medialward toward the uncus of the hippocampal gyrus. The medial stria turns medialward behind the parolfactory area and ends in the subcallosal gyrus; in some cases a small intermediate stria is seen running backward to the anterior perforated substance.

3) The olfactory trigone (trigonum olfactorium) is a small triangular area in front of the anterior perforated substance. Its apex, directed forward, occupies the posterior part of the olfactory sulcus, and is brought into view by throwing back the olfactory tract.

4) The parolfactory area of Broca (area parolfactoria) is a small triangular field on the medial surface of the hemisphere in front of the subcallosal gyrus, from which it is separated by the posterior parolfactory sulcus; it is continuous below with the olfactory trigone, and above and in front with the parolfactory area of Broca. It is limited anteriorly by the anterior parolfactory sulcus.

5) The anterior perforated substance (substantia perforata anterior) is an irregularly quadrilateral area in front of the optic tract and behind the olfactory trigone, from which it is separated by the fissure prima; medially and in front it is continuous with the subcallosal gyrus; laterally it is bounded by the lateral stria of the olfactory tract and is continued into the uncus. Its gray substance is confluent in front of the corpus callosum and is perforated anteriorly by numerous small bloodvessels.

The Uncus has already been described (page 826) as the recurved, hook-like portion of the hippocampal gyrus.

. The Subcallosal, Supracallosal, and Dentate Gyri form a rudimentary arch-shaped lamina of gray substance extending over the corpus callosum and above the hippocampal gyrus from the anterior perforated substance to the uncus.

i) The subcallosal gyrus (gyrus subcallosus; peduncle of the corpus callosum) is a narrow lamina on the medial surface of the hemisphere in front of the subcallosal gyrus, from which it is separated by the fissure prima; medially and in front it is continuous with the subcallosal gyrus; laterally it is bounded by the lateral stria of the olfactory tract and is continued into the uncus. Its gray substance is confluent anteriorly by that of the corpus callosum and is perforated anteriorly by numerous small bloodvessels.

. The Supracallosal gyrus (indusium griseum; gyrus epicallosus) consists of a thin layer of gray substance in contact with the upper surface of the corpus callosum and continuous laterally with the gray substance of the cingulate gyrus. It contains two longitudinally directed strands of cells termed respectively the medial and lateral longitudinal striae. The supracallosal gyrus is prolonged around the splenium of the corpus callosum as a delicate lamina, the fasciola cinerea, which is continuous below with the fascia dentata hippocampi.

. The fascia dentata hippocampi (gyrus dentatus) is a narrow band extending downward and forward above the hippocampal gyrus but
...separated from it by the hippocampal fissure; its free margin is notched and overlapped by the fimbria—the fimbriodentate fissure intervening. Anteriorly it is continued into the notch of the uncus, where it forms a sharp bend and is then prolonged as a delicate band, the band of acomini, over the uncus, on the lateral surface of which it is lost.

The remaining parts of the rhinencephalon, viz., the septum pellucidum, fornix, and hippocampus, will be described in connection with the eural ventricle.

terior of the Cerebral Hemispheres.—If the upper part of either hemisphere be removed, at a level about 1.25 cm. above the corpus lusom, the central white substance will be exposed as an oval-shaped area, the centrum ovale minus, surrounded by a narrow convoluted urgin of gray substance, and studded with numerous minute red dots (puncta vasculosa), produced by the escape of blood from divided odvessels. If the remaining portions of the hemispheres be slightly drawn apart a broad band of white substance, the corpus callosum, will be observed, connecting them at the bottom of the longitudinal fissure; the margins of the hemispheres which overlap the corpus callosum are led the labia cerebri. Each labrum is part of the cingulate gyrus already described; and the slit-like interval between it and the upper surface the corpus callosum is termed the callosal fissure (Fig. 727). If the hemispheres be sliced off to a level with the upper surface of the corpus lusom, the white substance of that structure will be seen connecting the two hemispheres. The large expanse of medullary matter now posed, surrounded by the convoluted margin of gray substance, is called the centrum ovale majus.

The Corpus Callosum (Fig. 733) is the great transverse comissure which unites the cerebral hemispheres and roofs in the lateral ventricles. A good conception of its position and size is obtained by examining a median sagittal section of the brain (Fig. 720), when it is seen to form an ehed structure about 10 cm. long. Its anterior end is about 4 cm. from the frontal pole, and its posterior end about 6 cm. from the occipital pole the hemisphere.

Fig. 733–Corpus callosum from above. (See enlarged image)
the slit-like callosal fissure. It is traversed by numerous transverse ridges and furrows, and is covered by a thin layer of gray matter, the supracallosal gyrus, which exhibits on either side of the middle line the medial and lateral longitudinal striae, already described (page 827). The inferior surface is concave, and forms on either side of the middle line the roof of the lateral ventricle. Medially, this surface is attached front to the septum pellucidum; behind this it is fused with the upper surface of the body of the fornix, while the splenium is in contact with tela chorioidea.

In either side, the fibers of the corpus callosum radiate in the white substance and pass to the various parts of the cerebral cortex; those curving forward from the genu into the frontal lobe constitute the forceps anterior, and those curving backward into the occipital lobe, the forceps posterior. Between these two parts is the main body of the fibers which constitute the tapetum and extend laterally on either side of the temporal lobe, and cover in the central part of the lateral ventricle.

Fig. 734—Scheme showing relations of the ventricles to the surface of the brain. (See enlarged image)

The Lateral Ventricles (ventriculus lateralis) (Fig. 734).—The two lateral ventricles are irregular cavities situated in the lower and medial parts of the cerebral hemispheres, one on either side of the middle line. They are separated from each other by a median vertical partition, the septum pellucidum, but communicate with the third ventricle and indirectly with each other through the interventricular foramen. They are lined by a thin, diaphanous membrane, the ependyma, covered by ciliated epithelium, and contain cerebrospinal fluid, which, even in health, may be secreted in considerable amount. Each lateral ventricle consists of a central part or body, and three prolongations from it, medcorna (Figs. 735, 736).

The central part (pars centralis ventriculi lateralis; cella) (Fig. 737) of the lateral ventricle extends from the interventricular foramen to the genu of the corpus callosum. It is an irregularly curved cavity, triangular on transverse section, with a roof, a floor, and a medial wall. The roof is formed by the under surface of the corpus callosum; the floor by the following parts, enumerated in their order of position, from before backward: the caudate nucleus of the corpus striatum, the stria terminalis and the terminal vein, the lateral portion of the upper surface of the thalamus, the choroid plexus, and the lateral part of the fornix; the medial wall is the posterior part of the septum pellucidum, which separates it from the opposite ventricle.
The anterior cornu (cornu anterius; anterior horn; precornu) (Fig. 736) passes forward and lateralward, with a slight inclination downward, in the interventricular foramen into the frontal lobe, curving around the anterior end of the caudate nucleus. Its floor is formed by the upper face of the reflected portion of the corpus callosum, the rostrum. It is bounded medially by the anterior portion of the septum pellucidum, laterally by the head of the caudate nucleus. Its apex reaches the posterior surface of the genu of the corpus callosum.

The posterior cornu (cornu posterius; postcornu) (Figs. 737, 738) passes into the occipital lobe, its direction being backward and lateralward, then medialward. Its roof is formed by the fibers of the corpus callosum passing to the temporal and occipital lobes. On its medial wall is a longitudinal eminence, the calcar avis (hippocampus minor), which is an involution of the ventricular wall produced by the calcarine fissure. Above this the forceps posterior of the corpus callosum, sweeping around to enter the occipital lobe, causes another projection, termed the bulb the posterior cornu. The calcar avis and bulb of the posterior cornu are extremely variable in their degree of development; in some cases they are ill-defined, in others prominent.
he inferior cornu (cornu inferior; descending horn; middle horn; medicornu) (Fig. 739), the largest of the three, traverses the temporal lobe of the brain, forming in its course a curve around the posterior end of the thalamus. It passes at first backward, lateralward, and downward, and then curves forward to within 2.5 cm. of the apex of the temporal lobe, its direction being fairly well indicated on the surface of the brain by the superior temporal sulcus. Its roof is formed chiefly by the inferior surface of the tapetum of the corpus callosum, but the tail of the caudate nucleus and the stria terminalis also extend forward in the roof of the inferior cornu to its extremity; the tail of the caudate nucleus joins the putamen. Its floor presents the following parts: the hippocampus, the fimbria hippocampi, the collateral eminence, and the choroid plexus. When the choroid plexus is removed, a cleft-like opening is left along the medial wall of the inferior cornu; this cleft constitutes the lower part of the choroidal fissure.
The **hippocampus** (*hippocampus major*) (Figs. 739, 740) is a curved eminence, about 5 cm. long, which extends throughout the entire length the floor of the inferior cornu. Its lower end is enlarged, and presents two or three rounded elevations or digitations which give it a paw-like pearance, and hence it is named the **pes hippocampi**. If a transverse section be made through the hippocampus, it will be seen that this inence is produced by the folding of the wall of the hemisphere to form the hippocampal fissure. The main mass of the hippocampus consists gray substance, but on its ventricular surface is a thin white layer, the **alveus**, which is continuous with the fimbria hippocampi.

The **collateral eminence** (*eminentia collateralis*) (Fig. 740) is an elongated swelling lying lateral to and parallel with the hippocampus. It responds with the middle part of the collateral fissure, and its size depends on the depth and direction of this fissure. It is continuous behind a flattened triangular area, the **trigonum collaterale**, situated between the posterior and inferior cornua.

The fimbria hippocampi is a continuation of the crus of the fornix, and will be discussed with that body; a description of the choroid plexus ll be found on page 840.
Fig. 741—Two views of a model of the striatum: A, lateral aspect; B, mesal aspect. (See enlarged image)

The corpus striatum has received its name from the striped appearance which a section of its anterior part presents, in consequence of diverging white fibers being mixed with the gray substance which forms its chief mass. A part of the corpus striatum is imbedded in the white substance of the hemisphere, and is therefore external to the ventricle; it is termed the extraventricular portion, or the lentiform nucleus; the remainder, however, projects into the ventricle, and is named the intraventricular portion, or the caudate nucleus (Fig. 737).

The caudate nucleus (nucleus caudatus; caudatum) (Figs. 741, 742) is a pear-shaped, highly arched gray mass; its broad extremity, head, is directed forward into the anterior cornu of the lateral ventricle, and is continuous with the anterior perforated substance and with the anterior end of the lentiform nucleus; its narrow end, or tail, is directed backward on the lateral side of the thalamus, from which it is separated by the stria terminalis and the terminal vein. It is then continued downward into the roof of the inferior cornu, and ends in the putamen near the apex of the temporal lobe. It is covered by the lining of the ventricle, and crossed by some veins of considerable size. It is separated from the lentiform nucleus, in the greater part of its extent, by a thick lamina of white substance, called the internal capsule, but the two portions of the corpus striatum are united in front (Figs. 743, 744).
The lentiform nucleus (nucleus lentiformis; lenticular nucleus; lenticula) (Fig. 741) is lateral to the caudate nucleus and thalamus, and is seen only in sections of the hemisphere. When divided horizontally, it exhibits, to some extent, the appearance of a biconvex lens (Fig. 742), while a coronal section of its central part presents a somewhat triangular outline. It is shorter than the caudate nucleus and does not extend as far forward. It is bounded laterally by a lamina of white substance called the external capsule, and lateral to this is a thin layer of gray substance med the claustrum. Its anterior end is continuous with the lower part of the head of the caudate nucleus and with the anterior perforated substance.

In a coronal section through the middle of the lentiform nucleus, two medullary laminae are seen dividing it into three parts. The lateral and largest part is of a reddish color, and is known as the putamen, while the medial and intermediate are of a yellowish tint, and together constitute the globus pallidus; all three are marked by fine radiating white fibers, which are most distinct in the putamen (Fig. 744).

The gray substance of the corpus striatum is traversed by nerve fibers, some of which originate in it. The cells are multipolar, both large and small; those of the lentiform nucleus contain yellow pigment. The caudate and lentiform nuclei are not only directly continuous with each other anteriorly, but are connected to each other by numerous fibers. The corpus striatum is also connected: (1) to the cerebral cortex, by what are med the corticostriate fibers; (2) to the thalamus, by fibers which pass through the internal capsule, and by a strand named the ansa lenticularis; (3) to the cerebral peduncle, by fibers which leave the lower aspect of the caudate and lentiform nuclei.

The claustrum (Figs. 742, 744) is a thin layer of gray substance, situated on the lateral surface of the external capsule. Its transverse section is irregular, with the apex directed upward. Its medial surface, contiguous to the external capsule, is smooth, but its lateral surface presents ridges of furrows corresponding with the gyri and sulci of the insula, with which it is in close relationship. The claustrum is regarded as a detached portion of the gray substance of the insula, from which it is separated by a layer of white fibers, the capsula extrema (band of Baillarger). Its cells are small and spindle-shaped, and contain yellow pigment; they are similar to those of the deepest layer of the cortex.

The nucleus amygdalae (amygdala) (Fig. 741), is an ovoid gray mass, situated at the lower end of the roof of the inferior cornu. It is merely a thickened portion of the gray cortex, continuous with that of the uncus; in front it is continuous with the putamen, behind with the stria minalis and the tail of the caudate nucleus.

The internal capsule (capsula interna) (Figs. 745, 746) is a flattened band of white fibers, between the lentiform nucleus on the lateral side and the caudate nucleus and thalamus on the medial side. In horizontal section (Figs. 742) it is seen to be somewhat abruptly curved, with its...
Convexity inward; the prominence of the curve is called the **genu**, and projects between the caudate nucleus and the thalamus. The portion in front of the genu is termed the frontal part, and separates the lentiform from the caudate nucleus; the portion behind the genu is the occipital part, and separates the lentiform nucleus from the thalamus.

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**Fig. 744**– Coronal section of brain through anterior commissure. ([See enlarged image](#))

The frontal part of the internal capsule contains: (1) fibers running from the thalamus to the frontal lobe; (2) fibers connecting the lentiform and caudate nuclei; (3) fibers connecting the cortex with the corpus striatum; and (4) fibers passing from the frontal lobe through the medial th of the base of the cerebral peduncle to the nuclei pontis. The fibers in the region of the genu are named the **geniculate fibers**; they originate in the motor part of the cerebral cortex, and, after passing downward through the base of the cerebral peduncle with the cerebrospinal fibers, undergo decussation and end in the motor nuclei of the cranial nerves of the opposite side. The anterior two-thirds of the occipital part of the internal capsule contains the **cerebrospinal fibers**, which arise in the motor area of the cerebral cortex and, passing downward through the middle three-fifths of the base of the cerebral peduncle, are continued into the pyramids of the medulla oblongata. The posterior third of the occipital part contains: (1) sensory fibers, largely derived from the thalamus, though some may be continued upward from the medial geniculate; (2) the fibers of optic radiation, from the lower visual centers to the cortex of the occipital lobe; (3) acoustic fibers, from the lateral geniculate to the temporal lobe; and (4) fibers which pass from the occipital and temporal lobes to the nuclei pontis.

The fibers of the internal capsule radiate widely as they pass to and from the various parts of the cerebral cortex, forming the **corona radiata** (Fig. 745) and intermingling with the fibers of the corpus callosum.

The **external capsule** (capsula externa) (Fig. 742) is a lamina of white substance, situated lateral to the lentiform nucleus, between it and the claustrum, and continuous with the internal capsule below and behind the lentiform nucleus. It probably contains fibers derived from the thalamus, the anterior commissure, and the subthalamic region.
The substantia innominata of Meynert is a stratum consisting partly of gray and partly of white substance, which lies below the anterior part of the thalamus and lentiform nucleus. It consists of three layers, superior, middle, and inferior. The superior layer is named the ansa lenticularis, and its fibers, derived from the medullary lamina of the lentiform nucleus, pass medially to end in the thalamus and subthalamic region, while others are said to end in the tegmentum and red nucleus. The middle layer consists of nerve cells and nerve fibers; fibers enter it from the parietal lobe through the external capsule, while others are said to connect it with the medial longitudinal fasciculus. The inferior layer forms the main part of the inferior stalk of the thalamus, and connects this body with the temporal lobe and the insula.

The stria terminalis (tania semicircularis) is a narrow band of white substance situated in the depression between the caudate nucleus and the thalamus. Anteriorly, its fibers are partly continued into the column of the fornix; some, however, pass over the anterior commissure to the gray substance between the caudate nucleus and septum pellucidum, while others are said to enter the caudate nucleus. Posteriorly, it is continued to the roof of the inferior cornu of the lateral ventricle, at the extremity of which it enters the nucleus amygdalae. Superficial to it is a large vein, the terminal vein (vein of the corpus striatum), which receives numerous tributaries from the corpus striatum and thalamus; it runs forward to the interventricular foramen and there joins with the vein of the choroid plexus to form the corresponding internal cerebral vein. On the surface of the terminal vein is a narrow white band, named the lamina affixa.

The Fornix (Figs. 720, 747, 748) is a longitudinal, arch-shaped lamella of white substance, situated below the corpus callosum, and continuous with it behind, but separated from it in front by the septum pellucidum. It may be described as consisting of two symmetrical bands, and for either hemisphere. The two portions are not united to each other in front and behind, but their central parts are joined together in the median line. The anterior parts are called the columns of the fornix; the intermediate united portions, the body; and the posterior parts, the crura.
The body (corpus fornixis) of the fornix is triangular, narrow in front, and broad behind. The medial part of its upper surface is connected to the septum pellucidum in front and to the corpus callosum behind. The lateral portion of this surface forms part of the floor of the lateral ventricle, and is covered by the ventricular epithelium. Its lateral edge overlaps the choroid plexus, and is continuous with the epithelial vening of this structure. The under surface rests upon the tela chorioidea of the third ventricle, which separates it from the epithelial roof of the cavity, and from the medial portions of the upper surfaces of the thalami. Below, the lateral portions of the body of the fornix are joined by a thin triangular lamina, named the psalterium (lyra). This lamina contains some transverse fibers which connect the two hippocampi across the middle line and constitute the hippocampal commissure. Between the psalterium and the corpus callosum a horizontal cleft, the so-called ventricle of the fornix (ventricle of Verga), is sometimes found.

The columns (columna fornices; anterior pillars; fornicolumns) of the fornix arch downward in front of the interventricular foramen and hinder the anterior commissure, and each descends through the gray substance in the lateral wall of the third ventricle to the base of the brain, where it ends in the corpus mammillare. From the cells of the corpus mammillare the thalamomammillary fasciculus (bundle of Vicq d’Azyr) takes origin and is prolonged into the anterior nucleus of the thalamus. The column of the fornix and the thalamomammillary fasciculus together form a loop resembling the figure 8, but the continuity of the loop is broken in the corpus mammillare. The column of the fornix is joined by the stria medullaris of the pineal body and by the superficial fibers of the stria terminalis, and is said to receive also fibers from the septum pellucidum. Zuckerkandl describes an olfactory fasciculus which becomes detached from the main portion of the column of the fornix, and passes downward in front of the anterior commissure to the base of the brain, where it divides into two bundles, one joining the medial stria of the olfactory tract; the other joins the subcallosal gyrus, and through it reaches the hippocampal gyrus.
The crura (crus fornicis; posterior pillars) of the fornix are prolonged backward from the body. They are flattened bands, and at their commencement are intimately connected with the under surface of the corpus callosum. Diverging from one another, each curves around the posterior end of the thalamus, and passes downward and forward into the inferior cornu of the lateral ventricle (Fig. 750). Here it lies along the concavity of the hippocampus, on the surface of which some of its fibers are spread out to form the alveus, while the remainder are continued as a narrow white band, the fimbria hippocampi, which is prolonged into the uncus of the hippocampal gyrus. The inner edge of the fimbria overlies the fascia dentata hippocampi (dentate gyrus) (page 827), from which it is separated by the fimbriodentate fissure; from its lateral margin, which is thin and ragged, the ventricular epithelium is reflected over the choroid plexus as the latter projects into the chorioidal fissure.

**terventricular Foramen (foramen of Monro).**—Between the columns of the fornix and the anterior ends of the thalami, an oval aperture is present on either side: this is the interventricular foramen, and through it the lateral ventricles communicate with the third ventricle. Behind the
ethelial lining of the foramen the choroid plexuses of the lateral ventricles are joined across the middle line.

he Anterior Commissure (precommissure) is a bundle of white fibers, connecting the two cerebral hemispheres across the middle line, and is situated in front of the columns of the fornix. On sagittal section it is oval in shape, its long diameter being vertical and measuring about 5 mm. Its fibers can be traced laterally and upward, on either side beneath the corpus striatum into the substance of the temporal lobe. It serves in some way to connect the two temporal lobes, but it also contains decussating fibers from the olfactory tracts.

he Septum Pellucidum (septum lucidum) (Fig. 720) is a thin, vertically placed partition consisting of two laminae, separated in the greater part of their extent by a narrow chink or interval, the cavity of the septum pellucidum. It is attached, above, to the under surface of the corpus callosum; below, to the anterior part of the fornix behind, and the reflected portion of the corpus callosum in front. It is triangular in form, broad in front and narrow behind; its inferior angle corresponds with the upper part of the anterior commissure. The lateral surface of each lamina is clefted toward the body and anterior cornu of the lateral ventricle, and is covered by the ependyma of that cavity.

he cavity of the septum pellucidum (cavum septi pellucidi; pseudocele; fifth ventricle) is generally regarded as part of the longitudinal ebral fissure, which has become shut off by the union of the hemispheres in the formation of the corpus callosum above and the fornix below. Each half of the septum therefore forms part of the medial wall of the hemisphere, and consists of a medial layer of gray substance, rived from that of the cortex, and a lateral layer of white substance continuous with that of the cerebral hemispheres. This cavity is not developed from the cavity of the cerebral vesicles, and never communicates with the ventricles of the brain.

he Choroid Plexus of the Lateral Ventricle (plexus chorioideus ventriculi lateralis; paraplexus) (Fig. 750) is a highly vascular, fringe-process of pia mater, which projects into the ventricular cavity. The plexus, however, is everywhere covered by a layer of epithelium continuous with the epithelial lining of the ventricle. It extends from the interventricular foramen, where it is joined with the plexus of the opposite ventricle, to the end of the inferior cornu. The part in relation to the body of the ventricle forms the vascular fringed margin of a angular process of pia mater, named the tela chorioidea of the third ventricle, and projects from under cover of the lateral edge of the nix. It lies upon the upper surface of the thalamus, from which the epithelium is reflected over the plexus on to the edge of the fornix (Fig. 3). The portion in relation to the inferior cornu lies in the concavity of the hippocampus and overlaps the fimbria hippocampi: from the lateral edge of the fimbria the epithelium is reflected over the plexus on to the roof of the cornu (Fig. 749). It consists of minute and highly vascular processes, each with an afferent and an efferent vessel. The arteries of the plexus are: (a) the anterior choroidal, a branch of the internal carotid, which enters the plexus at the end of the inferior cornu; and (b) the posterior choroidal, one or two small branches of the posterior cerebral, which pass forward under the splenium. The veins of the choroid plexus unite to form a tortuous vein, which courses from behind toward the interventricular foramen and there joins with the terminal vein to form the corresponding internal cerebral vein.

Fig. 749–Coronal section of inferior horn of lateral ventricle. (Diagrammatic.) (See enlarged image)

When the choroid plexus is pulled away, the continuity between its epithelial covering and the epithelial lining of the ventricle is severed, and left-like space is produced. This is named the choroidal fissure; like the plexus, it extends from the interventricular foramen to the end of the inferior cornu. The upper part of the fissure, i.e., the part nearest the interventricular foramen is situated between the lateral edge of the nix and the upper surface of the thalamus; farther back at the beginning of the inferior cornu it is between the commencement of the fimbria hippocampi and the posterior end of the thalamus, while in the inferior cornu it lies between the fimbria in the floor and the stria terminalis in the roof of the cornu.

he tela chorioidea of the third ventricle (tela chorioidea ventriculi tertii; velum interpositum) (Fig. 750) is a double fold of pia mater, angular in shape, which lies beneath the fornix. The lateral portions of its lower surface rest upon the thalamus, while its medial portion is in contact with the epithelial roof of the third ventricle. Its apex is situated at the interventricular foramen; its base corresponds with the splenium of the corpus callosum, and occupies the interval between that structure above and the corpora quadrigemina and pineal body below.
is interval, together with the lower portions of the choroidal fissures, is sometimes spoken of as the **transverse fissure of the brain.** At its
tese the two layers of the velum separate from each other, and are continuous with the pia mater investing the brain in this region. Its lateral
urings are modified to form the highly vascular choroid plexuses of the lateral ventricles. It is supplied by the anterior and posterior choroidal
eries already described. The veins of the tela choroidea are named the **internal cerebral veins** (*venæ Galeni*); they are two in number, and
ward between its layers, each being formed at the interventricular foramen by the union of the terminal vein with the choroidal vein. 
e internal cerebral veins unite posteriorly in a single trunk, the **great cerebral vein** (*vena magna Galeni*), which passes backward beneath the
nium and ends in the straight sinus.

![Image 750– Tela chorioidea of the third ventricle, and the choroid plexus of the left lateral ventricle, exposed from above. (See enlarged image)](image)

**Structure of the Cerebral Hemispheres.**—The cerebral hemispheres are composed of gray and white substance: the former covers their
face, and is termed the **cortex;** the latter occupies the interior of the hemispheres.

The **white substance** consists of medullated fibers, varying in size, and arranged in bundles separated by neuroglia. They may be divided,
ording to their course and connections, into three distinct systems. (1) **Projection fibers** connect the hemisphere with the lower parts of the
and with the medulla spinalis. (2) **Transverse or commissural fibers** unite the two hemispheres. (3) **Association fibers** connect different
utes in the same hemisphere; these are, in many instances, collateral branches of the projection fibers, but others are the axons of
ependent cells.

1. **The projection fibers** consist of efferent and afferent fibers uniting the cortex with the lower parts of the brain and with the medulla
alis. The principal efferent strands are: (1) the **motor tract,** occupying the genu and anterior two-thirds of the occipital part of the internal
ule, and consisting of (a) the geniculate fibers, which decussate and end in the motor nuclei of the cranial nerves of the opposite side; and
the cerebropinal fibers, which are prolonged through the pyramid of the medulla oblongata into the medulla spinalis: (2) the **corticopontine
ers,** ending in the nuclei pontis. The chief afferent fibers are: (1) those of the lemniscus which are not interrupted in the thalamus; (2) those of
uperior cerebellar peduncle which are not interrupted in the red nucleus and thalamus; (3) numerous fibers arising within the thalamus, and
ing through its stalks to the different parts of the cortex (page 810); (4) optic and acoustic fibers, the former passing to the occipital, the
er to the temporal lobe.

2. **The transverse or commissural fibers** connect the two hemispheres. They include: (a) the **transverse fibers** of the corpus callosum, (b) the
terior commissure, (c) the posterior commissure, and (d) the lyra or hippocampal commissure; they have already been described.
The association fibers (Fig. 751) unite different parts of the same hemisphere, and are of two kinds: (1) those connecting adjacent gyri, short association fibers; (2) those passing between more distant parts, long association fibers.

The short association fibers lie immediately beneath the gray substance of the cortex of the hemispheres, and connect together adjacent gyri.

The long association fibers include the following: (a) the uncinate fasciculus; (b) the cingulum; (c) the superior longitudinal fasciculus; (d) the inferior longitudinal fasciculus; (e) the perpendicular fasciculus; (f) the occipitofrontal fasciculus; and (g) the fornix.

1) The uncinate fasciculus passes across the bottom of the lateral fissure, and unites the gyri of the frontal lobe with the anterior end of the temporal lobe.

2) The cingulum is a band of white matter contained within the cingulate gyrus. Beginning in front at the anterior perforated substance, it passes forward and upward parallel with the rostrum, winds around the genu, runs backward above the corpus callosum, turns around the splenium, and ends in the hippocampal gyrus.

3) The superior longitudinal fasciculus passes backward from the frontal lobe above the lentiform nucleus and insula; some of its fibers end in the occipital lobe, and others curve downward and forward into the temporal lobe.

The inferior longitudinal fasciculus connects the temporal and occipital lobes, running along the lateral walls of the inferior and posterior cornua of the lateral ventricle.
The perpendicular fasciculus runs vertically through the front part of the occipital lobe, and connects the inferior parietal lobule with the inferiorm gyrus.

The occipitofrontal fasciculus passes backward from the frontal lobe, along the lateral border of the caudate nucleus, and on the mesial sect of the corona radiata; its fibers radiate in a fan-like manner and pass into the occipital and temporal lobes lateral to the posterior and inferior cornua. Déjerine regards the fibers of the tapetum as being derived from this fasciculus, and not from the corpus callosum.

The fornix connects the hippocampal gyrus with the corpus mamillare and, by means of the thalamomamillary fasciculus, with the danius (see page 839). Through the fibers of the hippocampal commissure it probably also unites the opposite hippocampal gyri.

The gray substance of the hemisphere is divided into: (1) that of the cerebral cortex, and (2) that of the caudate nucleus, the lentiform cleus, the claustrum, and the nucleus amygdale.

structure of the Cerebral Cortex (Fig. 754).—The cerebral cortex differs in thickness and structure in different parts of the hemisphere. It is thinner in the occipital region than in the anterior and posterior central gyri, and it is also much thinner at the bottom of the sulci than on the top the gyri. Again, the minute structure of the anterior central differs from that of the posterior central gyrus, and areas possessing a specialized type of cortex can be mapped out in the occipital lobe.

In examining a section of the cortex with a lens, it is seen to consist of alternating white and gray layers thus disposed from the surface inward: (1) a thin layer of white substance; (2) a layer of gray substance; (3) a second white layer (outer band of Baillarger or band of unari); (4) a second gray layer; (5) a third white layer (inner band of Baillarger); (6) a third gray layer, which rests on the medullary substance of the gyrus.

The cortex is made up of nerve cells of varying size and shape, and of nerve fibers which are either medullated or naked axis-cylinders, bedded in a matrix of neuroglia.

Nerve Cells.—According to Cajal, the nerve cells are arranged in four layers, named from the surface inward as follows: (1) the molecular layer, (2) the layer of small pyramidal cells, (3) the layer of large pyramidal cells, (4) the layer of polymorphous cells.

The Molecular Layer.—In this layer the cells are polygonal, triangular, or fusiform in shape. Each polygonal cell gives off some four or five dendrites, while its axon may arise directly from the cell or from one of its dendrites. Each triangular cell gives off two or three dendrites, from e of which the axon arises. The fusiform cells are placed with their long axes parallel to the surface and are mostly bipolar, each pole being prolonged into a dendrite, which runs horizontally for some distance and furnishes ascending branches. Their axons, two or three in number, se from the dendrites, and, like them, take a horizontal course, giving off numerous ascending collaterals. The distribution of the axons and ndrites of all three sets of cells is limited to the molecular layer.

The Layer of Small and the Layer of Large Pyramidal Cells.—The cells in these two layers may be studied together, since, with the exception the difference in size and the more superficial position of the smaller cells, they resemble each other. The average length of the small cells is on 10 to 15μ; that of the large cells from 20 to 30μ. The body of each cell is pyramidal in shape, its base being directed to the deeper parts...
and its apex toward the surface. It contains granular pigment, and stains deeply with ordinary reagents. The nucleus is of large size, and round oval in shape. The base of the cell gives off the axis cylinder, and this runs into the central white substance, giving off collaterals in its course, and is distributed as a projection, commissural, or association fiber. The apical and basal parts of the cell give off dendrites; the apical dendrite is directed toward the surface, and ends in the molecular layer by dividing into numerous branches, all of which may be seen, when prepared by the silver or methylene-blue method, to be studded with projecting bristle-like processes. The largest pyramidal cells are found in the upper part of the anterior central gyrus and in the paracentral lobule; they are often arranged in groups or nests of from three to five, and are termed the giant cells of Betz. In the former situation they may exceed 50μ in length and 40μ in breadth, while in the paracentral lobule they may attain a length of 65μ.

Layer of Polymorphous Cells.—The cells in this layer, as their name implies, are very irregular in contour; they may be fusiform, oval, angular, or star-shaped. Their dendrites are directed outward, but do not reach so far as the molecular layer; their axons pass into the subjacent white matter.

There are two other kinds of cells in the cerebral cortex. They are: (a) the cells of Golgi, the axons of which divide immediately after their origins into a large number of branches, which are directed toward the surface of the cortex; (b) the cells of Martinotti, which are chiefly found in the polymorphous layer; their dendrites are short, and may have an ascending or descending course, while their axons pass out into the molecular layer and form an extensive horizontal arborization.

Nerve Fibers.—These fill up a large part of the intervals between the cells, and may be medullated or non-medullated—the latter comprising the axons of the smallest pyramidal cells and the cells of Golgi. In their direction the fibers may be either tangential or radial. The tangential fibers run parallel to the surface of the hemisphere, intersecting the radial fibers at a right angle. They constitute several strata, of which the following are the more important: (1) a stratum of white fibers covering the superficial aspect of the molecular layer (plexus of Exner); (2) the band of Bechterew, in the outer part of the layer of small pyramidal cells; (3) the band of Gennari or external band of Baillarger, running through the layer of large pyramidal cells; (4) the internal band of Baillarger, between the layer of large pyramidal cells and the polymorphous layer; (5) the deep tangential fibers, in the lower part of the polymorphous layer. The tangential fibers consist of (a) the collaterals of the ramal and polymorphous cells and of the cells of Martinotti; (b) the branching axons of Golgi’s cells; (c) the collaterals and terminal arborizations of the projection, commissural, or association fibers. The radial fibers.—Some of these, viz., the axons of the pyramidal and polymorphous cells, descend into the central white matter, while others, the terminations of the projection, commissural, or association fibers, tend to end in the cortex. The axons of the cells of Martinotti are also ascending fibers.
Fig. 754—Cerebral cortex. (Poirier.) To the left, the groups of cells; to the right, the systems of fibers. Quite to the left of the figure a sensory nerve fiber is shown. (See enlarged image)

**Special Types of Cerebral Cortex.**—It has been already pointed out that the minute structure of the cortex differs in different regions of the hemisphere; and A. W. Campbell has endeavored to prove, as the result of an exhaustive examination of a series of human and anthropoid brains, “that there exists a direct correlation between physiological function and histological structure.” The principal regions where the ‘typical’ structure is departed from will now be referred to.

1. In the calcarine fissure and the gyri bounding it, the internal band of Baillarger is absent, while the band of Gennari is of considerable thickness, and forms a characteristic feature of this region of the cortex. If a section be examined microscopically, an additional layer of cells is seen to be interpolated between the molecular layer and the layer of small pyramidal cells. This extra layer consists of two or three strata of fusiform cells, the long axes of which are at right angles to the surface; each cell gives off two dendrites, external and internal, from the latter of which the axon arises and passes into the white central substance. In the layer of small pyramidal cells, fusiform cells, identical with the above, are seen, as well as ovoid or star-like cells with ascending axons (cells of Martinotti). This is the visual area of the cortex, and it has been shown by J. S. Bolton that in old-standing cases of optic atrophy the thickness of Gennari’s band is reduced by nearly 50 per cent.
A. W. Campbell says: “Histologically, two distinct types of cortex can be made out in the occipital lobe. The first of these coats the walls and unding convolutions of the calcarine fissure, and is distinguished by the well-known line of Gennari or Vicq d’Azyr; the second area forms investing zone a centimetre or more broad around the first, and is characterized by a remarkable wealth of fibers, as well as by curious riform cells of large size richly stocked with chromophilic elements—cells which seem to have escaped the observation of Ramón y Cajal, Bolton, and others who have worked at this region. As to the functions of these two regions there is abundant evidence, anatomical, embryological, and pathological, to show that the first or calcarine area is that to which visual sensations primarily pass, and we are gradually taining proof to the effect that the second investing area is constituted for the interpretation and further elaboration of these sensations. These therefore deserve the names visuo-sensory and visuo-psyhic.”

The anterior central gyrus is characterized by the presence of the giant cells of Betz and by “a wealth of nerve fibers immeasurably superior that of any other part” (Campbell), and in these respects differs from the posterior central gyrus. These two gyri, together with the paracentral nule, were long regarded as constituting the “motor areas” of the hemisphere; but Sherrington and Grunbaum have shown 128 that in the impanzee the motor area never extends on to the free face of the posterior central gyrus, but occupies the entire length of the anterior central rus, and in most cases the greater part or the whole of its width. It extends into the depth of the central sulcus, occupying the anterior wall, d in some places the floor, and in some extending even into the deeper part of the posterior wall of the sulcus.

In the hippocampus the molecular layer is very thick and contains a large number of Golgi cells. It has been divided into three strata: (a) s. convolutum or s. granulosum, containing many tangential fibers; (b) s. lacunosum, presenting numerous vascular spaces; (c) s. radiatum, exhibiting a rich plexus of fibrils. The two layers of pyramidal cells are condensed into one, and the cells are mostly of large size. The ons of the cells in the polymorphous layer may run in an ascending, a descending, or a horizontal direction. Between the polymorphous layer d the ventricular ependyma is the white substance of the alveus.

In the fascia dentata hippocampi or dentate gyrus the molecular layer contains some pyramidal cells, while the layer of pyramidal cells is nst entirely represented by small ovoid cells.

The Olfactory Bulb.—In many of the lower animals this contains a cavity which communicates through the olfactory tract with the lateral ventric. In man the original cavity is filled up by neuroglia and its wall becomes thickened, but much more so on its ventral than on its dorsal sect. Its dorsal part contains a small amount of gray and white substance, but it is scanty and ill-defined. A section through the ventral rt (Fig. 755) shows it to consist of the following layers from without inward:
A layer of olfactory nerve fibers, which are the non-medullated axons prolonged from the olfactory cells of the nasal cavity, and reach the bulb by passing through the cribriform plate of the ethmoid bone. At first they cover the bulb, and then penetrate it to end by forming synapses with the dendrites of the mitral cells, presently to be described.

1. **Glomerular Layer.**—This contains numerous spheroidal reticulated enlargements, termed glomeruli, produced by the branching and termination of the processes of the olfactory nerve fibers with the descending dendrites of the mitral cells.

2. **Molecular Layer.**—This is formed of a matrix of neuroglia, imbedded in which are the mitral cells. These cells are pyramidal in shape, and the basal part of each gives off a thick dendrite which descends into the glomerular layer, where it arborizes as indicated above, and others interlace with similar dendrites of neighboring mitral cells. The axons pass through the next layer into the white matter of the bulb, and then becoming bent on themselves at a right angle, are continued into the olfactory tract.

3. **Nerve Fiber Layer.**—This lies next the central core of neuroglia, and its fibers consist of the axons or afferent processes of the mitral cells sseing to the brain; some efferent fibers are, however, also present, and end in the molecular layer, but nothing is known as to their exact origin.

**Weight of the Encephalon.**—The average weight of the brain, in the adult male, is about 1380 gms.; that of the female, about 1250 gms. In the male, the maximum weight out of 278 cases was 1840 gms. and the minimum weight 964 gms. The maximum weight of the adult female brain, out of 191 cases, was 1585 gms. and the minimum weight 879 gms. The brain increases rapidly during the first four years of life, and reaches its maximum weight by about the twentieth year. As age advances, the brain decreases slowly in weight; in old age the decrease takes place more rapidly, to the extent of about 28 gms.

4. **Cerebral Localization.**—Physiological and pathological research have now gone far to prove that a considerable part of the surface of the brain may be mapped out into a series of more or less definite areas, each of which is intimately connected with some well-defined function. These chief areas are indicated in Figs. 756 and 757.

**Motor Areas.**—The motor area occupies the anterior central and frontal gyri and the paracentral lobule. The centers for the lower limb are located on the uppermost part of the anterior central gyrus and its continuation on the paracentral lobule; those for the trunk are on the upper portion, and those for the upper limb on the middle portion of the anterior central gyrus. The facial centers are situated on the lower part of the anterior central gyrus, those for the tongue, larynx, muscles of mastication, and pharynx on the frontal operculum, while those for the head and neck occupy the posterior end of the middle frontal gyrus.
Areas of localization on medial surface of hemisphere. Motor area in red. Area of general sensations in blue. Visual area in yellow. Olfactory area in purple. The psychic portions are in lighter tints. (See enlarged image)

Sensory Areas.—Tactile and temperature senses are located on the posterior central gyrus, while the sense of form and solidity is on the superior parietal lobule and precuneus. With regard to the special senses, the area for the sense of taste is probably related to the uncus and hippocampal gyrus. The auditory area occupies the middle third of the superior temporal gyrus and the adjacent gyri in the lateral fissure; the visual area, the calcarine fissure and cuneus; the olfactory area, the rhinencephalon. As special centers of much importance may be noted: the emissive center for speech on the left inferior frontal and anterior central gyri (Broca); the auditory receptive center on the transverse and superior temporal gyri, and the visual receptive center on the lingual gyrus and cuneus.

ote 125. Elliot Smith has named the lateral occipital sulcus the sulcus lunatus; he regards it as the representative, in the human brain, of the Affenspalte” of the brain of the ape. [back]

ote 126. Histological Studies on the Localization of Cerebral Function, Cambridge University Press. [back]

ote 127. Philosophical Transactions of Royal Society, Series B, cxciii, 165. [back]


4d. Composition and Central Connections of the Spinal Nerves

e typical spinal nerve consists of at least four types of fibers, the somatic sensory, sympathetic afferent or sensory, somatic motor and sympathetic efferent or preganglionic. The somatic sensory fibers, afferent fibers, arise from cells in the spinal ganglia and are found in all the spinal nerves, except occasionally the first cervical, and conduct impulses of pain, touch and temperature from the surface of the body through the posterior roots to the spinal cord and impulses of muscle sense, tendon sense and joint sense from the deeper structures. The sympathetic afferent fibers, conduct sensory impulses from the viscera through the rami communicantes and posterior roots to the spinal cord. They are probably limited to the white rami connected with the spinal nerves in two groups, viz., the first thoracic to the second lumbar and the second sacral to the fourth sacral nerves. The somatic motor fibers, efferent fibers, arise from cells in the anterior column of the spinal cord and pass out through the anterior roots to the voluntary muscles. The sympathetic efferent fibers, probably arise from cells in the lateral column or base of the anterior column and emerge through the anterior roots and white rami communicantes. These are preganglionic fibers which end in various sympathetic ganglia from which postganglionic fibers conduct the motor impulses to the smooth muscles of the viscera and vessels and secretory impulses to the glands. These fibers are also limited to two regions, the first thoracic to the second lumbar and the second sacral to the fourth sacral nerves.

fferent fibers which pass into the spinal cord establish various types of connections, some within the cord itself for spinal reflexes, others reflexes connected with higher centers in the brain, while still others conduct impulses of conscious sensation by a series of neurons to the cerebral cortex.
**Intrinsic Spinal Reflex Paths.**—The collaterals and terminals of the ascending and descending branches of the posterior root fibers which leave the substance of Rolando, others in the intermediate region between the dorsal and ventral columns, others traverse the whole thickness of the gray matter to reach the ventral column, others end in the dorsal nucleus, and others pass through the gray commissure to the dorsal lumn of the opposite side. All of these collaterals and terminals end in connection with cells or dendrites of cells in the gray columns. The axons of these cells have various destinations, some pass out into the lateral and ventral funiculi and turn upward to reach the brain. Those concerned with the intrinsic spinal reflexes come into relation either directly or indirectly with motor cells in the anterior column. It is very unlikely that either the terminals or collaterals of the dorsal root fibers effect simple direct connections with the motor cells of the ventral column, there is at least one if not several intercalated neurons in the path. These intercalated or correlation neurons may have short axons that do not pass out of the gray matter or the axons may pass out into the proper fasciculi and extend for varying distances up and down or in both directions giving off collaterals and finally terminating in the gray matter of the same or the opposite side. The shortest fibers of the proper fasciculi lie close to the gray matter, the longest ones are nearer the periphery of the proper fasciculi and are more or less intermingled with the ascending and descending fasciculi which occupy the more marginal regions of the spinal cord.

Each sensory neuron, with its ascending and descending branches, giving off as it does many collaterals into the gray matter, each one of which form a synapse with one or several correlation neurons, is thus brought into relation with many correlation neurons and each one of these in turn, with its ascending and descending branches and their numerous collaterals, is brought into relation, either directly or through the intercalation of additional correlation neurons, with great numbers of motor cells in the anterior column. The great complexity of these so-called simple reflex mechanisms, in the least complex portion of the nervous system the spinal cord, renders them extremely difficult of exact analysis. The association or correlation neurons are concerned not only with the reflex mechanisms of the spinal cord but play an equally important role in the transmission of impulses from the higher centers in the brain to the motor neurons of the spinal cord.

The complex mechanisms just described are probably concerned not so much in the contraction of individual muscles as in the complicated action of groups of muscles concerned in the enormous number of movements, which the limbs and trunk exhibit in the course of our daily life.

**Sensory Pathways from the Spinal Cord to the Brain.**—The posterior root fibers conducting the impulses of conscious muscle sense, tendon and joint sense, those impulses which have to do with the coordination and adjustment of muscular movements, ascend in the fasciculus gracilis and fasciculus cuneatus to the nucleus gracilis and nucleus cuneatus in the medulla oblongata (Fig. 759). The nucleus gracilis and nucleus cuneatus synaptic relations are found with neurons whose cell bodies are located in these nuclei and whose axons pass by way of the internal arcuate fibers, cross in the raphé to the opposite side in the region between the olives and turn abruptly upward to form the medial lemniscus or medial fillet. The medial fillet passes upward in the ventral part of the formatio reticularis through the medulla oblongata, pons and mid-brain to the principal sensory nucleus of the ventro-lateral region of the thalamus. Here the terminals form synapses.
th neurons of the third order whose axons pass through the internal capsule and corona radiata to the somatic sensory area of the cortex in the st-central gyrus.

Fibers conducting the impulses of unconscious muscle sense pass to the cerebellum partly by way of the fasciculus gracilis and fasciculus cuneatus to the nucleus gracilis and nucleus cuneatus, thence neurons of the second order convey the impulses either via the dorsal external arcuate fibers directly into the inferior peduncle of the cerebellum or via the ventral external arcuate fibers which are continued from the internal arcuate fibers through the ventral part of the raphé and after crossing the midline emerge on the surface of the medulla in the ventral sulcus between the pyramids or in the groove between the pyramid and the olive. They pass over the lateral surface of the medulla and olive to reach the inferior peduncle through which they pass to the cerebellum.

Other fibers conducting impulses of unconscious muscle sense pass upward in the dorsal spinocerebellar fasciculus, which arises from cells in the nucleus dorsalis. The posterior root fibers conducting these impulses pass into the fasciculus cuneatus and the collaterals from them to the nucleus dorsalis are said to come almost exclusively from the middle area of the fasciculus cuneatus. They form by their multiple division skets about the individual cells of the nucleus dorsalis, each fiber coming in relation with the bodies and dendrites of several cells. The axons the second order pass into the dorsal spinocerebellar fasciculus of the same side and ascend along the lateral surface of the spinal cord and medulla oblongata until they arrive at the level of the olive, they then curve backward beneath the external arcuate fibers into the inferior peduncle and pass into the cerebellum. Here they give off collaterals to the dentate nucleus and finally terminate in the cortex of the dorsal and superior portion of the vermis, partly on the same side, but to a great extent by way of a large commissure to the opposite side. The fibers lose their myelin sheaths as they enter the gray substance and terminate by end ramifications among the nerve cells and their processes. Some of the fibers are said to end in the nucleus dentatus and the roof nuclei of the cerebellum (the nucleus globosus, nucleus emboliformis and nucleus fastigius) and others pass through them to terminate in the inferior vermis. A few fibers of the dorsal spinocerebellar fasciculus are said not to enter the inferior peduncle but to pass with the ventral spinocerebellar fasciculus. The cerebellar reflex arc is supposed to be completed by the fibers of the superior peduncle which pass from the cerebellum to the red nucleus of the mid-brain where some of their terminals and collaterals form synapses with neurons whose axons descend to the spinal cord in the rubrospinal fasciculus. The terminal and collaterals of this fasciculus d either directly or indirectly about the motor cells in the anterior column.

Fig. 759– The sensory tract. (Modified from Poirier.) (See enlarged image)
The fibers which come from the opposite gray columns cross some in the white and some in the gray commissure and pass with fibers from the same side through the lateral funiculus to the marginal region ventral to the dorsal spino cerebellar fasciculus. The fasciculus begins about the level of the third lumbar nerve and continues upward on the lateral surface of the spinal cord and medulla oblongata til it passes under cover of the external arcuate fibers. It passes just dorsal to the olive and above this joins the lateral edge of the lateral nucisus along which it runs, ventral to the roots of the trigeminal nerve, almost to the level of the superior colliculus, it then crosses over the spinal cord into ascending and descending branches. Their distribution and reception while the fibers to the motor column at the margin of the lateral column. These preganglionic sympathetic fibers are not distributed throughout the entire series of spinal nerves but are confined to two groups, the thoraco-lumbar from the st thoracic to the second or third lumbar nerves and the sacral group from the second to the fourth sacral nerves. They pass out with the fibers of the posterior root conducting impulses of pain and temperature probably terminate in the posterior column or the intermediate region of the gray matter soon after they enter the spinal cord. The neurons of the second order are supposed to pass through the anterior commissure to the superficial antero-lateral fasciculus (tract of Gowers) and pass upward in that portion of it known as the lateral spinothalamic fasciculus. This fasciculus lies along the medial side of the ventral spino cerebellar fasciculus. It is stated by some authors that the pain fibers pass upward in the antero-lateral bundle. In some of the lower mammals this pathway carries the pain fibers upward by a series of neurons some of which pass to the opposite side, so that in part there is a double path. In man, however, the lateral spinothalamic fasciculus is probably the most important pathway. On reaching the medulla these fibers continue upward through the formatio reticularis in the neighborhood of the median line to the thalamus, probably its ventro-lateral region. Whether higher neurons convey the pain impulses to the cortex through the internal capsule or to other centers is uncertain. The pathway is probably more complex and Head is of the opinion that our sensations of pain are essentially thalamic. The in and temperature pathways in the lateral spinothalamic fasciculus are not so closely intermingled but that one can be destroyed without injury to the other.

Sensom suggests that the non-medullated fibers of the posterior roots, which turn into Lissauer’s tract and ascend or descend for short distances exceeding one or two segments and finally end in the substantia gelatinosa, are in part at least pain fibers and that the fasciculus of Lissauer which contains the substantia gelatinosa represent part of the mechanism for reflexes associated with pain conduction and reception while the fibers to the other centers pass up in the spinothalamic tract.

 synapses with these cells. The fibers which come from the opposite gray columns cross some in the white and some in the gray commissure and pass with fibers from the same side through the lateral funiculus to the marginal region ventral to the dorsal spino cerebellar fasciculus. The fasciculus begins about the level of the third lumbar nerve and continues upward on the lateral surface of the spinal cord and medulla oblongata til it passes under cover of the external arcuate fibers. It passes just dorsal to the olive and above this joins the lateral edge of the lateral nucisus along which it runs, ventral to the roots of the trigeminal nerve, almost to the level of the superior colliculus, it then crosses over the spinal cord into ascending and descending branches. Their distribution and reception while the fibers to the motor column at the margin of the lateral column. These preganglionic sympathetic fibers are not distributed throughout the entire series of spinal nerves but are confined to two groups, the thoraco-lumbar from the st thoracic to the second or third lumbar nerves and the sacral group from the second to the fourth sacral nerves. They pass out with the fibers of the posterior root conducting impulses of pain and temperature probably terminate in the posterior column or the intermediate region of the gray matter soon after they enter the spinal cord. The neurons of the second order are supposed to pass through the anterior commissure to the superficial antero-lateral fasciculus (tract of Gowers) and pass upward in that portion of it known as the lateral spinothalamic fasciculus. This fasciculus lies along the medial side of the ventral spino cerebellar fasciculus. It is stated by some authors that the pain fibers pass upward in the antero-lateral bundle. In some of the lower mammals this pathway carries the pain fibers upward by a series of neurons some of which pass to the opposite side, so that in part there is a double path. In man, however, the lateral spinothalamic fasciculus is probably the most important pathway. On reaching the medulla these fibers continue upward through the formatio reticularis in the neighborhood of the median line to the thalamus, probably its ventro-lateral region. Whether higher neurons convey the pain impulses to the cortex through the internal capsule or to other centers is uncertain. The pathway is probably more complex and Head is of the opinion that our sensations of pain are essentially thalamic. The in and temperature pathways in the lateral spinothalamic fasciculus are not so closely intermingled but that one can be destroyed without injury to the other.

The fibers of tactile discrimination, according to Head and Thompson, pass up in the fasciculus cuneatus and fasciculus gracilis of the same side and follow the path of the muscle-sense fibers. The axons of the second order arising in the nucleus cuneatus and gracilis cross with the eural arcuate fibers and ascend to the thalamus with the medial lemniscus, thence by neurons of higher order the impulses are carried to the natic sensory area of the cortex through the internal capsule. The other touch fibers, shortly after entering the spinal cord, terminate in the spinal cord or intermediate gray matter. Neurons of the second order send their axons through the anterior commissure to pass upward in the antero-lateral fasciculus probably in the ventral spinothalamic fasciculus. In the medulla they join or pass upward in the neighborhood of the medial lemniscus to the thalamus and thence by neurons of higher order to the somatic sensory area of the cortex.

The remaining ascending fasciculi form a part of the complex known as the superficial antero-lateral fasciculus (tract of Gowers). e spino-tectal fasciculus, as its name indicates, is supposed to have its origin in the gray matter of the cord and terminations in the superior d inferior (?) colliculi of the mid-brain serving for reflexes between the cord and the visceral and auditory centers of the mid-brain. he spino-olivary fasciculus (olivospinal; bulbo spinal, Helweg’s bundle) is likewise of unknown constitution and function; there is certainty even in regard to the direction of its fibers.

Sympathetic afferent fibers (visceral afferent; viscerosensory; splanchnic afferent) enter the spinal cord by the posterior roots of the thoracic d first two or three lumbar nerves and the second to the fourth sacral nerves. The fibers pass to these nerves from the peripheral sympathetic system through the white rami communicantes. Some of the cell bodies of these afferent fibers are located in the spinal ganglia and others are in sympathetic ganglia. Some of the afferent sympathetic fibers end about the cell bodies of somatic sensory neurons and visceral impulses are transmitted to these neurons which conduct them as well as their own special impulses to the spinal cord. Other sympathetic afferent fibers whose cell bodies are located in the spinal ganglia send collaterals to neighboring cells of somatic sensory neurons and thus have auble path of transmission to the spinal cord. Such an arrangement provides a mechanism for some of the referred pains.

These sympathetic afferent fibers presumably divide on entering the spinal cord into ascending and descending branches. Their distribution and mination within the spinal cord are unknown. Some of them probably eventually come into relation with the sympathetic efferent fibers whose d bodies are located in the lateral column. Our knowledge concerning both the termination and origin of these fibers is very unsatisfactory. he sympathetic efferent fibers (splanchnic motor; visceromotor; preganglionic fibers) are supposed to arise from cells in the intermediate region between the dorsal and ventral gray columns and in the intermedio-lateral column at the margin of the lateral column. These preganglionic sympathetic fibers are not distributed throughout the entire series of spinal nerves but are confined to two groups, the thoraco-lumbar from the st thoracic to the second or third lumbar nerves and the sacral group from the second to the fourth sacral nerves. They pass out with the terior root fibers and through the rami communicantes to end in sympathetic ganglia. The impulses are distributed from cells in these ganglia ough postganglionic fibers to the smooth muscles and glands. The thoraco-lumbar outflow and the sacral outflow form two distinct functional aups which are considered more fully under the sympathetic system.

4e. Composition and Central Connections of the Spinal Nerves
e cranial nerves are more varied in their composition than the spinal nerves. Some, for example, contain somatic motor fibers only, others contain the various types of fibers found in the spinal nerves, namely, somatic motor, sympathetic efferent, somatic sensory and sympathetic sensory. In addition there are included the nerves of the special senses, namely, the nerves of smell, sight, hearing, equilibration and taste.

The Hypoglossal Nerve (XII cranial) consists of somatic motor fibers only and supplies the muscles of the tongue. Its axons arise from cells in the hypoglossal nucleus and pass forward between the white reticular formation and the gray reticular formation to emerge from the anterolateral sulcus of the medulla. The hypoglossal nuclei of the two sides are connected by many commissural fibers and also by dendrites of motor fibers which extend across the midline to the opposite nucleus. The hypoglossal nucleus receives either directly or indirectly numerous collaterals from the opposite pyramidal tract (cortico-bulbar or cerebrobulbar fibers) which convey voluntary motor impulses from the cerebral cortex. Many reflex collaterals enter the nucleus from the secondary sensory paths of the trigeminal and vagus and probably also from the vagus intermedius and the glossopharyngeal. Collaterals from the posterior longitudinal bundle and the ventral longitudinal bundle are said to pass to the nucleus.

The Accessory Nerve (XI cranial) contains somatic motor fibers. The spinal part arises from lateral cell groups in the anterior column near its rostral margin in the upper five or six segments of the cord, its roots pass through the lateral funiculus to the lateral surface of the cord. It supplies the Trapezius and Sternocleidomastoideus. The cranial part arises from the nucleus ambiguous, the continuation in the medulla longata of the lateral cell groups of the anterior column of the spinal cord from which the spinal part has origin. The upper part of the nucleus ambiguous gives motor fibers to the vagus and glossopharyngeal nerves. The cranial part sends it fibers through the vagus to the laryngeal nerves supplying the muscles of the larynx. The root fibers of the cranial part of the accessory nerve pass anterior to the spinal tract of the trigeminal nerve of the ala cinerea. The shorter lateral sulcus of the medulla. The nucleus of origin of the spinal part undoubtedly receives either directly or indirectly terminals and collaterals controlling voluntary movements from the pyramidal tract. It is probable that terminals and collaterals reach the nucleus either directly or indirectly from the rubrospinal and vestibulospinal tracts. It is also connected indirectly with the spinal somatic sensory nerves by association fibers of the proper fasciculi. The cranial part receives primarily or directly terminals and collaterals from the opposite pyramidal tract and form the terminal sensory nuclei of the cranial nerves. A few of the cranial part are said to arise in the dorsal nucleus of the vagus and are thus sympathetic efferent. They are said to join the vagus nerve.

The Vagus Nerve (X cranial) contains somatic sensory, sympathetic afferent, somatic motor, sympathetic efferent and (taste fibers?). The cranial part (somatic sensory, sympathetic, and taste) have their cells of origin in the jugular ganglion and in the nodosal ganglion (ganglion of the trunk) and on entering the medulla divide into ascending and descending branches as do the sensory fibers of the posterior roots of the spinal nerves after they enter the spinal cord.

1) The somatic sensory fibers are few in number, convey impulses from a limited area of the skin on the back of the ear and posterior part of the external auditory meatus, and probably join the spinal tract of the trigeminal nerve to terminate in its nucleus. Connections are probably abolished through the central path of the trigeminal with the thalamus and somatic sensory area of the cortex for the conscious recognition of pulses. The descending fibers in the spinal tract of the trigeminal terminating in the nucleus of the tract probably establish relations through connecting neurons with motor nuclei in the anterior column of the spinal cord and with motor nuclei of the medulla.

2) The sympathetic afferent fibers are usually described as terminating in the dorsal nucleus of the vagus and glossopharyngeal. Some thoracic, however, believe they join the tractus solitarius and terminate in its nucleus. These afferent fibers convey impulses from the heart, the aorta, and probably from the stomach, esophagus and respiratory tract. Their terminals in the dorsal nucleus come into relation with neurons of axons probably descend into the spinal cord, conveying impulses to the motor nuclei supplying fibers to the muscles of respiration, i.e., the phrenic nerve and the nerves to the intercostal and levatores costarum muscles. Other axons probably convey vasmotor impulses to sympathetic efferent neurons throughout the spinal cord. The dorsal nucleus (nucleus of the ala cinerea) and the posterior continuation of the commissural nucleus of the ala cinerea constitute probably the so-called respiratory and vaso-motor center of the medulla. The shorter efferent neurons of the dorsal nucleus probably effect connections either directly or indirectly with motor cells of the vagus itself and other cranial nerves.

3) Taste fibers conducting impulses from the epiglottis and larynx are supposed to pass in the vagus and to join the tractus solitarius, finally minating in the nucleus of the tractus solitarius. It is not certain that this nucleus represents the primary terminal center for taste and some thors maintain that the taste fibers terminate in the dorsal nucleus. The secondary ascending pathways from the primary gustatory nucleus to the cortex as well as the location of the cortical center for taste are unknown. A gustatory center has been described near the anterior end of the temporal lobe. The nucleus of the tractus solitarius is connected with motor centers of the pons, medulla and spinal cord for the reactions of stiction and swallowing.

4) Somatic motor fibers to the cross striated muscles of the pharynx and larynx arise in the nucleus ambiguus. This nucleus undoubtedly receives either directly or indirectly collaterals or terminals from the opposite pyramidal tract controlling the voluntary movements of the arynx and larynx. The reflex pathways conveying impulses from the terminal sensory nuclei are unknown, but probably form part of the reticular formation constituting the reticular formation.

5) Sympathetic efferent fibers arise from cells in the dorsal nucleus (nucleus of the ala cinerea). These are preganglionic fibers of the
The sympathetic system and all terminate in sympathetic ganglia from which postganglionic fibers are distributed to various organs, i.e., motor fibers to the esophagus, stomach, small intestine, gallbladder, and to the lungs; inhibitory fibers to the heart; secretory fibers to the stomach and pancreas. The dorsal nucleus not only receives terminals of sympathetic afferent fibers for reflexes but undoubtedly receives terminals and collaterals from many other sources, but the exact pathways are at present unknown.

The Glossopharyngeal Nerve (IX cranial) is similar to the vagus nerve as regards its central connections and is usually described with it. It contains somatic sensory, sympathetic afferent, taste, somatic motor and sympathetic efferent fibers. The afferent sensory fibers arise from cells in the superior ganglion and in the petrosal ganglion. The same uncertainty exists concerning the nuclei of termination and nuclei of origin of the various components as for the vagus.

1) The somatic sensory fibers are few in number. Some are distributed with the auricular branch of the vagus to the external ear; others probably pass to the pharynx and fauces. They are supposed to join the spinal tract of the trigeminal and terminate in its nucleus. The connections are similar to those of the somatic sensory fibers of the vagus.

2) Sympathetic afferent fibers from the pharynx and middle ear are supposed to terminate in the dorsal nucleus. Connections are probably established with motor nuclei concerned in chewing and swallowing; very little is known, however, about the connections with other parts of the brain.

3) Taste fibers from the tongue probably terminate in the nucleus of the tractus solitarius. These fibers together with similar fibers from the facial (nervus intermedius) and the vagus are supposed to form the tractus solitarius and terminate in its nucleus. The central connections have been considered under the vagus.

4) Somatic motor fibers to the Stylopharyngeus muscle arise in the upper end of the nucleus ambiguus. The existence of these fibers in the glossopharyngeal is uncertain, as there are other paths by which such fibers might reach the glossopharyngeal from the vagus. The sources of impulses passing to the nucleus ambiguus are considered under the vagus.

5) Sympathetic efferent fibers (motor and secretory fibers) arise from the nucleus dorsalis. Some authors believe that the secretory fibers to the parotid gland arise from a distinct nucleus, the inferior salivatory nucleus, situated near the dorsal nucleus. The preganglionic fibers from this nucleus terminate in the otic ganglion; the postganglionic fibers from the otic ganglion pass to the parotid gland.

The Acoustic Nerve (VIII cranial) consists of two distinct nerves the cochlear nerve, the nerve of hearing, and the vestibular nerve, the nerve of equilibration.

Fig. 760– Terminal nuclei of the cochlear nerve, with their upper connections. (Schematic.) The vestibular nerve with its terminal nuclei and efferent fibers have been suppressed. On the other hand, in order not to obscure the trapezoid body, the efferent fibers of the terminal nuclei on the right side have been resected in a considerable portion of their extent. The trapezoid body, therefore, shows only one-half of its fibers, viz., those which come from the left. 1. Vestibular nerve, divided at its entrance into the medulla oblongata. 2. Cochlear nerve. 3. Accessory nucleus of acoustic nerve. 4. Tuberculum acusticum. 5. Efferent fibers of accessory nucleus. 6. Efferent fibers of tuberculum acusticum, forming the stria medullares, with 6’, their direct bundle going to the superior olivary nucleus of the same side; 6”, their decussating bundles going to the superior olivary nucleus of the opposite side. 7. Superior olivary nucleus. 8. Trapezoid body. 9. Trapezoid nucleus. 10. Central acoustic tract (laterallemniscus). 11. Raphé. 12. Cerebrospinal fasciculus. 13. Fourth ventricle. 14. Inferior peduncle. (Testut.) (See enlarged image)

The Cochlear Nerve arises from bipolar cells in the spiral ganglion of the cochlea; the peripheral fibers end in the organ of Corti, the central fibers bifurcate as they enter the cochlear nucleus; the short ascending branches end in the ventral portion of the nucleus, the longer descending branches terminate in the dorsal portion of the nucleus. From the dorsal portion of the cochlear nucleus axons arise which pass across the dorsal aspect of the inferior peduncle and the floor of the fourth ventricle, the stria medullares, to the median sulcus. Here they dip into the substance...
the pons, cross the median plane, and join the lateral lemniscus. Some of the fibers terminate in the superior olivary nucleus. The fibers of the nzerve fibers and the pyramid bundles. The axons come from the dorsal and ventral portions of the cochlear nucleus. After crossing the shé, where they decussate with those from the opposite side, they turn upward to form the lateral lemniscus. Fibers from the striæ medullares ntribute to the trapezoid body, in addition it sends terminals or collaterals to and receives axons from the superior olivary nucleus, the nucleus the trapezoid body, the lateral preolivary or semilunar nucleus and the mesial preolivary nucleus.

**The trapezoid body** consists of horizontal fibers in the ventral part of the formatio reticularis of the lower part of the pons behind its deep as the superficial white layer ascend through the inferior brachium to the medial geniculate body. Others mainly from the nuclei of the opposite side. Numerous small masses of cells are scattered along the path of the lateral lemniscus and probably join the trapezoid body of the opposite side. Other fibers from the ventral portion of the cochlear clews pass dorsal to the inferior peduncle and then dip into the substance of the pons to join the trapezoid body or the superior olivary nucleus the same side. From the superior olivary nucleus of the same and opposite sides axons join the lateral lemniscus. Collaterals and probably mninals also pass from the lateral lemniscus to other nuclei in its path and receive in turn axons from these nuclei. They are the accessory clews, the medial preolivary nucleus, the lateral preolivary or semilunar nucleus and the nucleus of the lateral lemniscus.

**The cochlear nucleus**, the terminal nucleus for the nerve of hearing, is usually described as consisting of a larger dorsal nucleus on the dorsal lateral aspect of the inferior peduncle forming a prominent projection, the *acoustic tubercle*, and a ventral or accessory cochlear nucleus more ventral to the inferior peduncle. The two nuclei are continuous and are merely portions of one large nucleus. The axons from cells of the dorsal ganglion of the cochlear nerve on reaching the nucleus divide into ascending and descending branches which enter the ventral and dorsal nuclei respectively. A central large fusiform cells of the dorsal nucleus pass partly by way of the striæ medullares to the trapezoid body lateral lemniscus and the nuclei associated with the former, and partly transversely beneath the inferior peduncle and spiral tract of the semilunar to the trapezoid body. Axons from the ventral cochlear nucleus pass partly by the striæ medullares but for the most part horizontally the trapezoid body.

**The superior olivary nucleus** is a small mass of gray matter situated on the dorsal surface of the lateral part of the trapezoid body. Some of its axons pass backward to the abducent nucleus, this bundle is known as the *peduncle of the superior olivary nucleus*. Other fibers from the clues join the posterior longitudinal bundle and terminate in the nuclei of the trochlear and oculomotor nerves. The majority of its axons, after passing to the nucleus itself join the lateral lemniscus of the same side, other axons pass in the trapezoid body toward the ventral portion of the cochlear nucleus.

**The nucleus of the trapezoid body** lies between the root fibers of the abducent nerve and the superior olivary nucleus. Its cells lie among the fibers of the trapezoid body. In it terminate fibers and collaterals of the trapezoid body which come from the cochlear nucleus of the opposite side. The same is the case with the opposite trapezoid nucleus. They terminate in the nucleus of the trapezoid body in diffuse arborizations and cular end plaques or acoustic calyces of yellowish color which fuse with the cell bodies. Its cells are round and of medium size; their axons into the trapezoid body, cross the median line and probably join the lateral fillet.

**The lateral preolivary or semilunar nucleus** lies ventral to the superior olivary nucleus. In it end terminals and collaterals of the trapezoid body and probably fibers of the accessory cochlear nucleus. Its axons mingle with the trapezoid body and join the lateral fillet.

**The mesial preolivary nucleus** is in contact with the ventral side of the nucleus of the trapezoid body. It receives many collaterals from the pons. Its cells are smaller than those of the trapezoid nucleus, their axons join the lateral fillet.

**The lateral lemniscus** (*lateral fillet*), the continuation upward of the central path of hearing, consists of fibers which come from the cochlear clei of the same and the opposite side by way of the trapezoid body and from the preolivary nuclei. It lies in the ventral or ventro-lateral part of the formatio reticularis of the pons, at first ventral then lateral to the median fillet. Above the pons these ascending fibers come to the surface the side of the reticular formation in the trigonum lemnisci and are covered by a layer of ependyma. This part of the lateral lemniscus is known the *fillet of Reil*. On reaching the level of the inferior colliculus the dorsal fibers which overlie the superior peduncle decussate in the velum dularia anterius with similar fibers of the opposite side. Numerous small masses of cells are scattered along the path of the lateral lemniscus to the superior olivary nucleus and constitute *lower and upper nuclei of the lateral lemniscus*. They are supplied with many collaterals and sibly terminals from the fibers of the lemniscus. The axons of the lower nucleus of the lateral lemniscus, which arise from the larger stellate spindle-shaped cells, with long, smooth, much branched dendrites, are said by some authors to join the lateral lemniscus, but according to others they pass medially toward the raphé; their termination is unknown. The cells of the upper nucleus of the lateral lemniscus are more numerous. The same uncertainty exists in regard to their termination.

Fibers of the lateral lemniscus end by terminals or collaterals in the inferior colliculus and the medial geniculate body. A few of the fibers said to pass by the inferior colliculus to terminate in the middle portion of the stratum griseum of the superior colliculus, and are probably concerned with reflex movements of the eyes depending on acoustic stimuli.

**The inferior colliculi** (*lower or posterior quadrigeminal bodies*) are important auditory reflex centers. Each consists of a compact nucleus of my matter covered by a superficial white layer and separated from the central gray matter about the aqueduct by a thin, deep, white layer. Many of the axons which appear in the superficial white layer ascend through the inferior brachium to the medial geniculate body. Others mainly from the cells in the dorso-mesial part of the nucleus pass through the deep white layer into the tegmentum of the same and the opposite side and...
Their termination is unknown, but they probably constitute an auditory reflex path to the lower motor centers, perhaps descending into the spinal cord with the tectospinal fasciculus. Other axons are said to descend in the lateral lemniscus to the various nuclei in the auditory pathway and probably to motor nuclei of the medulla and spinal cord.

The medial geniculate body receives terminals and collaterals from the lateral lemniscus (the central auditory path) and also large numbers of axons from the inferior colliculus of the same side and a few from the opposite side. It is thus a station in the central auditory path. A large portion of its axons pass forward beneath the optic tract to join the corona radiata and then sweep backward and lateralward as the auditory radiation to terminate in the cortex of the superior temporal gyrus. V. Monakow holds that Golgi cells type II are interpolated between the terminations of the incoming fibers to the medial geniculate body and the cells located there which give rise to the fibers of the auditory radiation. The medial geniculate bodies are united by the long, slender commissure of Gudden. These fibers join the optic tract as it passes over the edge of the medial geniculate and passes through the posterior part of the optic chiasma. It is probably a commissure connected with the auditory system.

The Vestibular Nerve (vestibular root, VIII cranial) arise from the bipolar cells in the vestibular ganglion (Scarpa’s ganglion). The peripheral fibers end in the semicircular canals, the sacculus and the utricle, the end-organs concerned with mechanism for the maintenance of bodily equilibrium. The central fibers enter the medulla oblongata and pass between the inferior peduncle and the spinal tract of the trigeminal. They bifurcate into ascending and descending branches as do the dorsal root fibers of all the spinal nerves and all afferent cranial nerves. The descending branches terminate in the dorsal (medial) vestibular nucleus, the principal nucleus of the vestibular nerve. This nucleus is prolonged downward into a descending portion in which end terminals and collaterals of the descending branch. The ascending branches pass to Deiters’s nucleus, to Bechterew’s nucleus and through the inferior peduncle of the cerebellum to the nucleus tecti of the opposite side. The dorsal vestibular nucleus (medial or principal nucleus) is a large mass of small cells in the floor of the fourth ventricle under the area acustica, located partly in the medulla and partly in the pons. The striæ medullares cross the upper part of it. It is separated from the median plane by the nucleus intercalatus. Its axons pass into the posterior longitudinal bundle of the same and the opposite side and ascend to terminate in the nucleus abducens of the same side and in the trochlear nucleus and the oculo-motor nucleus of the opposite side, and to the motor nuclei of the trigeminal on both sides. The descending portion, the nucleus of the descending tract extends downward as far as the upper end of the nucleus gracilis, and the decussation of the medial lemniscus. It is sometimes called the inferior vestibular nucleus. Many of its axons cross the midline and probably ascend with the medial lemniscus to the ventro-lateral region of the thalamus.


The lateral vestibular nucleus (Deiters’s nucleus) is the continuation upward and lateralward of the principal nucleus, and in it terminate many of the ascending branches of the vestibular nerve. It consists of very large multiglomerular cells whose axons form an important part of the posterior longitudinal bundle of the same and the opposite side. The axons bifurcate as they enter the posterior longitudinal bundle, the ascending branches send terminals and collaterals to the motor nuclei of the abducens, trochlear and oculomotor nerves, and are concerned in coordinating movements of the eyes with alterations in the position of the head; the descending branches pass down in the posterior longitudinal bundle to the anterior funiculus of the spinal cord as the vestibulospinal fasciculus (anterior marginal bundle) and are distributed to motor nuclei of the
terior column by terminals and collaterals. Other fibers are said to pass directly to the vestibulospinal fasciculus without passing into the sterior longitudinal bundle. The fibers which pass into the vestibulospinal fasciculus are intimately concerned with equilibratory reflexes. her axons from Deiters’s nucleus are supposed to cross and ascend in the opposite medial lemniscus to the ventro-lateral nuclei of the dansus; still other fibers pass into the cerebellum with the inferior peduncle and are distributed to the cortex of the vermis and the roof nuclei the cerebellum; according to Cajal they merely pass through the nucleus fastigii on their way to the cortex of the vermis and the hemisphere.

The superior vestibular nucleus (Bechterew’s nucleus) is the dorso-lateral part of the vestibular nucleus and receives collaterals and terminals on the ascending branches of the vestibular nerve. Its axons terminate in much the same manner as do those from the lateral nucleus.

The Facial Nerve (VII cranial) consists of somatic sensory, sympathetic afferent, taste, somatic motor and sympathetic efferent fibers. The efferent or sensory fibers arise from cells in the geniculate ganglion. This portion of the nerve is often described as the nervus intermedius.

1) The somatic sensory fibers are few in number and convey sensory impulses from the middle ear region. Their central termination is likewise uncertain, it is possible that they join the spinal tract of the trigeminal as do the somatic sensory ers of the vagus and glossopharyngeal.

2) The sympathetic afferent fibers are likewise few in number and of unknown termination.

3) Taste fibers convey impulses from the anterior two-thirds of the tongue via the chorda tympani. They are supposed to join the tractus itarius and terminate in its nucleus. The central connections of this nucleus have already been considered.

4) Somatic motor fibers, supplying the muscles derived from the hyoid arch, arise from the large multipolar cells of the nucleus of the facial rve. This nucleus is serially homologous with the nucleus ambiguus and lateral part of the anterior column of the spinal cord. Voluntary pulses from the cerebral cortex are conveyed by terminals and collaterals of the pyramidal tract of the opposite side, indirectly, that is with the erpolation of a connecting neuron, to the facial nucleus. This nucleus undoubtedly receives many reflex fibers from various sources, i.e., from superior colliculus via the ventral longitudinal bundle (tectospinal fasciculus) for optic reflexes; from the inferior colliculus via the auditory lex path; and indirectly from the terminal sensory nuclei of the brain-stem. Through the posterior longitudinal bundle it is intimately excited with other motor nuclei of the brain-stem.

5) Sympathetic efferent fibers (preganglionic fibers) arise according to some authors from the small cells of the facial nucleus, or according others from a special nucleus of cells scattered in the reticular formation, dorso-medial to the facial nucleus. This is sometimes called superior salivatory nucleus. These preganglionic fibers are distributed partly via the chorda tympani and lingual nerves to the submaxillary nglion, thence by postganglionic (vasodilator) fibers to the submaxillary and sublingual glands. Some of the preganglionic fibers pass to the xenopalatine ganglion via the great superficial petrosal nerve.

The Abducens Nerve (VI cranial) contains somatic motor fibers only which supply the lateral rectus muscle of the eye. The fibers arise from nucleus of the abducens nerve and pass ventrally through the formatio reticularis of the pons to emerge in the transverse groove between the adal edge of the pons and the pyramid. The nucleus is serially homologous with the nuclei of the trochlear and oculomotor above and with the poglossal and medial part of the anterior column of the spinal cord below. It is situated close to the floor of the fourth ventricle, just above the strie medullares. Voluntary impulses from the cerebral cortex are conducted by the pyramidal tract fibers (corticopontine fibers).

ese fibers probably terminate in relation with association neurons which control the coordinated action of all the eye muscles. This association d coördination mechanism is interposed between the terminals and collaterals of the voluntary fibers and the neurons within the nuclei of the motor fibers to the eye muscles. The fibers of the posterior longitudinal bundle are supposed to play an important role in the ordination of the movements of the eyeball. Whether it is concerned only with coördinations between the vestibular apparatus and the eye or th more extensive co-ordinations is unknown. Many fibers of the posterior longitudinal bundle have their origin in the terminal nuclei of the stibular nerve and from the posterior longitudinal bundle many collaterals and terminals are given off to the abducens nucleus as well as to the chlear and oculomotor nuclei. The abducens nucleus probably receives collaterals and terminals from the ventral longitudinal bundle (ospinal fasciculus); fibers which have their origin in the superior colliculus, the primary visual center, and are concerned with visual lexes. Others probably come from the reflex auditory center in the inferior colliculus and from other sensory nuclei of the brain-stem.

The Trigeminal Nerve (V cranial) contains somatic motor and somatic sensory fibers. The motor fibers arise in the motor nucleus of the germal and pass ventro-laterally through the pons to supply the muscles of mastication. The sensory fibers arise from the unipolar cells of the nilunar ganglion; the peripheral branches of the T-shaped fibers are distributed to the face and anterior two-thirds of the head; the central ers pass into the pons with the motor root and bifurcate into ascending and descending branches which terminate in the sensory nuclei of the germal.

The motor nucleus of the trigeminal is situated in the upper part of the pons beneath the lateral angle of the fourth ventricle. It is serially mologous with the facial nucleus and the nucleus ambiguus (motor nucleus of the vagus and glossopharyngeal) which belong to the motor clei of the lateral somatic group. The axons arise from large pigmented multipolar cells. The motor nucleus receives reflex collaterals and minals, (1) from the terminal nucleus of the trigeminal of the same and a few from the opposite side, via the central sensory tract igmenothalamic tract); (2) from the mesencephalic root of the trigeminal; (3) from the posterior longitudinal bundle; (4) and probably from ers in the formatio reticularis. It also receives collaterals and terminals from the opposite pyramidal tract (corticopontine fibers) for voluntary vements. There is probably a connecting or association neuron interposed between these fibers and the motor neurons.

The terminal sensory nucleus consists of an enlarged upper end, the main sensory nucleus, and a long more slender descending portion.
ich passes down through the pons and medulla to become continuous with the dorsal part of the posterior column of the gray matter especially of substantia gelatinosa of the spinal cord. This descending portion consists mainly of substantia gelatinosa and is called the nucleus of the central tract of the trigeminal nerve.

The main sensory nucleus lies lateral to the motor nucleus beneath the superior peduncle. It receives the short ascending branches of the sensory root. The descending branches which form the tractus spinalis, pass down through the pons and medulla on the lateral side of the nucleus of the tractus spinalis, in which they end by collaterals and terminals, into the spinal cord on the level of the second cervical segment. It decreases rapidly in size as it descends. At first it is located between the emergent part of the facial nerve and the vestibular nerve, in between the nucleus of the facial nerve and the inferior peduncle. Lower down in the upper part of the medulla it lies beneath the inferior diencephalon and is broken up into bundles by the olivocerebellar fibers and the roots of the ninth and tenth cranial nerves. Finally it comes to the face of the medulla under the tubercle of Rolando and continues in this position lateral to the fasciculus cuneatus as far as the upper part of the cervical region where it disappears.

The cells of the sensory nucleus are of large and medium size and send their axons into the formatio reticularis where they form a distinct bundle, the central path of the trigeminal (trigeminothalamic tract), which passes upward through the formatio reticularis and tegmentum to the ventro-lateral part of the thalamus. Most of the fibers cross to the trigeminothalamic tract of the opposite side. This tract lies dorsal to the diencephalon; approaches close to it in the tegmentum and terminates in a distinct part of the thalamus. From the thalamus impulses are conveyed to the somatic sensory area of the cortex by axons of cells in the thalamus through the internal capsule and corona radiata. Many collaterals are given off in the medulla and pass from the trigeminothalamic tract to the motor nuclei, especially to the nucleus ambiguus, the facial nucleus and the motor nucleus of the trigeminal.

The somatic sensory fibers of the vagus, the glossopharyngeal and the facial nerves probably end in the nucleus of the descending tract of the genticulomesencephalic tract and their cortical impulses are probably carried up in the central sensory path of the trigeminal.

The mesencephalic root (descending root of the trigeminal) arises from unipolar cells arranged in scattered groups in a column at the lateral edge of the central gray matter surrounding the upper end of the fourth ventricle and the cerebral aqueduct. They have usually been considered as motor fibers that join the motor root, but Johnston claims that they join the sensory root of the trigeminal, that they develop in the alar, not in the sal lamina, and that the pear-shaped unipolar cells are sensory in type.

The Trochlear nerve (IV cranial) contains somatic motor fibers only. It supplies the superior oblique muscle of the eye. Its nucleus of origin, the trochlear nucleus, is a small, oval mass situated in the ventral part of the central gray matter of the cerebral aqueduct at the level of the per part of the inferior colliculus. The axons from the nucleus pass downward in the tegmentum toward the pons, but turn abruptly dorsalward before reaching it, and pass into the superior medullary velum, in which they cross horizontally, to decussate with the nerve of the opposite side, from the surface of the velum, immediately behind the inferior colliculus. The cells of the trochlear nucleus are large, irregular and llowish in color. The nuclei of the two sides are separated by the raphé through which dendrites extend from one nucleus to the other. They give many collaterals and terminals from the posterior longitudinal bundle which lies on the ventral side of the nucleus.

Here are no branches from the fibers of the pyramidal tracts to these nuclei; the volitional pathway must be an indirect one, as is the case with the motor nuclei.

The Oculomotor nerve (III cranial) contains somatic motor fibers to the Obliquus inferior, Rector inferior, Rectus superior, Levator palpebrae superioris and Rectus medialis muscles and sympathetic efferent fibers (preganglionic fibers) to the ciliary ganglion. The postganglionic fibers connected with these supply the ciliary muscle and the sphincter of the iris. The axons arise from the nucleus of the oculomotor nerve and pass in the trigeminothalamic tract to the motor nucleus, the red nucleus and the medial margin of the substantia nigra in a series of rves and finally emerge from the oculomotor sulcus on the medial side of the cerebral peduncle.

The oculomotor nucleus lies in the gray substance of the floor of the cerebral aqueduct subjacent to the superior colliculus and extends in front of the aqueduct a short distance into the floor of the third ventricle. The inferior end is continuous with the trochlear nucleus. It is from 6 to 10 m. in length. It is intimately related to the posterior longitudinal bundle which lies against its ventro-lateral aspect and many of its cells lie along the fibers of the posterior longitudinal bundle. The nucleus of the oculomotor nerve contains several distinct groups of cells which differ in size and appearance from each other and are supposed to send their axons each to a separate muscle. Much uncertainty still exists as to which supply which muscle. There are seven of these groups or nuclei on either side of the midline and one medial nucleus. The cells of the two nuclei are smaller and are supposed to give off the sympathetic efferent axons. The majority of fibers arise from the nucleus of the same side, however, cross from the opposite side and are supposed to supply the Rectus medialis muscle. Since oculomotor and abducens nuclei are intimately connected by the posterior longitudinal bundle this decussation of fibers to the Medial rectus may facilitate the conjugate movements of the eyes in which the Medial and Lateral recti are especially involved.

Any collaterals and terminals are given off to the oculomotor nucleus from the posterior longitudinal bundle and thus connect it with the stibular nucleus, the trochlear and abducens nuclei and probably with other cranial nuclei. Fibers from the visual reflex center in the superior lliculus pass to the nucleus. It is also connected with the cortex of the occipital lobe of the cerebrum by fibers which pass through the optic tract. The pathway for voluntary motor impulses is probably similar to that for the abducent nerve.

The Optic Nerve or Nerve of Sight (II cranial) consists chiefly of coarse fibers which arise from the ganglionic layer of the retina. They constitute the third neuron in the series composing the visual path and are supposed to convey only visual impressions. A number of fine fibers
o pass in the optic nerve from the retina to the primary centers and are supposed to be concerned in the pupillary reflexes. There are in addition a few fibers which pass from the brain to the retina; they are supposed to control chemical changes in the retina and the movements of pigment cells and cones. Each optic nerve has, according to Salzer, about 500,000 fibers.

Fig. 762–Figure showing the different groups of cells, which constitute, according to Perlia, the nucleus of origin of the oculomotor nerve. 1. Posterior dorsal nucleus. 1’. Posterior ventral nucleus. 2. Anterior dorsal nucleus. 2’. Anterior ventral nucleus. 3. Central nucleus. 4. Nucleus of Edinger and Westphal. 5. Antero-internal nucleus. 6. Antero-external nucleus. 8. Crossed fibers. 9. Trochlear nerve, with 9’, its nucleus of origin, and 9”, its decussation. 10. Third ventricle. M, M. Median line. (Testut.) (See enlarged image)

In the optic chiasma the nerves from the medial half of each retina cross to enter the opposite optic tract, while the nerves from the lateral half of each retina pass into the optic tract of the same side. The crossed fibers tend to occupy the medial side of each optic nerve, but in the chiasma they are more intermingled. The optic tract is attached to the tuber cinereum and lamina terminalis and also to the cerebral peduncle as it crosses obliquely over its under surface. These are not functional connections. A small band of fibers from the medial geniculate body joins the optic tract as the latter passes over it and crosses to the opposite tract and medial geniculate body in the posterior part of the chiasma. This is the commissure of Gudden and is probably connected with the auditory system.

Most of the fibers of the optic tract terminate in the lateral geniculate body, some pass through the superior brachium to the superior colliculus, others either pass over or through the lateral geniculate body to the pulvinar of the thalamus. These end-stations are often called the primary visual centers.

The lateral geniculate body consists of medium-sized pigmented nerve cells arranged in several layers by the penetrating fibers of the optic tract. Their axons pass upward beneath the longer fibers of the optic tract, the tænia semicircularis, the caudate nucleus and the posterior horn of the lateral ventricle where they join the optic radiation of Gratiolet. They pass backward and medially to terminate in the visuo-sensory cortex in the immediate neighborhood of the calcarine fissure of the occipital lobe. This center is connected with the one in the opposite side by minissural fibers which course in the optic radiation and the splenium of the corpus callosum. Association fibers connect it with other regions of the cortex of the same side.
he region of the pulvinar in which optic tract fibers terminate resembles in structure the lateral geniculate body. Its axons also have a similar course though in a somewhat more dorsal plane.

he superior colliculus receives fibers from the optic tract through the superior brachium. Some enter by the superficial white layer (stratum nasal), others appear to dip down into the gray cap (stratum cinereum) while others probably decussate across the midline to the opposite lliculus. Other fibers from the superior brachium pass into the stratum opticum (upper gray-white layer). Some of these turn upward into the cap while others terminate among the cells of this layer. Since the superior colliculi appear to be the central organs concerned in the control of eye-muscle movements and eye-muscle reflexes we should expect to find them receiving fibers from other sensory paths. Many fibers pass to the superior colliculus from the medial fillet as the latter passes through the tegmentum bringing the superior colliculus into relation with the sensory fibers of the spinal cord. Fibers from the central sensory path of the trigeminal probably pass with these. Part of the ventral occipitocerebellar tract (Gowers) is said to pass up through the reticular formation of the pons and mid-brain toward the superior colliculus and the diencephalon. The superior colliculus is intimately connected with the central auditory path (the lateral lemniscus), as part of its fibers pass the superior colliculus and terminate in the superior colliculus. They are probably concerned with reflex movements of the eyes depending on auditory stimuli. The superior colliculus is said to receive fibers from the stria medullaris thalamus of the opposite side which pass through the commissura habenulæ and turn back to the roof of the mid-brain, especially to the superior colliculus. By this path both the primary and cortical auditory centers are brought into relation with the eye-muscle reflex apparatus.

he fibers which pass to the nuclei of the eye muscles arise from large cells in the stratum opticum and stratum lemnisci and pass around the ventral aspect of the central gray matter where most of them cross the midline in the fountain decussation of Meynert, and then turn downward to form the ventral longitudinal bundle. This bundle runs down partly through the red nucleus, in the formatio reticularis, ventral to the posterior tectal bundle of the mid-brain, pons and medulla oblongata into the ventral funiculus of the spinal cord where it is known as the tectospinal fasciculus. Some of the fibers are said to pass down with the rubrospinal tract in the lateral funiculus. Some fibers do not pass but pass down in the ventral longitudinal bundle of the same side on which they arise unless possibly they come from the opposite lliculus over the aqueduct. From the ventral longitudinal bundle collaterals are given off to the nuclei of the eye muscles, the oculomotor, the trochlear and the abducens. Many collaterals pass to the red nucleus, and are probably concerned with the reflexes of the rubrospinal tract. The fibers of the tectospinal tract end by collaterals and terminals either directly or indirectly among the motor cells in the anterior column of the spinal cord.

he superior colliculus receives fibers from the visual sensory area of the occipital cortex; they pass in the optic radiation. Probably no fibers pass from the superior colliculus to the visual sensory cortex.

he Olfactory Nerves (I cranial) or nerves of smell arise from spindle-shaped bipolar cells in the surface epithelium of the olfactory region of the nasal cavity. The non-medullated axons pass upward in groups through numerous foramina in the cribriform plate to the olfactory bulb; here axonal fibers, each ending in a tuft of terminal filaments, come into relation with the brush-like end of a single dendrite from a mitral cell. This...
erlacing gives rise to the olfactory glomeruli of the bulb. The termination of several or many olfactory fibers in a single glomerulus where
they form synapses with the dendrites of one or two mitral cells provides for the summation of stimuli in the mitral cells and accounts in part at
least for the detection by the olfactory organs of very dilute solutions. Lateral arborizations of the dendrites of the mitral cells and the connection
neighboring glomeruli by the axons of small cells of the glomeruli and the return of impulses of the mitral cells by collaterals either directly or
through the interpolation of granule cells to the dendrites of the mitral cells reinforce the discharge of the mitral cells along their axons. The
axons turn abruptly backward in the deep fiber layer of the bulb to form the olfactory tract. The olfactory tract is continued into the olfactory
bulb, just in front of the anterior perforated substance. The axons of the mitral cells on reaching the olfactory trigone separate into three
des, the lateral olfactory stria, the medial olfactory stria and the less marked intermedial olfactory stria.

he lateral olfactory stria curve lateralward, a few of the fibers end in the olfactory trigone and the antero-lateral portion of the anterior
perforated substance. Most of the fibers, however, pass into the uncus, the anterior end of the hippocampal gyrus, and there end in the
complicated cortex of the hippocampal gyri. The lateral stria more or less disappear as they cross the antero-lateral region of the anterior
perforated substance.

he greater mass of the fibers of the olfactory tract pass into the lateral stria. Numerous collaterals are given into the plexiform layer of the
frontal cortex, over which the stria pass on their way to the uncus, where they intermingle with the apical dendrons of the medium-sized and
all pyramidal cells of the pyramidal layer of this subfrontal or frontal olfactory cortex. The axons give rise to projection fibers which take an
tero-posterior direction to the subthalamic region sending collaterals and terminal branches to the stria medullaris and others toward the
thalamus. Some of the fibers extend farther back and are believed to reach the pons and medulla oblongata.

ost of the fibers of the lateral olfactory stria pass to the hippocampal region of the cortex, especially to the gyrus hippocampi, which may be

arded as the main ending place of the secondary olfactory path derived from axons of the mitral cells.

he fibers of the medial olfactory stria terminate for the most part in the parolfactory area (Broca’s area), a few end in the subcallosal gyrus
and a few in the anterior perforated substance and the adjoining part of the septum pellucidum. Some of the fibers pass into the anterior

mammillary (pars olfactoria) to the olfactory tract of the opposite side where they end partly within the granular layer and partly in the
neighborhood of the glomeruli of the olfactory bulb, thus connecting the bulbs of the two sides.

he intermediate olfactory stria are as a rule scarcely visible, the fibers terminate in the anterior perforated substance, a few are said to
ntinue to the uncus.

he trigonum olfactorium, anterior perforated substance and the adjoining part of the septum pellucidum are important primary olfactory
structures, especially for olfactory reflexes; in these centers terminate many axons from the mitral cells of the olfactory bulb. In addition the gray
stance of the olfactory tract and the gyrus subcallosus receive terminals of the mitral cells.

he pathways from these centers to lower centers in the brain-stem and spinal cord are only partially known. The most direct path, the tractus
actomesencephalicus (basal olfactory bundle of Wallenburg), is supposed to arise from cells in the gray substance of the olfactory tract, the
‘actor trigone, the anterior perforated substance and the adjoining part of the septum pellucidum. The fibers are said to pass direct to the tuber
ereum, to the corpus mammillare, to the brainstem and the spinal cord. The fibers which enter the mammillary body probably come into
action with cells whose axons give rise to the fasciculus mammillo-tegmentalis (mammillo-tegmental bundle of Gudden) which is supposed to
d in the gray substance of the tegmentum and of the aqueduct; some of its fibers are said to join the posterior longitudinal bundle and others to
tend as far as the reticular formation of the pons.

one of the fibers of the medial olfactory stria came into relation with cells in the parolfactory area of Broca and in the anterior perforated
stance, whose axons course in the medullary stria of the thalamus. As the axons pass through the lower part of the septum pellucidum they
join by other fibers whose cells receive impulses from the mitral cells. These fibers of the medullary stria end for the most part in the
bunlar nucleus of the same side, some, however, cross in the habenular commissure (dorsal part of the posterior commissure) to the habenular
clesus of the opposite side. A few fibers of the medullary stria are said to pass by the habenular nucleus to the roof of the mid-brain, especially
in superior colliculus, while a few others come into relation with the posterior longitudinal bundle and association tracts of the mesencephalon.

he ganglion of the habenule located in the trigonum habenulae just in front of the superior colliculus contains a mesial nucleus with small cells
d a lateral nucleus with larger cells. The axons of these cells are grouped together in a bundle, the fasciculus retroflexus of Meynert, which
sses ventrally medial to the red nucleus and terminates in a small medial ganglion in the substantia perforata posterior, immediately in front of
pons, called the interpeduncular ganglion.

he interpeduncular ganglion has rather large nerve cells whose axons curve backward and downward as the tegmental bundle of
Schütz, to end partly in the dorsal tegmental nucleus and surrounding gray substance where they come into relation with association neurons
d the dorsal longitudinal bundle of Schütz.

he majority of the axons that arise from the mitral cells of the olfactory bulb and course in the olfactory tract course in the lateral olfactory
tract to the uncus and hippocampal gyrus, and terminate in the cortex. Other fibers probably pass to the uncus and hippocampal gyrus from the
mary olfactory centers in the trigonum and anterior perforated substance. The gyrus hippocampus is continued through the isthmus into the
cus cinguli which passes over the corpus callosum to the area parolfactoria. The cortical portions of these gyri are connected together by a
ck association bundle, the cingulum, that lies buried in the depth of the gyrus cinguli extending forward to the parolfactory area and backward
the hippocampal region. The axons from the gyrus cinguli pass into the cingulum, many of them bifurcate, the anterior branches together
The descending fasciculi which convey impulses from the higher centers to the spinal cord and located in the lateral and ventral funiculi. These gyri constitute the vertical center for smell.

The **dentate gyrus** which may be considered as a modified part of the hippocampus is partially separated from the gyrus hippocampus by the hippocampal fissure and from the fimbria by the fimbrio-dentate sulcus; it is intimately connected with the hippocampal gyrus and the hippocampus. When followed backward the dentate gyrus separates from the fimbria at the splenium, loses its incisions and knobs, and as the **insula cinerea** passes over the splenium onto the dorsal surface of the corpus callosum and spreads out into a thin layer of gray substance own as the **indusium**, which can be traced forward around the genu of the corpus callosum into the gyrus subcallosum. The white matter of the lusium known as the **medial longitudinal striae** (nerves of Lancisi) and the **lateral longitudinal striae**, are related to the indusium somewhat the cingulum is to the gyrus cinguli. Axons from the indusium pass into the longitudinal striae, some running forward and others backward till some after entering the medial longitudinal stria, pierce the corpus callosum to join the fornix. Some of the fibers which pass forward tend around the front of the corpus callosum and the anterior commissure, then curve downward, according to Cajal, to enter the corpus icatum where they join the olfactory projection-path. Other fibers are said to arise in the parolfactory area, the **gyrus subcallosum** and the **anterior perforated substance** (diagonal band of Broca) and course backward in the longitudinal striae to the dentate gyrus and the hippocampal region. The indusium is usually considered as a rudimentary part of the rhinencephalon.

The **olfactory projection fibers** which arise from the pyramid cells of the uncus and hippocampus and from the polymorphic cells of the nate gyrus form a dense stratum on the ventricular surface, especially on the hippocampus, called the **alveus**. These fibers pass over into the **fimbria** and are continued into the **fornix**. About one-fourth of all the fibers of the fimbria are large projection fibers, the other three-fourths consist of fine commissural fibers which pass from the hippocampus of one side through the fimbria and **hippocampal commissure** (ventral alterium or lyre), to the fimbria and hippocampus of the opposite side where they penetrate the pyramidal layer and terminate in the stratum liatium. The fibers which course in the fornix pass forward and downward into the corpora mammillare where numerous collaterals are given and a few terminate. Most of the fibers in the fornix, however, pass through the corpora, cross the middle line and turn downward in the icular formation in which they are said to be traceable as far as the pons and possibly farther. As the fornix passes beneath the corpus callosum receives fibers from the longitudinal striae of the indusium and from the cingulum; these are the perforating fibers of the fornix which pass around the corpus callosum and course in the fornix toward the mammillary body. As the fornix passes the anterior end of the thalamus a few fibers are given off to the stria medullaris of the thalamus and turn back in the stria to the habenular ganglion of the same and the opposite side, ving probably the same relation that the reflex fibers have which arise from the primary centers and course in the stria medullaries of the thalamus. Aside from the fibers of the fornix which pass through the mammillary body to decussate and descend (as the mammillo-thecampal fasciculus), many fibers are said to pass into the **bundle of Vicq d’Azyr**, and one bundle of fibers is said to pass from the fornix to the tuber cinereum.

The mammillary bodies receive collaterals and terminals then from the cortical centers via the fornix and probably other collaterals and minals are received directly from the primary centers through the tractus olfactomesencephalicus. According to Cajal fibers also reach the unmyillar body through the peduncle of the corpus mammillare from the arcuate fibers of the tegmentum and from the main fillet. The fornix obably brings the cortical centers into relation with the reflex path that runs from the primary centers to the mammillary body and the tuber cinereum.

The **bundle of Vicq d’Azyr** (mammillo-thalamic fasciculus) arises from cells in both the medial and lateral nuclei of the mammillary body and fibers that are directly continued from the fornix. There axons divide within the gray matter, the coarser branches pass into the anterior crus of the thalamus as the bundle of Vicq d’Azyr, the finer branches pass downward as the mammillo-tegmental bundle of Gudden. The bundle of Vicq d’Azyr spreads out fan-like as it terminates in the anterior or dorsal nucleus of the thalamus. A few of the fibers pass through the rnal nucleus to the angular nucleus of the thalamus. The axons from these nuclei are supposed to form part of the thalamocortical system.

The mammillo-tegmental bundle has already been considered under the olfactory reflex paths.

The **amygdaloid nucleus** and the **taenia semicircularis** (stria terminalis) probably belong to the central olfactory apparatus. The taenia nicicaricis extends from the region of the anterior perforated substance to the nucleus amygdale. Its anterior connections are not clearly derstood. Fibers are said to arise from cells in the anterior perforated substance; some of the fibers pass in front of the anterior commissure, ters join the fornix for a short distance as they pass behind the anterior commissure. The two strands ultimately join to form the taenia and ss backward in the groove between the caudate nucleus and the thalamus to the amygdaloid nucleus. Other fibers are said to pass in the posite direction from the amygdaloid nucleus to the thalamus.

**1F. Pathways from the Brain to the Spinal Cord**

e descending fasciculi which convey impulses from the higher centers to the spinal cord and located in the lateral and ventral funiculi. The **Motor Tract (Fig. 764)**, conveying voluntary impulses, arises from the pyramid cells situated in the motor area of the cortex, the anterior
nal and the posterior portions of the frontal gyri and the paracentral lobule. The fibers are at first somewhat widely diffused, but as they send through the corona radiata they gradually approach each other, and pass between the lentiform nucleus and thalamus, in the genu and terior two-thirds of the occipital part of the internal capsule; those in the genu are named the geniculate fibers, while the remainder constitute the cerebrospinal fibers; proceeding downward they enter the middle three-fifths of the base of the cerebral peduncle. The geniculate fibers pass the middle line, and end by arborizing around the cells of the motor nuclei of the cranial nerves. The cerebrospinal fibers are continued onward into the pyramids of the medulla oblongata, and the transit of the fibers from the medulla oblongata is effected by two paths. The fibers nearest to the anterior median fissure cross the middle line, forming the decussation of the pyramids, and descend in the opposite side of the medulla spinalis, as the lateral cerebrospinal fasciculus (crossed pyramidal tract). Throughout the length of the medulla spinalis fibers from the column pass into the gray substance, to terminate either directly or indirectly around the motor cells of the anterior column. The more laterally placed portion of the tract does not decussate in the medulla oblongata, but descends as the anterior cerebrospinal fasciculus (direct pyramidal tract); these fibers, however, end in the anterior gray column of the opposite side of the medulla spinalis by passing across in the anterior white commissure. There is considerable variation in the extent to which decussation takes place in the medulla oblongata; about two-thirds or three-fourths of the fibers usually decussate in the medulla oblongata and the remainder in the medulla spinalis.

The axons of the motor cells in the anterior column pass out as the fibers of the anterior roots of the spinal nerves, along which the impulses are conducted to the muscles of the trunk and limbs.

From this it will be seen that all the fibers of the motor tract pass to the nuclei of the motor nerves on the opposite side of the brain or medulla spinalis, a fact which explains why a lesion involving the motor area of one side causes paralysis of the muscles of the opposite side of the body. Further, it will be seen that there is a break in the continuity of the motor chain; in the case of the cranial nerves this break occurs in the nuclei of these nerves; and in the case of the spinal nerves, in the anterior gray column of the medulla spinalis. For clinical purposes it is convenient to emphasize this break and divide the motor tract into two portions: (1) a series of upper motor neurons which comprises the motor cells in the cortex and their descending fibers down to the nuclei of the cranial nerves; and in the case of the spinal nerves, in the anterior gray column of the medulla spinalis. The red nucleus is intimately related to the cerebellum by terminals and collaterals of the superior peduncle which arises in the dentate nucleus of the cerebellum, the rubrospinal fasciculus is supposed to be concerned with cerebellar reflexes, complex motor coordination necessary in locomotion and equilibrium. The afferent paths concerned in these reflexes have already been partly considered, namely, the dorsal and ventral spinocerebellar fasciculi, and probably some of the fibers of the posterior funiculi which reach the cerebellum by the inferior peduncle.
The tectospinal fasciculus arises from the superior colliculus of the roof (tectum) of the mid-brain. The axons come from large cells in the \textit{stratum opticum} and \textit{stratum lemnisci} and sweep ventrally around the central gray matter of the aqueduct, cross the \textit{raphé} in the \textit{fountain} decussation of Meynert and turn downward in the tegmentum in the ventral longitudinal bundle. Some of the fibers do not cross in the \textit{raphé} but pass down on the same side; it is uncertain whether they come from the superior colliculus of the same side or arch over the aqueduct from the \textit{colliculus} of the opposite side. The tectospinal fasciculus which comprises the major part of the ventral longitudinal bundle passes down through the \textit{tegmentum} and \textit{reticular formation} of the pons and medulla oblongata ventral to the \textit{medial longitudinal bundle}. In the medulla the two bundles are more or less intermingled and the tectospinal portion is continued into the \textit{ventral} longitudinal bundle of the spinal cord ventral to the \textit{rubrospinal fasciculus} with which some of its fibers are intermingled. Some of the fibers of the tectospinal fasciculus pass through the \textit{red nucleus} giving off collaterals to it, others are given off to the motor nuclei of the cranial nerves and in the spinal cord they terminate either directly or indirectly by terminals and collaterals among the nuclei of the anterior column. Since the superior colliculus is an important optic reflex center, this tract is probably concerned in optic reflexes; and possibly also with auditory reflexes since some of the fibers of the \textit{central auditory path}, the \textit{lateral lemniscus}, terminate in the superior colliculus.

The vestibulospinal fasciculus (part of the anterior marginal fasciculus or \textit{Loewenthal’s tract}) situated chiefly in the marginal part of the anterior funiculus is mainly derived from the cells of the terminal nuclei of the vestibular nerve, probably Deiters’s and Bechterew’s, and some of its fibers are supposed to come from the nucleus fastigius (roof nucleus of the cerebellum). The latter nucleus is intimately connected with \textit{Dieters’s} and \textit{Bechterew’s} nuclei. The vestibulospinal fasciculus is concerned with \textit{equilibratory} reflexes. Its terminals and collaterals end about the motor cells in the anterior column. It extends to the sacral region of the cord. Its fibers are intermingled with the \textit{ascending spinothalamic} fasciculus, with the anterior proper fasciculus and laterally with the tectospinal fasciculus. Its fibers are supposed to be both crossed and uncrossed. In the brain-stem it is associated with the dorsal longitudinal bundle.

The pontospinal fasciculus (\textit{Bechterew}) arises from the cells in the reticular formation of the pons from the same and the opposite side and is associated in the brain-stem with the ventral longitudinal bundle. In the cord it is intermingled with the fibers of the vestibulospinal fasciculus in the anterior funiculus. Not much is known about this tract.

Here are probably other descending fasciculi such as the thalamospinal but not much is known about them.

\textbf{4g. The Meninges of the Brain and Medulla Spinalis}
The brain and medulla spinalis are enclosed within three membranes. These are named from without inward: the dura mater, the arachnoid, and the pia mater.

**The Dura Mater**

The dura mater is a thick and dense inelastic membrane. The portion which encloses the brain differs in several essential particulars from that which surrounds the medulla spinalis, and therefore it is necessary to describe them separately; but at the same time it must be distinctly understood that the two form one complete membrane, and are continuous with each other at the foramen magnum.

**The Cranial Dura Mater** (dura mater encephali; dura of the brain) lines the interior of the skull, and serves the twofold purpose of an internal periosteum to the bones, and a membrane for the protection of the brain. It is composed of two layers, an inner or meningeal and an outer or endosteal, closely connected together, except in certain situations, where, as already described (page 654), they separate to form sinuses for the passage of venous blood. Its outer surface is rough and fibrillated, and adheres closely to the inner surfaces of the bones, the adhesions being most marked opposite the sutures and at the base of the skull. Its inner surface is smooth and lined by a layer of endothelium. It sends inward four processes which divide the cavity of the skull into a series of freely communicating compartments, for the lodgement and protection of the different parts of the brain; and it is prolonged to the outer surface of the skull, through the various foramina which exist at the base, and thus becomes continuous with the pericranium; its fibrous layer forms sheaths for the nerves which pass through these apertures. Around the margin the foramen magnum it is closely adherent to the bone, and is continuous with the spinal dura mater.

**Fig. 765**– Dura mater and its processes exposed by removing part of the right half of the skull and the brain. (See enlarged image)

**Processes.**—The processes of the cranial dura mater, which projects into the cavity of the skull, are formed by reduplications of the inner or meningeal layer of the membrane, and are four in number: the falx cerebri, the tentorium cerebelli, the falx cerebelli, and the diaphragma.

The falx cerebri (Fig. 765), so named from its sickle-like form, is a strong, arched process which descends vertically in the longitudinal fissure between the cerebral hemispheres. It is narrow in front, where it is attached to the crista galli of the ethmoid; and broad behind, where it is
connected with the upper surface of the tentorium cerebelli. Its upper margin is convex, and attached to the inner surface of the skull in the middle line, as far back as the internal occipital protuberance; it contains the superior sagittal sinus. Its lower margin is free and concave, and stains the inferior sagittal sinus.

**The tentorium cerebelli** (Fig. 766) is an arched lamina, elevated in the middle, and inclining downward toward the circumference. It covers the superior surface of the cerebellum, and supports the occipital lobes of the brain. Its anterior border is free and concave, and bounds a large oval opening, the **incisura tentorii**, for the transmission of the cerebral peduncles. It is attached, behind, by its convex border, to the transverse ridges on the inner surface of the occipital bone, and there encloses the transverse sinuses; in front, to the superior angle of the petrous part of the temporal bone on either side, enclosing the superior petrosal sinuses. At the apex of the petrous part of the temporal bone the free and attached borders meet, and, crossing one another, are continued forward to be fixed to the anterior and posterior clinoid processes respectively. To the middle line of its upper surface the posterior border of the falx cerebri is attached, the straight sinus being placed at their line of junction.

**Fig. 766**– Tentorium cerebelli seen from above. (See enlarged image)

The **falx cerebri** is a small triangular process of dura mater, received into the posterior cerebellar notch. Its base is attached, above, to the der and back part of the tentorium; its posterior margin, to the lower division of the vertical crest on the inner surface of the occipital bone. As it descends, it sometimes divides into two smaller folds, which are lost on the sides of the foramen magnum.

**The diaphragma sellæ** is a small circular horizontal fold, which roofs in the sella turcica and almost completely covers the hypophysis; a small central opening transmits the infundibulum.

**Structure.**—The cranial dura mater consists of white fibrous tissue and elastic fibers arranged in flattened laminae which are imperfectly parted by lacunar spaces and bloodvessels into two layers, **endosteal** and **meningeal**. The **endosteal layer** is the internal periosteum for the cranial bones, and contains the bloodvessels for their supply. At the margin of the foramen magnum it is continuous with the periosteum lining the vertebral canal. The **meningeal or supporting layer** is lined on its inner surface by a layer of nucleated flattened mesothelium, similar to that found on serous membranes.

**Arteries.**—The cranial dura mater consists of white fibrous tissue and elastic fibers arranged in flattened laminae which are imperfectly parted by lacunar spaces and bloodvessels into two layers, **endosteal** and **meningeal**. The **endosteal layer** is the internal periosteum for the cranial bones, and contains the bloodvessels for their supply. At the margin of the foramen magnum it is continuous with the periosteum lining the vertebral canal. The **meningeal or supporting layer** is lined on its inner surface by a layer of nucleated flattened mesothelium, similar to that found on serous membranes.

**Arteries** of the dura mater are very numerous. Those in the anterior fossa are the anterior meningeal branches of the anterior and posterior ethmoidal and internal carotid, and a branch from the middle meningeal. Those in the middle fossa are the middle and accessory meningeal of the internal maxillary; a branch from the ascending pharyngeal, which enters the skull through the foramen lacerum; branches from the internal carotid, and a recurrent branch from the lacrimal. Those in the posterior fossa are meningeal branches from the occipital, one entering the skull...
though the jugular foramen, and another through the mastoid foramen; the posterior meningeal from the vertebral; occasional meningeal inches from the ascending pharyngeal, entering the skull through the jugular foramen and hypoglossal canal; and a branch from the middle meningeal.

Veins returning the blood from the cranial dura mater anastomose with the diploic veins and end in the various sinuses. Many of the meningeal veins do not open directly into the sinuses, but indirectly through a series of ampullae, termed venous lacunae. These are found on her side of the superior sagittal sinus, especially near its middle portion, and are often invaginated by arachnoid granulations; they also exist at the transverse and straight sinuses. They communicate with the underlying cerebral veins, and also with the diploic and emissary veins. Nerves of the cranial dura mater are filaments from the semilunar ganglion, from the ophthalmic, maxillary, mandibular, vagus, and hypoglossal nerves, and from the sympathetic.

Spinal Dura Mater (dura mater spinalis; spinal dura) (Fig. 767) forms a loose sheath around the medulla spinalis, and represents only the inner or meningeal layer of the cranial dura mater; the outer or endosteal layer ceases at the foramen magnum, its place being taken by the arachnoid lining the vertebral canal. The spinal dura mater is separated from the arachnoid by a potential cavity, the subdural cavity; the two membranes are, in fact, in contact with each other, except where they are separated by a minute quantity of fluid, which serves to moisten the opposed surfaces. It is separated from the wall of the vertebral canal by a space, the epidural space, which contains a quantity of loose areolar tissue and a plexus of veins; the situation of these veins between the dura mater and the periosteum of the vertebræ corresponds therefore to that of the cranial sinuses between the meningeal and endosteal layers of the cranial dura mater. The spinal dura mater is attached to the circumference of the foramen magnum, and to the second and third cervical vertebra; it is also connected to the posterior longitudinal ligament, especially near the lower end of the vertebral canal, by fibrous slips. The subdural cavity ends at the lower border of the second sacral vertebra; low this level the dura mater closely invests the filum terminale and descends to the back of the coccyx, where it blends with the periosteum. Sheath of dura mater is much larger than is necessary for the accommodation of its contents, and its size is greater in the cervical and lumbar regions than in the thoracic. On each side may be seen the double openings which transmit the two roots of the corresponding spinal nerve, the dura mater being continued in the form of tubular prolongations on them as they pass through the intervertebral foramina. These prolongations are short in the upper part of the vertebral column, but gradually become longer below, forming a number of tubes of fibrous membrane, which close the lower spinal nerves and are contained in the vertebral canal.

Fig. 767– The medulla spinalis and its membranes. (See enlarged image)
ructure.—The spinal dura mater resembles in structure the meningeal or supporting layer of the cranial dura mater, consisting of white fibrous elastic tissue arranged in bands or lamellæ which, for the most part, are parallel with one another and have a longitudinal arrangement. Its inner surface is smooth and covered by a layer of mesothelium. It is sparingly supplied with bloodvessels, and a few nerves have been traced to it.

The Arachnoid—The arachnoid is a delicate membrane enveloping the brain and medulla spinalis and lying between the pia mater internally and the dura mater externally; it is separated from the pia mater by the subarachnoid cavity, which is filled with cerebrospinal fluid. The Cranial Part (arachnoidea encephali) of the arachnoid invests the brain loosely, and does not dip into the sulci between the gyri, nor into fissures, with the exception of the longitudinal. On the upper surface of the brain the arachnoid is thin and transparent; at the base it is thicker, and slightly opaque toward the central part, where it extends across between the two temporal lobes in front of the pons, so as to leave a considerable interval between it and the brain.

The Spinal Part (arachnoidea spinalis) of the arachnoid is a thin, delicate, tubular membrane loosely investing the medulla spinalis. Above, it is continuous with the cranial arachnoid; below, it widens out and invests the cauda equina and the nerves proceeding from it. It is separated from the dura mater by the subdural space, but here and there this space is traversed by isolated connective-tissue trabeculae, which are most abundant on the posterior surface of the medulla spinalis.

The arachnoid surrounds the cranial and spinal nerves, and encloses them in loose sheaths as far as their points of exit from the skull and vertebral canal.

ructure.—The arachnoid consists of bundles of white fibrous and elastic tissue intimately blended together. Its outer surface is covered with a layer of low cuboidal mesothelium. The inner surface and the trabeculae are likewise covered by a somewhat low type of cuboidal mesothelium; in places they are flattened to a pavement type. Vessels of considerable size, but few in number, and, according to Bochdalek, a rich plexus of nerves derived from the motor root of the trigeminal, the facial, and the accessory nerves, are found in the arachnoid.

The Subarachnoid Cavity (cavum subarachnoideale; subarachnoid space) is the interval between the arachnoid and pia mater. It is occupied by a spongy tissue consisting of trabeculae of delicate connective tissue, and intercommunicating channels in which the subarachnoid fluid is contained. This cavity is small on the surface of the hemispheres of the brain; on the summit of each gyrus the pia mater and the arachnoid are in close contact; but in the sulci between the gyri, triangular spaces are left, in which the subarachnoid trabecular tissue is found, for the pia mater dips into the sulci, whereas the arachnoid bridges across them from gyrus to gyrus. At certain parts of the base of the brain, the arachnoid is separated from the pia mater by wide intervals, which communicate freely with each other and are named subarachnoid cisternæ; in these the arachnoid tissue is less abundant.

Subarachnoid Cisternae (cisternæ subarachnoidales) (Fig. 768).—The cisterna cerebellomedullaris (cisterna magna) is triangular on sagittal section, and results from the arachnoid bridging over the interval between the medulla oblongata and the undersurface of the hemispheres of the cerebellum; it is continuous with the subarachnoid cavity of the medulla spinalis at the level of the foramen magnum. The cisterna pontis is a considerable space on the ventral aspect of the pons. It contains the basilar artery, and is continuous behind with the subarachnoid cavity of the medulla spinalis, and with the cisterna cerebellomedullaris; and in front of the pons with the cisterna interpeduncularis. The cisterna cerebri (cisterna basalis) is a wide cavity where the arachnoid extends across between the two temporal lobes. It encloses the cerebral peduncles and the structures contained in the interpeduncular fossa, and contains the arterial circle of Willis. In front, the cisterna cerebri is continuous with the optic chiasma, forming the cisterna chiasmatis, and on to the upper surface of the corpus callosum, the arachnoid stretches across from one cerebral hemisphere to the other immediately beneath the free border of the falx cerebri, and thus encloses a space in which the anterior cerebral arteries are contained. The cisterna fossae cerebri lateralis is formed in front of either temporal lobe by the arachnoid bridging across the lateral fissure. This cavity contains the middle cerebral artery. The cisterna venae magnum cerebri occupies the interval between the splenium of the corpus callosum and the superior surface of the cerebellum; it extends between the undersurfaces of the tela chorioidea of the third ventricle and contains the great cerebral vein.
The subarachnoid cavity communicates with the general ventricular cavity of the brain by three openings; one, the **foramen of Majendie**, is in the middle line at the inferior part of the roof of the fourth ventricle; the other two are at the extremities of the lateral recesses of that ventricle, hind the upper roots of the glosopharyngeal nerves and are known as the **foramina of Luschka**. It is still somewhat uncertain whether these foramina are actual openings or merely modified areas of the inferior velum which permit the passage of the cerebrospinal fluid from the ventricle into the subarachnoid spaces as through a permeable membrane.

The spinal part of the subarachnoid cavity is a very wide interval, and is the largest at the lower part of the vertebral canal, where the arachnoid closes the nerves which form the cauda equina. Above, it is continuous with the cranial subarachnoid cavity; below, it ends at the level of the lower border of the second sacral vertebra. It is partially divided by a longitudinal septum, the **subarachnoid septum**, which connects the arachnoid with the pia mater opposite the posterior median sulcus of the medulla spinalis, and forms a partition, incomplete and cribriform above, but more perfect in the thoracic region. The spinal subarachnoid cavity is further subdivided by the **ligamentum denticulatum**, which will be described with the pia mater.

The cerebrospinal fluid is a clear limpid fluid, having a saltish taste, and a slightly alkaline reaction. According to Lassaigne, it consists of 98.5 per cent of water, the remaining 1.5 per cent being solid matters, animal and saline. It varies in quantity, being most abundant in old persons, and is quickly secreted.

The **Arachnoid Villi** (granulationes arachnoideales; glandulae Pacchioni; Pacchionian bodies) (Fig. 769) are small, fleshy-looking elevations, usually collected into clusters of variable size, which are present upon the outer surface of the dura mater, in the vicinity of the superior sagittal sinus, and in some other situations. Upon laying open the sagittal sinus and the venous lacunae on either side of it villi will be found protruding into its interior. They are not seen in infancy, and very rarely until the third year. They are usually found after the seventh year; and from this period they increase in number and size as age advances. They are not glandular in structure, but are enlarged normal villi of the arachnoid. As they grow they push the thinned dura mater before them, and cause absorption of the bone from pressure, and so produce the pits or depressions in the inner wall of the calvarium.
Structure.—An arachnoidal villus represents an invasion of the dura by the arachnoid membrane, the latter penetrates the dura in such a manner that the arachnoid mesothelial cells come to lie directly beneath the vascular endothelium of the great dural sinuses. It consists of the following parts: (1) In the interior is a core of subarachnoid tissue, continuous with the meshwork of the general subarachnoid tissue through a narrow pedicle, by which the villus is attached to the arachnoid. (2) Around this tissue is a layer of arachnoid membrane, limiting and enclosing the subarachnoid tissue. (3) Outside this is the thinned wall of the lacuna, which is separated from the arachnoid by a potential space which corresponds to and is continuous with the subdural cavity. (4) And finally, if the villus projects into the sagittal sinus, it will be covered by the greatly thinned wall of the sinus which may consist merely of endothelium. It will be seen, therefore, that fluid injected into the subarachnoid cavity will find its way into these villi, and it has been found experimentally that it passes from the villi into the venous sinuses into which they project.

The Pia Mater.—The pia mater is a vascular membrane, consisting of a minute plexus of bloodvessels, held together by an extremely fine areolar tissue and covered by a reflexion of the mesothelial cells from the arachnoid trabeculae. It is an incomplete membrane, absent probably at the foramen of Majendie and the two foramina of Luschka and perforated in a peculiar manner by all the bloodvessels as they enter or leave the nervous system. In the perivascular spaces, the pia apparently enters as a mesothelial lining of the outer surface of the space; a variable distance from the exterior these cells become unrecognizable and are apparently lacking, replaced by neuroglia elements. The inner walls of these perivascular spaces seem likewise covered for a certain distance by the mesothelial cells, reflected with the vessels from the arachnoid covering these vascular channels as they traverse the subarachnoid spaces.

The Cranial Pia Mater (pia mater encephali; pia of the brain) invests the entire surface of the brain, dips between the cerebral gyri and cerebellar laminae, and is invaginated to form the tela chorioidea of the third ventricle, and the choroid plexuses of the lateral and third ventricles (see pages 840 and 841); as it passes over the roof of the fourth ventricle, it forms the tela chorioidea and the choroid plexuses of this ventricle. On the cerebellum the membrane is more delicate; the vessels from its deep surface are shorter, and its relations to the cortex are not so intimate.
The Spinal Pia Mater (pia mater spinalis; pia of the cord) (Figs. 767, 770) is thicker, firmer, and less vascular than the cranial pia mater: this is due to the fact that it consists of two layers, the outer or additional one being composed of bundles of connective-tissue fibers, arranged for the most part longitudinally. Between the layers are cleft-like spaces which communicate with the subarachnoid cavity, and a number of vessels which are enclosed in perivascular lymphatic sheaths. The spinal pia mater covers the entire surface of the medulla spinalis, and is intimately adherent to it; in front it sends a process backward into the anterior fissure. A longitudinal fibrous band, called the linea tendens, extends along the middle line of the anterior surface; and a somewhat similar band, the ligamentum denticulatum, is situated on her side. Below the conus medullaris, the pia mater is continued as a long, slender filament (filum terminale), which descends through the outer of the mass of nerves forming the cauda equina. It blends with the dura mater at the level of the lower border of the second sacral vertebra, and extends downward as far as the base of the coccyx, where it fuses with the periosteum. It assists in maintaining the medulla spinalis in its sition during the movements of the trunk, and is, from this circumstance, called the central ligament of the medulla spinalis.

The pia mater forms sheaths for the cranial and spinal nerves; these sheaths are closely connected with the nerves, and blend with their common membranous investments.

The ligamentum denticulatum (dentate ligament) (Fig. 767) is a narrow fibrous band situated on either side of the medulla spinalis throughout its entire length, and separating the anterior from the posterior nerve roots. Its medial border is continuous with the pia mater at the side of the dura spinalis. Its lateral border presents a series of triangular tooth-like processes, the points of which are fixed at intervals to the dura mater. These processes are twenty-one in number, on either side, the first being attached to the dura mater, opposite the margin of the foramen magnum, and the last near the lower end of the medulla spinalis.

4h. The Cerebrospinal Fluid

e cerebrospinal fluid, 129 for the most part elaborated by the choroid plexuses, is poured into the cerebral ventricles which are lined by smooth ependyma. That portion of the fluid formed in the lateral ventricles escapes by the foramen of Monro into the third ventricle and thence by the aqueduct into the fourth ventricle. Likewise an ascending current of fluid apparently occurs in the central canal of the spinal cord; this, representing a possible product of the ependyma, may be added to the intraventricular supply. From the fourth ventricle the fluid is poured into the subarachnoid spaces through the medial foramen of Majendie and the two lateral foramina of Luschka. There is no evidence that functional communications between the cerebral ventricles and the subarachnoid spaces exist in any region except from the fourth ventricle.

In addition to the elaboration of the cerebrospinal fluid by the choroid plexuses, there seems fairly well established a second source of the fluid on the nervous system itself. The bloodvessels that enter and leave the brain are surrounded by perivascular channels. It seems most likely that the outer wall of these channels is lined by a continuation inward of the pial mesothelium while the inner wall is probably derived from the mesothelial covering of the vessels, which are thus protected throughout the subarachnoid spaces. These mesothelial cells continue inward only a short distance, neuroglia cells probably replacing on the outer surface the mesothelial elements. Through these perivascular channels there is probably a small amount of fluid flowing from nerve-cell to subarachnoid space. The chemical differences between the subarachnoid fluid product of choroid plexuses and perivascular system) and the ventricular fluid (product of choroid plexuses alone) indicate that the products of rye-metabolism are poured into the subarachnoid space.

The absorption of the cerebrospinal fluid is a dual process, being chiefly a rapid drainage through the arachnoid villi into the great dural sinuses, d, in small part, a slow escape into the true lymphatic vessels, by way of an abundant but indirect perineural course.

In general the arachnoid channels are equipped as fluid retainers with unquestionable powers of diffusion or absorption in regard to certain elements in the normal cerebrospinal fluid, deriving in this way a cellular nutrition.

The subdural space (between arachnoid and dura) is usually considered to be a part of the cerebrospinal channels. It is a very small space, the
two limiting surfaces being separated by merely a capillary layer of fluid. Whether this fluid is exactly similar to the cerebrospinal fluid is very difficult to ascertain. Likewise our knowledge of the connections between the subdural and subarachnoid spaces is hardly definite. In some ways the subdural space may be likened to a serous cavity. The inner surface of the dura is covered by flattened polygonal mesothelial cells but the outer surface of the arachnoid is covered by somewhat cuboidal mesothelium. The fluid of the subdural space has probably a local origin from the cells lining it.