Lecture 1 in Anatomy of CNS

By

Dr. Mohammad Ahmad Abdulla

VAULT OF THE SKULL

The internal surface of the vault shows the coronal, sagittal, and lambdoid sutures. In the midline is a shallow sagittal groove that lodges the **superior sagittal sinus**. On each side of the groove are several small pits, called granular pits, which lodge the lateral lacunae and arachnoid granulations. Several narrow grooves are present for the anterior and posterior divisions of the middle meningeal vessels as they pass up the side of the skull to the vault.

BASE OF THE SKULL

The interior of the base of the skull is divided into three cranial fossae: anterior, middle, and posterior. The anterior cranial fossa is separated from the middle cranial fossa by the lesser wing of the sphenoid, and the middle cranial fossa is separated from the posterior cranial fossa by the petrous part of the temporal bone.

Anterior Cranial Fossa

The anterior cranial fossa lodges the frontal lobes of the cerebral hemispheres. It is bounded anteriorly by the inner surface of the frontal bone, and in the midline is a crest or the attachment of the **falx cerebri**. Its posterior boundary is the sharp lesser wing of the sphenoid, which articulates laterally with the frontal bone and meets the anteroinferior angle of the parietal bone, or the pterion. The medial end of the lesser wing of the sphenoid forms the **anterior clinoid process** on each side, which gives attachment to the **tentorium cerebelli**. The median part of the anterior cranial fossa is limited posteriorly by the groove for the optic chiasma.

The floor of the fossa is formed by the ridged orbital plates of the frontal bone laterally and by the **cribriform plate** of the ethmoid medially. The **crista galli** is a sharp upward projection of the ethmoid bone in the midline for the attachment of the falx cerebri. Between the crista galli and the crest of the frontal bone is a small aperture, the **foramen cecum**, for the transmission of a small vein from the nasal mucosa to the superior sagittal sinus. Alongside the crista galli is a narrow slit in the **cribriform plate** for the passage of the **anterior ethmoidal nerve** into the nasal cavity. The upper surface of the cribriform plate supports the **olfactory bulbs**, and the small perforations in the cribriform plate are for the **olfactory nerves**.

Middle Cranial Fossa

The middle cranial fossa consists of a small median part and expanded lateral parts. The median raised part is formed by the body of the sphenoid, and the expanded lateral parts form concavities on either side, which lodge the **temporal lobes** of the **cerebral hemispheres**.

It is bounded anteriorly by the lesser wings of the sphenoid and posteriorly by the superior borders of the petrous parts of the temporal bones. Laterally lie the squamous parts of the temporal bones, the greater wings of the sphenoid, and the parietal bones.

The floor of each lateral part of the middle cranial fossa is formed by the greater wing of the sphenoid and the squamous and petrous parts of the temporal bone.

The sphenoid bone resembles a bat having a centrally placed body with greater and lesser wings that are outstretched on each side. The body of the sphenoid contains the sphenoid air

Lecture 2 in Anatomy of CNS

By

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General Appearance of The Cerebral Hemispheres

The cerebral hemispheres are the largest part of the brain and are separated by a deep midline sagittal fissure, the **longitudinal cerebral fissure**. The fissure contains The sickle-shaped fold of dura mater, the falx cerebri, and the anterior cerebral arteries. In the depths of the fissure, the great commissure, the corpus callosum, connects the hemispheres across the midline. A second horizontal fold of dura mater separates the cerebral hemispheres from the cerebellum and is called the tentorium cerebelli.

To increase the surface area of the cerebral cortex maximally, the surface of each cerebral hemisphere is thrown **into folds** or **gyri,** which are separated from each other by **sulci** or **fissures**. For ease of description, it is customary to divide each hemisphere into **lobes,** which are named according to the cranial bones under which they lie. The **central** and **parieto-occipital sulci** and the **lateral and calcarine sulci** are boundaries used for the division of the cerebral hemisphere into **frontal, parietal, temporal, occipital lobes**.

Main Sulci:-

The **central sulcus** is of great importance because the gyrus that lies anterior to it contains the motor cells that initiate the movements of the opposite side of the body; posterior to it lies the general sensory cortex that receives sensory information from the opposite side of the body. The central sulcus indents the superior medial border of the hemisphere about 0.4 inch (1 cm) behind the midpoint. It runs downward and forward across the lateral aspect of the hemisphere, and its lower end is separated from the posterior ramus of the lateral sulcus by a narrow bridge of cortex. The central sulcus is the only sulcus of any length on this surface of the hemisphere that indents the superomedial border and lies between two parallel gyri.

The **lateral sulcus** is a deep cleft found mainly on the inferior and lateral surfaces of the cerebral hemisphere. It consists of a short stem that divides into three rami. The stem arises on the inferior surface and on reaching the lateral surface it divides into the **anterior horizontal ramus** and the **anterior ascending ramus,** and continues as the **posterior ramus**. An area of cortex called the **insula** lies at the bottom of the deep lateral sulcus and cannot be seen from the surface unless the lips of the sulcus are separated.

The **parieto-occipital sulcus** begins on the superior medial margin of the hemisphere about 2 inches (5 cm) anterior to the occipital pole**.** It passes downward and anteriorly on the medial surface to meet the calcarine sulcus.

The **calcarine sulcus** is found on the medial surface of the hemisphere. It commences under the posterior end of the corpus callosum and arches upward and backward to reach the occipital pole, where it stops. In some brains, however, it continues for a short distance onto the lateral surface of the hemisphere. The calcarine sulcus is joined at an acute angle by the parieto-occipital sulcus about halfway along its length.

Lobes Of The Cerebral Hemisphere

Superolateral Surface of the Hemisphere:-

The **frontal lobe** occupies the area anterior to the central sulcus and superior to the lateral sulcus. The superolateral surface of the frontal lobe is divided by three sulci into four gyri. The **precentral sulcus** runs parallel to the central sulcus and the **precentral gyrus** lies between them. Extending anteriorly from the precentral sulcus are the superior and inferior frontal sulci. The superior frontal

gyrus lies superior to the superior frontal sulcus, the middle frontal gyrus lies between the superior and inferior frontal sulci, and the inferior frontal gyrus lies inferior to the inferior frontal sulcus. The inferior frontal gyrus is invaded by the anterior and ascending rami of the lateral sulcus.

The **parietal lobe** occupies the area posterior to the central sulcus and superior to the lateral sulcus; it extends posteriorly as far as the parieto-occipital sulcus. The lateral surface of the parietal lobe is divided by two sulci into three gyri. The postcentral sulcus runs parallel to the central sulcus and the postcentral gyrus lies between them. Running posteriorly from the middle of the postcentral sulcus is the **intraparietal sulcus**. The **intraparietal sulcus** has superior to it the **superior parietal lobule (gyrus)** and inferior to it the **inferior parietal lobule (gyrus).**

The **temporal lobe** occupies the area inferior to the lateral sulcus. The lateral surface of the temporal lobe is divided into three gyri by two sulci. The **superior** and **middle temporal sulci** run parallel to the posterior ramus of the lateral sulcus, and divide the temporal lobe into the **superior, middle,** and **inferior temporal gyri;** the inferior temporal gyrus is continued onto the inferior surface of the hemisphere.

The **occipital lobe** occupies the small area behind the parieto-occipital sulcus.

Medial and Inferior Surfaces of the Hemisphere:-

The lobes of the cerebral hemisphere are not clearly defined on the medial and inferior surfaces. However, there are many important areas that should be recognized. The **corpus callosum,** which is the largest commissure of the brain, forms a striking feature on this surface. The **cingulate gyrus** begins beneath the anterior end of the corpus callosum and continues above the corpus callosum until it reaches its posterior end. The gyrus is separated from the corpus callosum by the **callosal sulcus.** The cingulate gyrus is separated from the superior frontal gyrus by the **cingulate sulcus**.

The **paracentral lobule** is the area of the cerebral cortex that surrounds the indentation produced by the central sulcus on the superior border. The anterior part of this lobule is a continuation of the precentral gyrus on the superior lateral surface, and the posterior part of the lobule is a continuation of the postcentral gyrus. The **precuneus** is an area of cortex bounded anteriorly by the upturned posterior end of the cingulate sulcus and posteriorly by the parieto-occipital sulcus.

The **cuneus** is a triangular area of cortex bounded above by the parieto-occipital sulcus, inferiorly by the calcraine sulcus and posteriorly by the superior medial margin.

The **collateral sulcus** is situated on the inferior surface of the hemisphere. This runs anteriorly below the calcarine sulcus. Between the collateral sulcus and the **calcarine sulcus** is the **lingual gyrus.** Anterior to the lingual gyrus is the **parahippocampal gyrus;** the latter terminates in front as the hook-like **uncus**.

The **medial occipitotemporal gyrus** extends from the occipital pole to the temporal pole. It is bounded medially by the **collateral** and **rhinal sulci** and laterally by the **occipitotemporal sulcus.** The **occipitotemporal gyrus** lies lateral to the sulcus and is continuous with the inferior temporal gyrus.

On the inferior surface of the frontal lobe, the olfactory bulb and tract overlie a sulcus called the **olfactory sulcus**. Medial to the olfactory sulcus is the **gyrus rectus** and lateral to the sulcus are a number of **orbital gyri.**

Cerebral Cortex Areas

The precise division of the cortex into different areas of specialization, as described by **Brodmann**, oversimplifies and misleads the reader. The simple division of cortical areas into motor and sensory is erroneous. The main cortical areas will be named by their anatomical location.

Frontal Lobe

1- The precentral area is situated in the precentral gyrus and includes the anterior wall of the central sulcus and the posterior parts of the superior, middle, and inferior frontal gyri; it extends over the superomedial border of the hemisphere into the paracentral lobule.

The precentral area may be divided into :-

A- **motor area, primary motor area, or Brodmann's area 4** occupies the precentral gyrus extending over the superior border into the paracentral lobule.

B- **premotor area, secondary motor area,** or **Brodmann's area 6 and parts of areas 8, 44 and 45**. It occupies the anterior part of the precentral gyrus and the posterior parts of the superior, middle, and inferior frontal gyri.

The movement areas of the body are represented inverted form in the precentral gyrus. Starting from below and passing superiorly are structures involved the swallowing, tongue, jaw, lips, larynx, eyelid, and brow. The next area is an extensive region for movements of the fingers especially the thumb, hand, wrist, elbow, shoulder, and trunk

The movements of the hip, knee, and ankle are represented in the highest areas of the precentral gyrus; the toes are situated on the medial surface of the cerebral hemisphere in the paracentral lobule. The anal and vesical sphincters are also located in the paracentral lobule. The area of cortex controlling a particular movement is proportional to the skill involved in performing the movement and is unrelated to the mass of muscle participating in the movement.

The function of the primary motor area is thus to carry out the individual movements of different parts of the body. To assist in this function, it receives numerous afferent fibers from the premotor area, the sensory cortex, the thalamus, the cerebellum, and the basal ganglia. The primary motor cortex is not responsible for the design of the pattern of movement but is the final station for conversion of the design into execution of the movement.

The function of the premotor area is to store programs of motor activity assembled as the result of past experience. The premotor area thus programs the activity of the primary motor area. It is particularly involved in controlling coarse postural movements through its connections with the basal ganglia.

2-The supplementary motor area is situated in the medial frontal gyrus on the medial surface of the hemisphere and anterior to the paracentral lobule. Removal of the supplementary motor area produces no permanent loss of movement.

3-The frontal eye field extends forward from the facial area of the precentral gyrus into the middle frontal gyrus **(parts of Brodmann's areas 6, 8, and 9).** Electrical stimulation of this region causes conjugate movements of the eyes, especially toward the opposite side. The frontal eye field is considered to control voluntary scanning movements of the eye and is independent of visual stimuli. The involuntary following of moving objects by the eyes involves the visual area of the occipital cortex to which the frontal eye field is connected by association fibers.

4-The motor speech area of Broca is located in the inferior frontal gyrus between the anterior and ascending rami and the ascending and posterior rami of the lateral fissure (**Brodmann's areas 44 and 45)**. In the majority of individuals, this area is important on the left or dominant hemisphere and ablation will result in paralysis of speech. In those individuals in whom the right hemisphere is dominant, the area on the right side is of importance. The ablation of this region in the nondominant hemisphere has no effect on speech.

Broca's speech area brings about the formation of words by its connections with the adjacent primary motor areas; the muscles of the larynx, mouth, tongue, soft palate, and the respiratory muscles are appropriately stimulated.

5-The prefrontal cortex is an extensive area that lies anterior to the precentral area. It includes the greater parts of the superior, middle, and inferior frontal gyri; the orbital gyri; most of the medial frontal gyrus; and the anterior half of the cingulate gyrus **(Brodmann's areas 9, 10, 11, and 12)**. Large numbers of afferent and efferent pathways connect the prefrontal area with other areas of the cerebral cortex, the thalamus, the hypothalamus, and the corpus striatum.

The prefrontal area is concerned with the makeup of the individual's personality. As the result of the input from many cortical and subcortical sources, this area plays a role as a regulator of the person's depth of feeling. It also exerts its influence in determining the initiative and judgment of an individual.

Parietal Lobe

1-The primary somesthetic area (Primary Somatic Sensory Cortex S1) occupies the postcentral gyrus on the lateral surface of the hemisphere and the posterior part of the paracentral lobule on the medial surface **(Brodmann's areas 3, 1, and 2)**.. The primary somesthetic areas of the cerebral cortex receive projection fibers from nuclei of the thalamus. The opposite half of the body is represented as inverted. The pharyngeal region, tongue, and jaws are represented in the most inferior part of the postcentral gyrus; this is followed by the face, fingers, hand, arm, trunk, and thigh. The leg and the foot areas are found on the medial surface of the hemisphere in the posterior part of the paracentral lobule. The anal and genital regions are also found in this latter area. The apportioning of the cortex for a particular part of the body is related to its functional importance rather than to its size. The face, lips, thumb, and index finger have particularly large areas assigned to them.

2-The secondary somesthetic area (Secondary Somatic Sensory Cortex, S2) is in the superior lip of the posterior limb of the lateral fissure. The secondary sensory area is much smaller and less important than the primary sensory area. The face area lies most anterior and the leg area is posterior. The body is bilaterally represented with the contralateral side dominant. The functional significance of this area is not understood.

3-The somesthetic association area occupies the superior parietal lobule extending onto the medial surface of the hemisphere **(Brodmann's areas 5 and 7)**. This area has many connections with other sensory areas of the cortex. It is believed that its main function is to receive and integrate different sensory modalities. For example, it enables one to recognize objects placed in the hand without the help of vision. In other words, it not only receives information concerning the size and shape of an object but also relates this to past sensory experiences, so that the information may be interpreted and recognition occurs. A quarter placed in the hand can be distinguished from a dime or a nickel by the size, shape, and feel of the coin without having to use one's eyes.

Occipital Lobe

1-The primary visual area (Brodmann's area 17) is situated in the walls of the posterior part of the calcarine sulcus and occasionally extends around the occipital pole onto the lateral surface of the hemisphere. The visual cortex receives afferent fibers from the **lateral geniculate body**. The fibers first pass forward in the white matter of the temporal lobe and then turn back to the primary visual cortex in the occipital lobe. The visual cortex receives fibers from the temporal half of the ipsilateral retina and the nasal half of the contralateral retina. The right half of the field of vision, therefore, is represented in the visual cortex of the left cerebral hemisphere and vice versa.

The **macula lutea**, which is the central area of the retina and the area for most perfect vision, is represented on the cortex in the posterior part of area 17 and accounts for one-third of the visual cortex. The visual impulses from the peripheral parts of the retina terminate in concentric circles anterior to the occipital pole in the anterior part of area 17.

2-The secondary visual area (Brodmann's areas 18 and 19) surrounds the primary visual area on the medial and lateral surfaces of the hemisphere. This area receives afferent fibers from area 17 and other cortical areas, as well as from the thalamus. The function of the secondary visual area is to relate the visual information received by the primary visual area to past visual experiences, thus enabling the individual to recognize and appreciate what he or she is seeing.

3-The occipital eye field is thought to exist in the secondary visual area in humans. Stimulation produces conjugate deviation of the eyes, especially to the opposite side. The function of this eye field is believed to be reflex and associated with movements of the eye when it is following an object. The occipital eye fields of both hemispheres are connected by nervous pathways, and also are thought to be connected to the superior colliculus. By contrast, the frontal eye field controls voluntary scanning movements of the eye and is independent of visual stimuli.

Temporal Lobe

1-The primary auditory area (Brodmann's areas 41 and 42) is situated in the inferior wall of the lateral sulcus. Projection fibers to the auditory area arise principally in the medial geniculate body and form the **auditory radiation of the internal capsule.** A unilateral lesion of the auditory area produces partial deafness in both ears, the greater loss being in the contralateral ear; this can be explained on the basis that the medial geniculate body receives fibers mainly from the organ of Corti of the opposite side well as some fibers from the same side.

2-The secondary auditory area (auditory association cortex) is situated posterior to the primary auditory area in the lateral sulcus and in the superior temporal gyrus **(Brodmann's area 22).** It receives impulses from the primary auditory area and from the thalamus. The secondary auditory area is thought to be necessary for the interpretation of sounds and for the association of the auditory input with other sensory information.

3-The sensory speech area of Wernicke is localized in the left dominant hemisphere, mainly in the superior temporal gyrus, with extensions around the posterior end of the lateral sulcus into the parietal region. Wernicke's area is connected to Broca's area by a bundle of nerve fibers called the **arcuate fasciculus.** It receives fibers from the visual cortex in the occipital lobe and the auditory cortex in the superior temporal gyrus. Wernicke's area permits the understanding of the written and spoken language and enables a person to read a sentence, understand it, and say it out loud.

Since Wernicke's area represents the site on the cerebral cortex where somatic, visual, and auditory associations areas all come together, it should be regarded as an area of very great importance.

Other Cortical Areas

1-The taste area is situated at the lower end of the postcentral gyrus in the superior wall of the lateral sulcus and in the adjoining area of the insula **(Brodmann's area 43)**.

2-The vestibular area is believed to be situated near the part of the postcentral gyrus concerned with sensations of the face. Its location lies opposite the auditory area in the superior temporal gyrus. The vestibular area and the vestibular part of the inner ear are concerned with appreciation of the positions and movements of the head in space.

3-The insula is an area of the cortex that is buried within the lateral sulcus and forms its floor. It can be examined only when the lips of the lateral sulcus are separated widely. Its fiber connections are incompletely known. It is believed that this area is important for planning or coordinating the articulatory movements necessary for speech.

Association Cortex

The original concept, that they receive information from the primary sensory areas that is to be integrated and analyzed in the association cortex and then fed to the motor areas, has not been established. Three main association areas are recognized: **prefrontal (**explained in page 2 of this lecture**), anterior temporal, and posterior parietal**.

The anterior temporal cortex is thought to play a role in the storage of previous sensory experiences. Stimulation may cause the individual to recall objects seen or music heard in the past.

In the posterior parietal cortex, the visual information from it and the sensory input of touch and pressure and proprioception from the anterior parietal cortex is integrated into concepts of size, form, and texture. This ability is known as **stereognosis**. An appreciation of the body image is also assembled in the posterior parietal cortex. A person is able to develop a body scheme that he or she is able to appreciate consciously.

Cerebral Dominance

An anatomical examination of the two cerebral hemispheres shows that the cortical gyri and fissures are almost identical. Nevertheless, certain nervous activity is predominantly performed by one of the two cerebral hemispheres. Handedness, perception of language, and speech are functional areas of behavior that in most individuals are controlled by the dominant hemisphere. By contrast, spatial perception, recognition of faces, and music are interpreted by the nondominant hemisphere.

More than 90 percent of the adult population are right-handed and are therefore left hemisphere-dominant. About 96 percent of the adult population are left hemisphere-dominant for speech.

This would suggest that in most individuals the anterior horn cells on the right side of the spinal cord have a greater corticospinal innervation than those on the left side, which might explain the dominance of the right hand.

Other workers have shown that the speech area of the adult cortex is larger on the left than on the right. It is believed that the two hemispheres of the newborn have equipotential capabilities. During childhood, one hemisphere slowly comes to dominate the other, and it is only after the first decade that the dominance becomes fixed. This would explain why a 5-year-old child with damage to the dominant hemisphere can easily learn to become left-handed and speak well, whereas in the adult this is almost impossible.

White Matter of the Cerebral Hemispheres

The white matter is composed of myelinated nerve fibers of different diameters supported by neuroglia. The nerve fibers may be classified into three groups according to their connections: **(1) commissural fibers, (2) association fibers, and (3) projection fibers.**

1- Commissure Fibers:-

These fibers essentially connect corresponding regions of the two hemispheres. They are as follows: the corpus callosum, the anterior commissure, the posterior commissure, the fornix and the habenular commissure.

A- The **corpus callosum,** the largest commissure of the brain, connects the two cerebral hemispheres. It lies at the bottom of the longitudinal fissure. For purposes of description, it is divided into the rostrum, the genu, the body, and the splenium.

1. The **rostrum** is the thin part of the anterior end of the corpus callosum, which is prolonged posteriorly to be continuous with the upper end of the lamina terminalis.
2. The **genu** is the curved anterior end of the corpus callosum that bends inferiorly in front of the septum pellucidum.
3. The **body** of the corpus callosum arches posteriorly and ends as the thickened posterior portion called the **splenium**.

Traced laterally, the fibers of the genu curve forward into the frontal lobes and form the **forceps minor**. The fibers of the body extend laterally as the **radiation of the corpus callosum**. They intersect with bundles of association and projection fibers as they pass to the cerebral cortex. Some of the fibers form the roof and lateral wall of the posterior horn of the lateral ventricle and the lateral wall of the inferior horn of the lateral ventricle; these fibers are referred to as the **tapetum.** Traced laterally, the fibers in the splenium arch backward into the occipital lobe and form the **forceps major**.

B- The **anterior commissure** is a small bundle of nerve fibers that cross the midline in the **lamina terminalis**. A larger bundle curves posteriorly on each side and grooves the inferior surface of the lentiform nucleus to reach the temporal lobes.

C- The **posterior commissure** is a bundle of nerve fibers that cross the midline immediately above the opening of the cerebral aqueduct into the third ventricle ; it is related to the inferior part of the stalk of the pineal gland. Various collections of nerve cells are situated along its length. The destinations and functional significance of many of the nerve fibers are not known.

D- The **fornix** is composed of myelinated nerve fibers and constitutes the efferent system of the hippocampus that passes to the mammillary bodies of the hypothalamus. The nerve fibers first form the **alveus** , which is a thin layer of white matter covering the ventricular surface of the hippocampus, and then converge to form the **fimbria**. The fimbriae of the two sides increase in thickness and, on reaching the posterior end of the hippocampus, they arch forward above the thalamus and below the corpus callosum to form the **posterior columns of the fornix**. The two columns then come together in the midline to form the **body of the fornix**. The **commissure of the fornix** consists of transverse fibers that cross the midline from one column to another just before the formation of the body of the fornix. The function of the commissure of the **fornix is to connect the** hippocampal formations of the two sides.

E- The **habenular commissure** is a small bundle of nerve fibers that cross the midline in the superior part of the root of the pineal stalk. The commissure is associated with the habenular nuclei, which are situated on either side of the midline in this region. **The habenular nuclei** receive many afferents from the amygdaloid nuclei and the hippocampus. These afferent fibers pass to the habenular nuclei in the **stria medullaris thalami**. The function of the habenular nuclei and its connections in humans is unknown.

2- Association Fibers:-

These nerve fibers essentially connect various cortical regions within the same hemisphere and may be divided into short and long groups.

A- The **short association fibers** lie immediately beneath the cortex and connect adjacent gyri; these fibers run transversely to the long axis of the sulci.

B- The **long association fibers** are collected into named bundles that can be dissected in a formalin-hardened brain.

C- The **uncinate fasciculus** connects the first motor speech area and the gyri on the inferior surface of the frontal lobe with the cortex of the pole of the temporal lobe.

D- The **cingulum** is a long, curved fasciculus lying within the white matter of the cingulate gyrus. It connects the frontal and parietal lobes with parahip-pocampal and adjacent temporal cortical regions.

E- The **superior longitudinal fasciculus** is the largest bundle of nerve fibers. It connects the anterior part of the frontal lobe to the occipital and temporal lobes.

F- The **inferior longitudinal fasciculus** runs anteriorly from the occipital lobe, passing lateral to the optic radiation, and is distributed to the temporal lobe.

G- The **fronto-occipital fasciculus** connects the frontal lobe to the occipital and temporal lobes. It is situated deep within the cerebral hemisphere and is related to the lateral border of the caudate nucleus.

3- Projection Fibers:-

Afferent and efferent nerve fibers passing to and from the brainstem to the entire cerebral cortex must travel between large nuclear masses of gray matter within the cerebral hemisphere. At the upper part of the brainstem these fibers form a compact band known as the **internal capsule**, which is flanked medially by the caudate nucleus and the thalamus, and laterally by the lentiform nucleus. Because of the wedge shape of the lentiform nucleus, as seen on horizontal section, the internal capsule is bent to form an **anterior limb** and a **posterior limb**, which are continuous with each other at **the genu**.

Once the nerve fibers have emerged superiorly from between the nuclear masses, they radiate in all directions to the cerebral cortex. These radiating projection fibers are known as the **corona radiata**. Most of the projection fibers lie medial to the association fibers, but they intersect the commissural fibers of the corpus callosum and the anterior commissure. The nerve fibers lying within the most posterior part of the posterior limb of the internal capsule radiate toward the calcarine sulcus and are known as the **optic radiation**.

Septum Pellucidum

The septum pellucidum is a thin vertical sheet of nervous tissue consisting of white and gray matter. It stretches between the fornix and the corpus callosum. Anteriorly, it occupies the interval between the body of the corpus callosum and the rostrum. It is essentially a double membrane with a closed, slitlike cavity between the membranes. The septum pellucidum forms a partition between the anterior horns of the lateral ventricles.

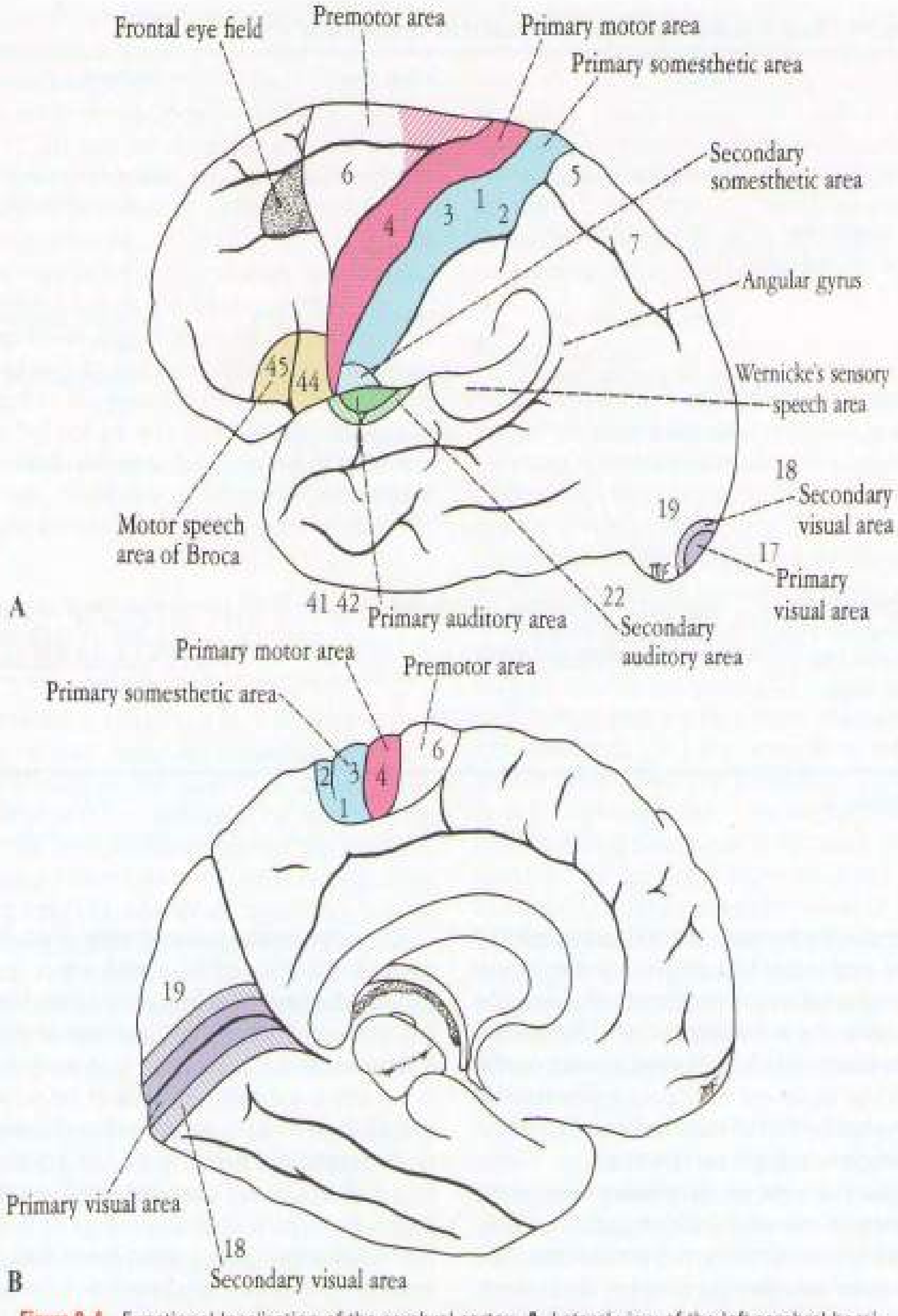


Figure 8–4 Functional localization of the cerebral cortex. **A**. Lateral view of the left cerebral hemisphere. **B**. Medial view of the left cerebral hemisphere.

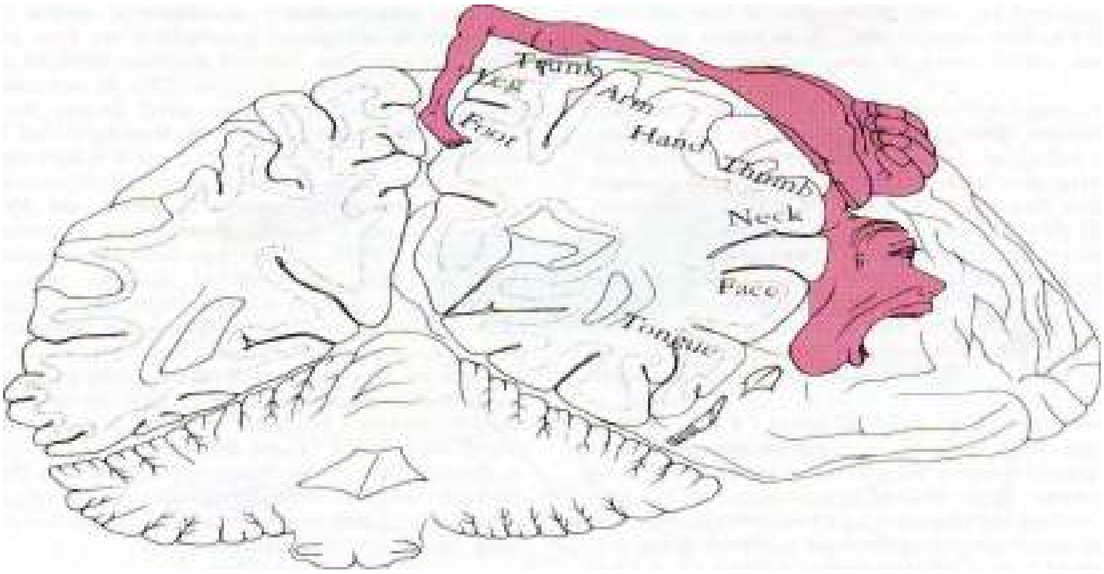


Figure 8-5 Motor homunculus on the precentral gyrus.

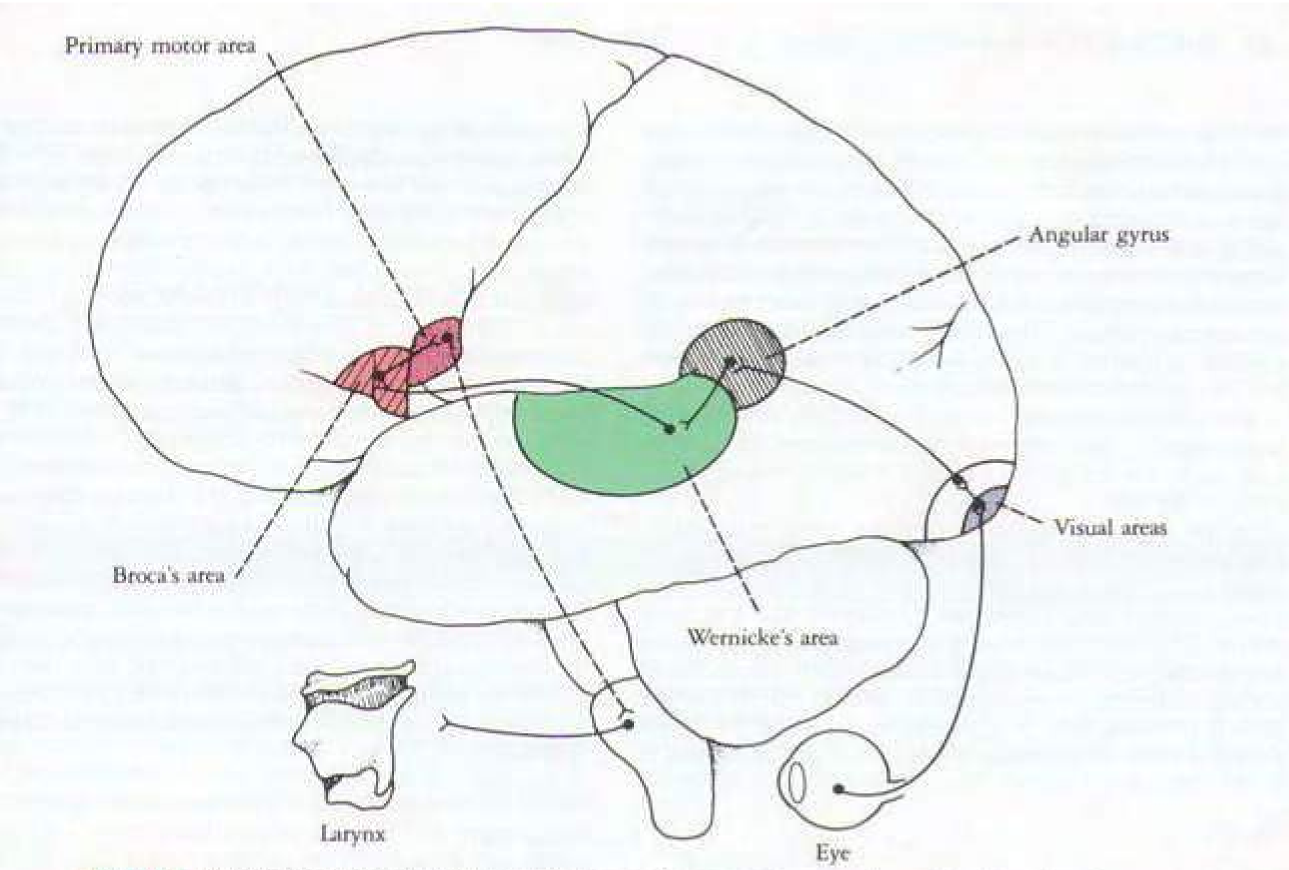


Figure 8-6 Probable nerve pathways involved in reading a sentence and repeating it out loud.

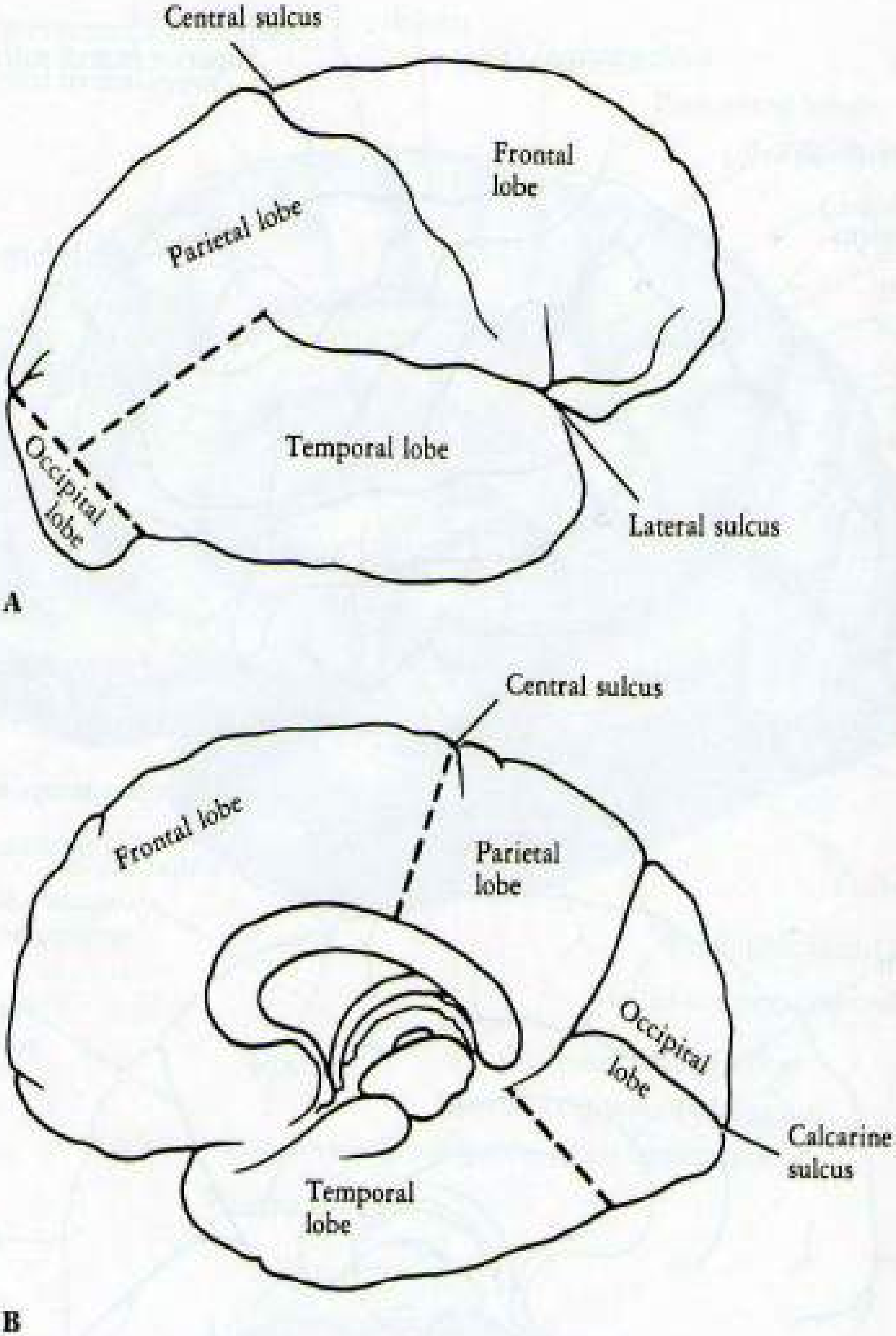


Figure 7–11 **A**. Lateral view of the right cerebral hemisphere showing the lobes. **B**. Medial view of the right cerebral hemisphere showing the lobes. Note that the dashed lines indicate the approximate position of the boundaries where there are no sulci.

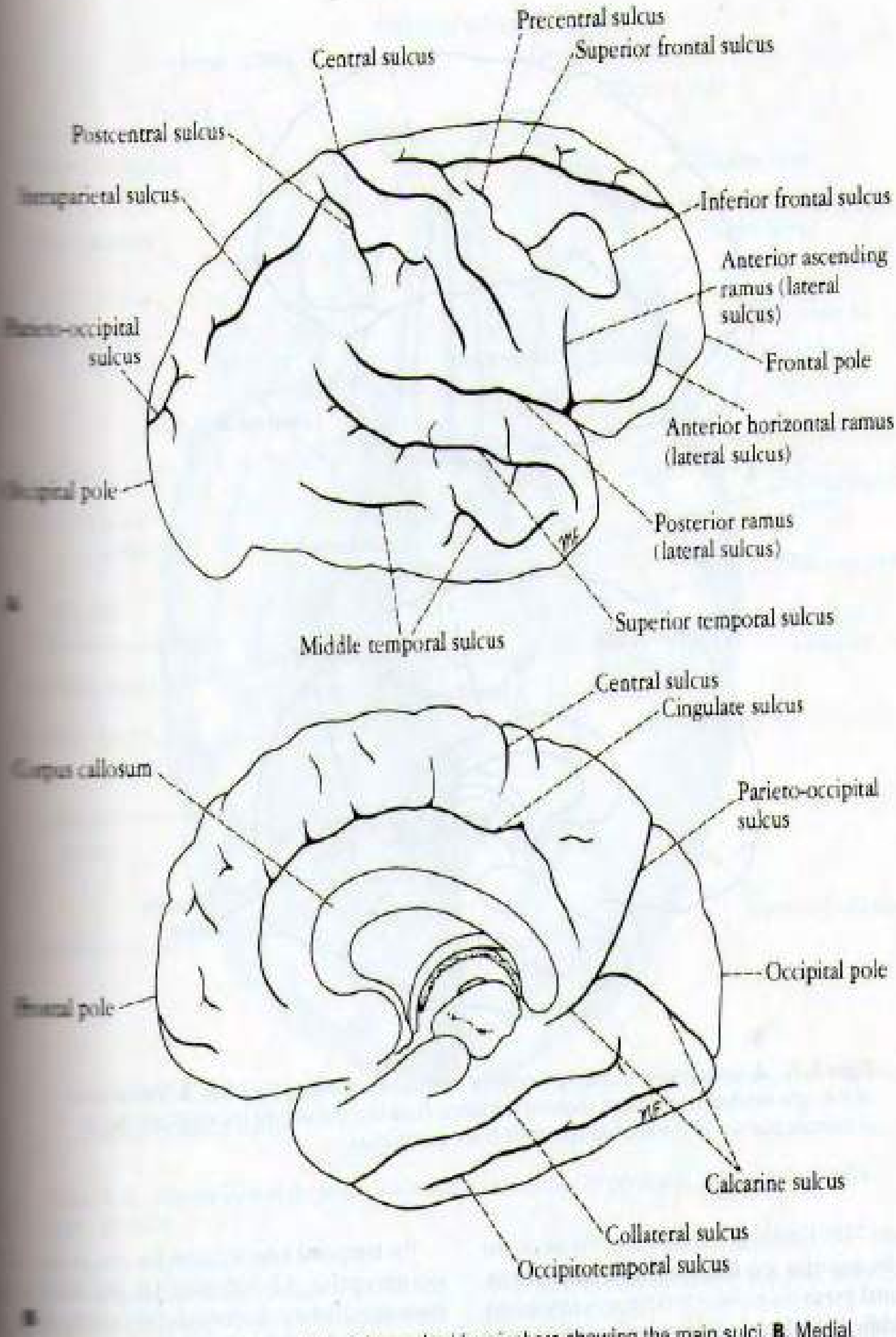


Figure 7–10 **A.** Lateral view of the right cerebral hemisphere showing the main sulci. **B.** Medial view of the right cerebral hemisphere showing the main sulci.

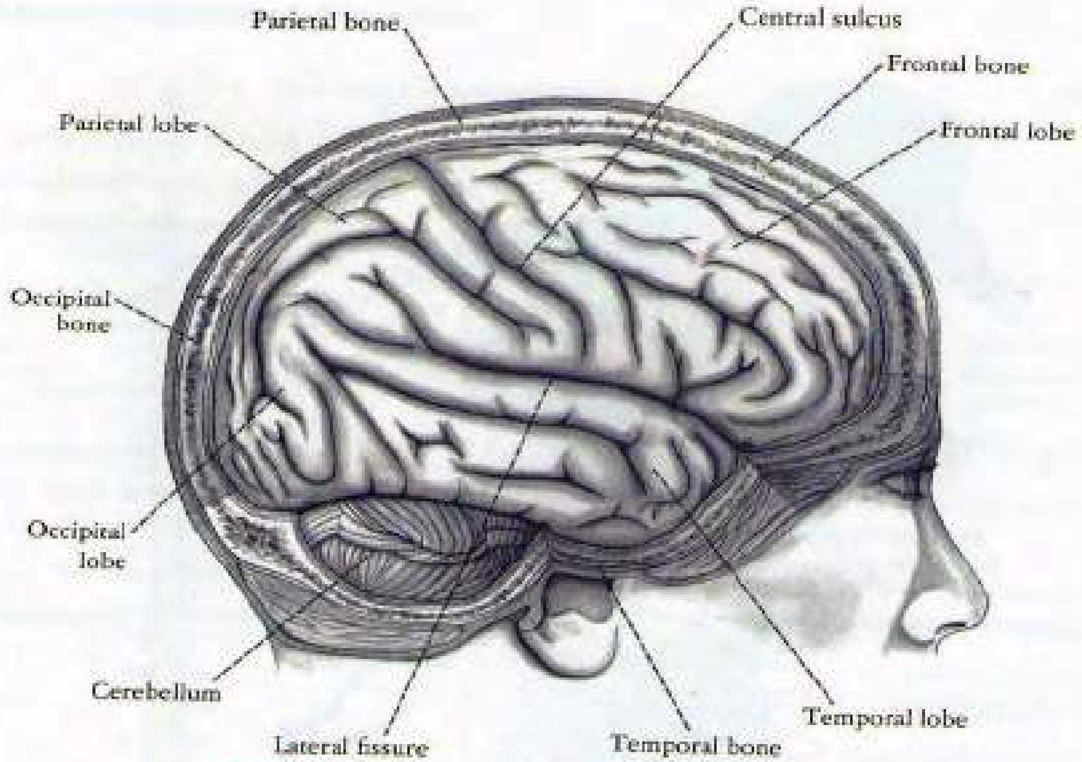


Figure 1–8 Lateral view of the brain within the skull.

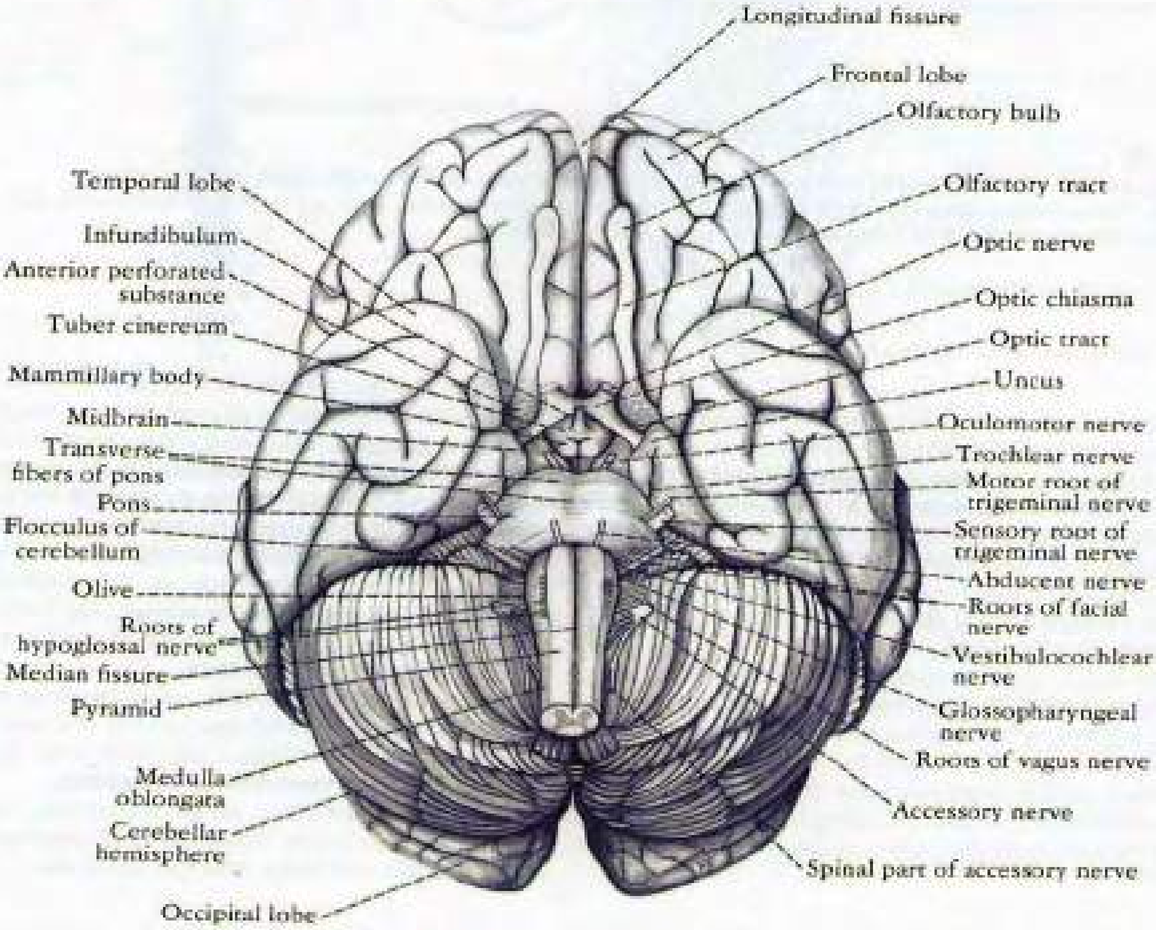


Figure 1–9 Inferior view of the brain.

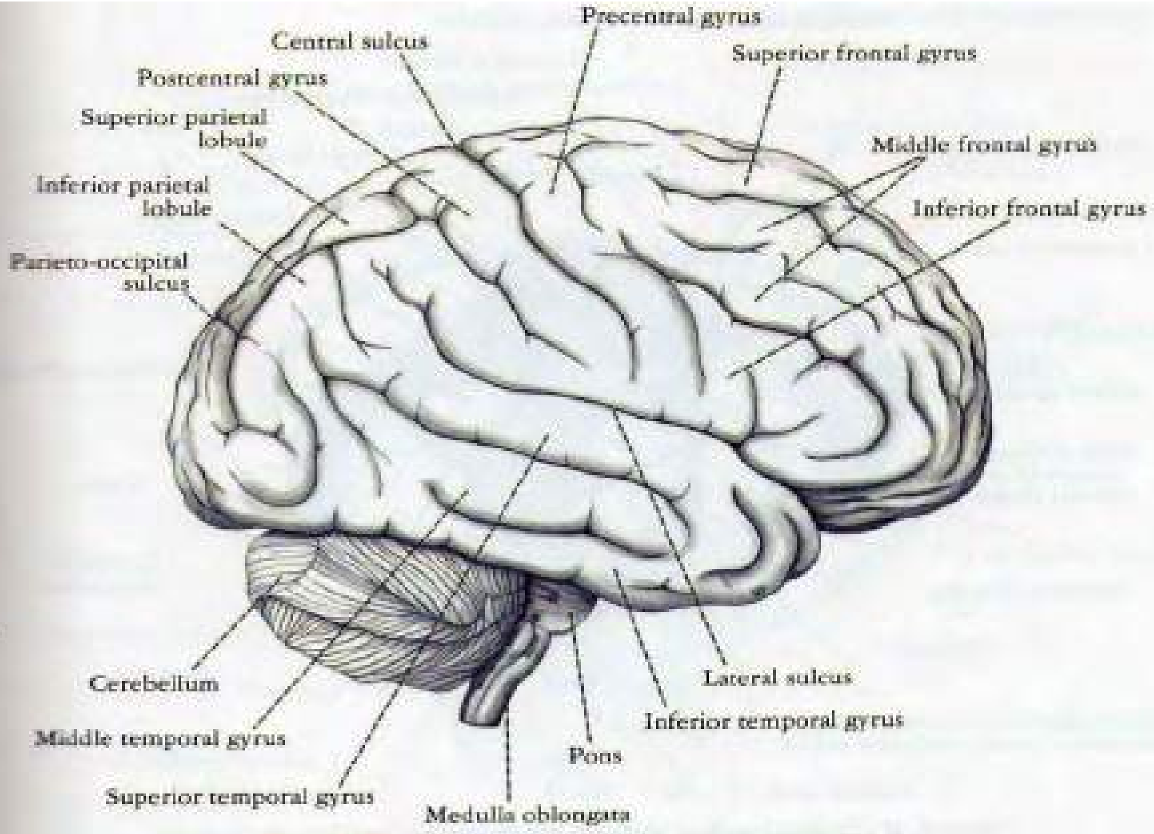


Figure 1–10 Brain viewed from its right lateral aspect.

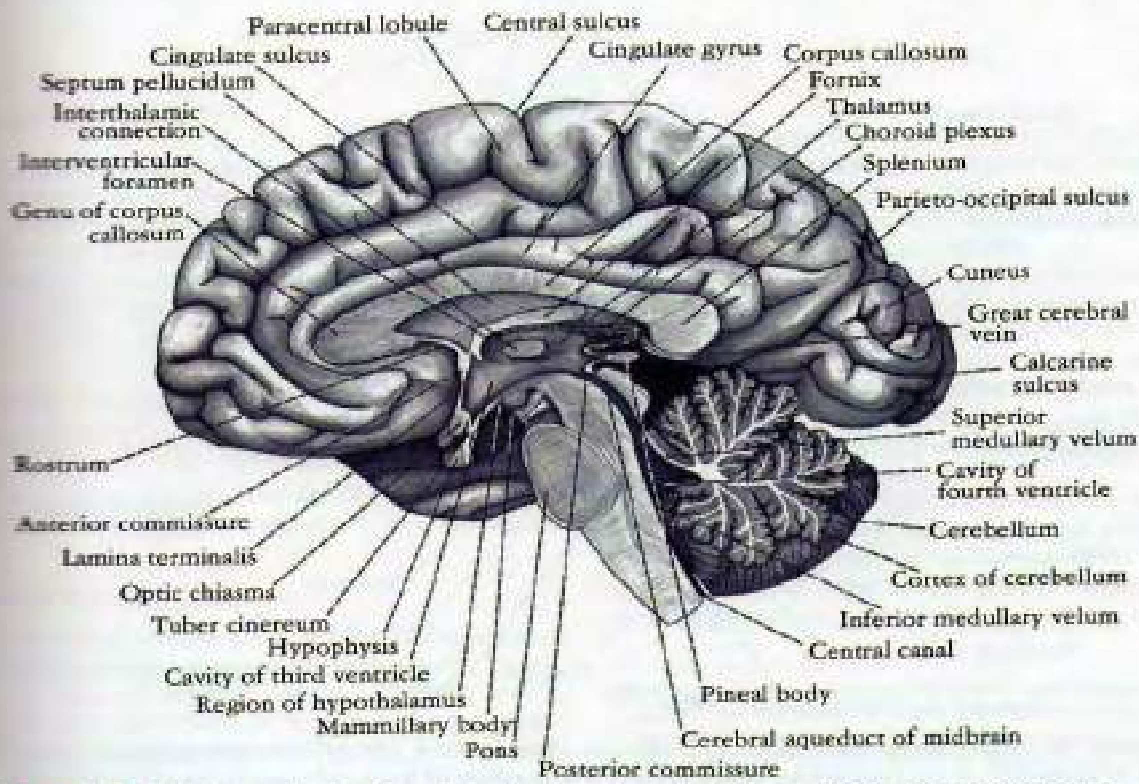


Figure 1–11 Median sagittal section of the brain to show the third ventricle, the cerebral aqueduct, and the fourth ventricle.

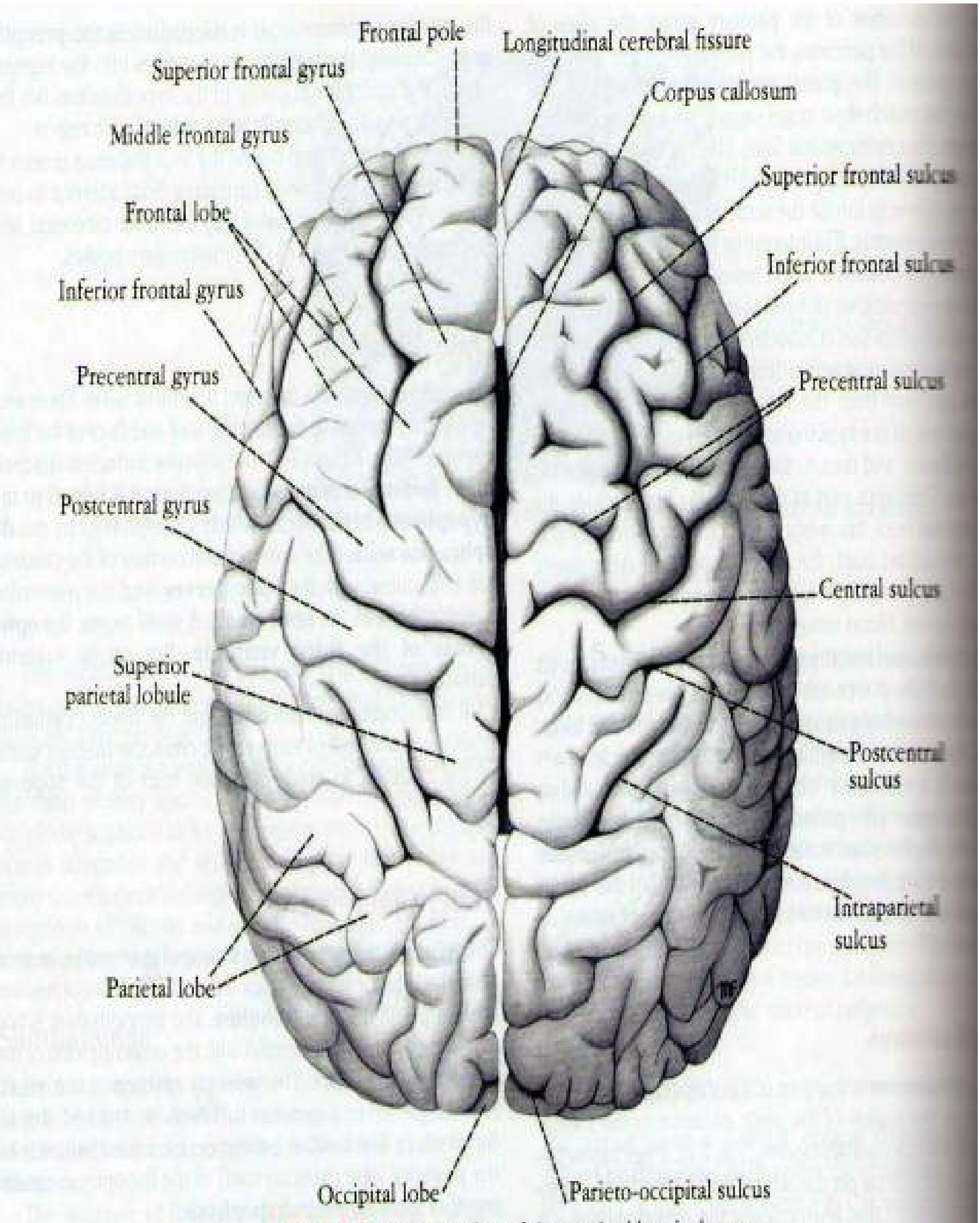


Figure 7–6 Superior view of the cerebral hemispheres.

sinuses, which are lined with mucous membrane and communicate with the nasal cavity; they serve as voice resonators.

Anteriorly, the **optic canal** transmits the optic nerve and the ophthalmic artery, a branch of the internal carotid artery, to the orbit. The **superior orbital fissure**, which is a slitlike opening between the lesser and greater wings of the sphenoid, **transmits the lacrimal, frontal, trochlear, oculomotor, nasociliary, and abducent nerves, together with the superior ophthalmic vein**. The sphenoparietal venous sinus runs medially along the posterior border of the lesser wing of the sphenoid and drains into the cavernous sinus.

The **foramen rotundum**, which is situated behind the medial end of the superior orbital fissure, perforates the greater wing of the sphenoid and transmits the **maxillary nerve** from the trigeminal ganglion to the pterygopalatine fossa.

The **foramen ovale** lies posterolateral to the foramen rotundum. It perforates the greater wing of the sphenoid and transmits the large sensory root and small motor root of the **mandibular nerve** to the infratemporal fossa; the lesser petrosal nerve also passes through it.

The small **foramen spinosum** lies posterolateral to the foramen ovale and also perforates the greater wing of the sphenoid. The foramen transmits the **middle meningeal artery** from the infratemporal fossa into the cranial cavity. The artery then runs forward and laterally in a groove on the upper surface of the squamous part of the temporal bone and the greater wing of the sphenoid. After a short distance the artery divides into anterior and posterior branches. The anterior branch passes forward and upward to the anteroinferior angle of the parietal bone. Here, the bone is deeply grooved or tunneled by the artery for a short distance before it runs backward and upward on the parietal bone. It is at this site that the artery may be damaged after a blow to the side of the head. The posterior branch passes backward and upward across the squamous part of the temporal bone to reach the parietal bone.

The large and irregularly shaped **foramen lacerum** lies between the apex of the petrous part of the temporal bone and the sphenoid bone. The inferior opening of the foramen lacerum in life is filled by cartilage and fibrous tissue, and only small blood vessels pass through this tissue from the cranial cavity to the neck.

The **carotid canal** opens into the side of the foramen lacerum above the closed inferior opening. The **internal carotid artery** enters the foramen through the carotid canal and immediately turns upward to reach the side of the body of the sphenoid bone. Here, the artery turns forward in the cavernous sinus to reach the region of the anterior clinoid process. At this point, the internal carotid artery turns vertically upward, medial to the anterior clinoid process, and emerges from the cavernous sinus.

Lateral to the foramen lacerum is an impression on the apex of the petrous part of the temporal bone for the **trigeminal ganglion**. On the anterior surface of the petrous bone are two grooves for nerves; the largest medial groove is for the **greater petrosal nerve**, a branch of the facial nerve; the smaller lateral groove is for the **lesser petrosal nerve**, a branch of the tympanic plexus. The greater petrosal nerve enters the foramen lacerum deep to the trigeminal ganglion and joins the **deep petrosal nerve** (sympathetic fibers from around the internal carotid artery), to form the **nerve of the pterygoid canal**. The lesser petrosal nerve passes forward to the foramen ovale.

The abducent nerve bends sharply forward across the apex of the petrous bone, medial to the trigeminal ganglion. Here, it leaves the posterior cranial fossa and enters the cavernous sinus.

The **arcuate eminence** is a rounded eminence found on the anterior surface of the petrous bone and is caused by the underlying **superior semicircular canal**.

The **tegmen tympani**, a thin plate of bone, is a forward extension of the petrous part of the temporal bone and adjoins the squamous part of the bone (Fig. 11-34). From behind forward, it forms the roof of the mastoid antrum, the tympanic cavity, and the auditory tube. This thin

plate of bone is the only major barrier that separates infection in the tympanic cavity from the temporal lobe of the cerebral hemisphere .

The median part of the middle cranial fossa is formed by the body of the sphenoid bone. In front is the **sulcus chiasmatis**, which is related to the optic chiasma and leads laterally to the **optic canal** on each side. Posterior to the sulcus is an elevation, the **tuberculum sellae**. Behind the elevation is a deep depression, the **sella turcica**, which lodges the hypophysis cerebri. The sella turcica is bounded posteriorly by a square plate of bone called the **dorsum sellae**. The superior angles of the dorsum sellae have two tubercles, called the **posterior clinoid processes**, which give attachment to the fixed margin of the tentorium cerebelli.

The cavernous sinus is directly related to the side of the body of the sphenoid. It carries in its lateral wall the third and fourth cranial nerves and the ophthalmic and maxillary divisions of the fifth cranial nerve. The internal carotid artery and the sixth cranial nerve pass forward through the sinus.

Posterior Cranial Fossa

The posterior cranial fossa is deep and lodges the parts of the hindbrain, namely, the **cerebellum, pons,** and **medulla oblongata**. Anteriorly the fossa is bounded by the superior border of the petrous part of the temporal bone, and posteriorly it is bounded by the internal surface of the squamous part of the occipital bone. The floor of the posterior fossa is formed by the basilar, condylar, and squamous parts of the occipital bone and the mastoid part of the temporal bone.

The roof of the fossa is formed by a fold of dura, the tentorium cerebelli, which intervenes between the cerebellum below and the occipital lobes of the cerebral hemispheres above.

The **foramen magnum** occupies the central area of the floor and transmits the medulla oblongata and its surrounding meninges, the ascending spinal parts of the accessory nerves, and the two vertebral arteries.

The **hypoglossal canal** is situated above the anterolateral boundary of the foramen magnum and transmits the hypoglossal nerve.

The **jugular foramen** lies between the lower border of the petrous part of the temporal bone and the condylar part of the occipital bone. It transmits the following structures from before backward: the **inferior petrosal sinus**; the **ninth, tenth,** and **eleventh cranial nerves**; and the large **sigmoid sinus**. The inferior petrosal sinus descends in the groove on the lower border of the petrous part of the temporal bone to reach the foramen. The sigmoid sinus turns down through the foramen to become the **internal jugular vein**.

The **internal acoustic meatus** pierces the posterior surface of the petrous part of the temporal bone. It transmits the vestibulocochlear nerve and the motor and sensory roots of the facial nerve.

The **internal occipital crest** runs upward in the midline posteriorly from the foramen magnum to the internal occipital protuberance; to it is attached the small falx cere-belli over the occipital sinus.

On each side of the internal occipital protuberance is a wide groove for the **transverse sinus**. This groove sweeps around on either side, on the internal surface of the occipital bone, to reach the posteroinferior angle or corner of the parietal bone. The groove now passes onto the mastoid part of the temporal bone, and here the transverse sinus becomes the **sigmoid sinus**. The **superior petrosal sinus** runs backward along the upper border of the petrous bone in a narrow groove and drains into the sigmoid sinus. As the sigmoid sinus descends to the jugular foramen, it deeply grooves the back of the petrous bone and the mastoid part of the temporal bone. Here, it lies directly posterior to the mastoid antrum.

Table 11-3 Summary of the More Important Openings in the Base of the Skull and the Structures That Pass Through Them

Opening in Skull	Bone of Skull	Structures Transmitted
Anterior Cranial Fossa		
Perforations in cribriform plate	Ethmoid	Olfactory nerves
Middle Cranial Fossa		
Optic canal	Lesser wing of sphenoid	Optic nerve, opthalmic artery
Superior orbital fissure	Between lesser and greater wings of sphenoid	Lacrimal, frontal, trochlear oculomotor, nasociliary, and abducent nerves; superior ophthalmic vein
Foramen rotundum	Greater wing of sphenoid	Maxillary division of the trigeminal nerve
Foramen ovale	Greater wing of sphenoid	Mandibular division of the trigeminal nerve, lesser petrosal nerve
Foramen spinosum	Greater wing of sphenoid	Middle meningeal artery
Foramen lacerum	Between petrous part of temporal and sphenoid	Internal carotid artery
Posterior Cranial Fossa		
Foramen magnum	Occipital	Medulla oblongata, spinal part of accessory nerve, and right and left vertebral arteries
Hypoglossal canal	Occipital	Hypoglossal nerve
Jugular foramen	Between petrous part of temporal and condylar part of occipital	Glossopharyngeal, vagus, and accessory nerves; sigmoid sinus becomes internal jugular vein
Internal acoustic meatus	Petrous part of temporal	Vestibulocochlear and facial nerves

Parts of the Brain

The brain is that part of the central nervous system that lies inside the cranial cavity. It is continuous with the spinal cord through the foramen magnum. It is composed of the following parts:-

1- Forebrain (consists of Cerebrum and Diencephalon)

2- Midbrain

3- Hindbrain (consists of Pons, Medulla oblongata and Cerebellum)

CEREBRUM

The cerebrum is the largest part of the brain and consists of **two cerebral hemispheres** connected by a mass of white matter called the **corpus callosum**. Each hemisphere extends from the frontal to the occipital bones, above the anterior and middle cranial fossae, and, posteriorly, above the tentorium cerebelli. The hemispheres are separated by a deep cleft, the **longitudinal fissure**, into which projects the **falx cerebri**.

The surface layer of each hemisphere is called the **cortex** and is composed of **gray matter**. The cerebral cortex is thrown into folds, or **gyri**, separated by fissures, or **sulci**. By this means the surface area of the cortex is greatly increased. Several of the large sulci conveniently subdivide the surface of each hemisphere into **lobes**. The lobes are named for the bones of the cranium under which they lie.

The **frontal lobe** is situated in front of the **central sulcus** and above the **lateral sulcus**. The **parietal lobe** is situated behind the central sulcus and above the lateral sulcus. The **occipital lobe** lies below the parieto-occipital sulcus. Below the lateral sulcus is situated the **temporal lobe**.

The **precentral gyrus** lies immediately anterior to the central sulcus and is known as the **motor area**. The large motor nerve cells in this area control voluntary movements on the opposite side of the body. Most nerve fibers cross over to the opposite side in the medulla oblongata as they descend to the spinal cord.

In the motor area the body is represented in an inverted position, with the nerve cells controlling the movements of the feet located in the upper part and those controlling the movements of the face and hands in the lower part.

The **postcentral gyrus** lies immediately posterior to the central sulcus and is known as the **sensory area**. The small nerve cells in this area receive and interpret sensations of pain, temperature, touch, and pressure from the opposite side of the body.

The **superior temporal gyrus** lies immediately below the lateral sulcus. The middle of this gyrus is concerned with the reception and interpretation of sound and is known as the auditory area.

Broca's area, or the **motor speech area**, lies just above the lateral sulcus. It controls the movements employed in speech. It is dominant in the left hemisphere in right-handed persons and in the right hemisphere in left-handed persons.

The **visual area** is situated on the posterior pole and medial aspect of the cerebral hemisphere in the region of the **calcarine sulcus**. It is the receiving area for visual impressions.

The cavity present within each cerebral hemisphere is called the **lateral ventricle**. The lateral ventricles communicate with the third ventricle through the **interventricular foramina**

DIENCEPHALON

The diencephalon is almost completely hidden from the surface of the brain. It consists of a dorsal **thalamus** and a ventral **hypothalamus**. The thalamus is a large mass of gray matter that lies on either side of the third ventricle. It is the great relay station on the afferent sensory pathway to the cerebral cortex.

The hypothalamus forms the lower part of the lateral wall and floor of the third ventricle. The following structures are found in the floor of the third ventricle from before backward: the **optic chiasma**, the **tuber cinereum** and the **infundibulum**, the **mammillary bodies**, and the **posterior perforated substance**.

MIDBRAIN

The midbrain is the narrow part of the brain that passes through the tentorial notch and connects the forebrain to the hindbrain.

The midbrain comprises two lateral halves called the **cerebral peduncles**; each of these is divided into an anterior part, the **crus cerebri**, and a posterior part, the **tegmentum**, by a pigmented band of gray matter, the **substantia nigra**. The narrow cavity of the midbrain is the cerebral aqueduct, which connects the third and fourth ventricles. The **tectum** is the part of the midbrain posterior to the cerebral aqueduct; it has four small surface swellings, namely, the **two superior** and **two inferior colliculi**. The colliculi are deeply placed between the cerebellum and the cerebral hemispheres.

The **pineal body** is a small glandular structure that lies between the superior colliculi. It is attached by a stalk to the region of the posterior wall of the third ventricle. The pineal commonly calcifies in middle age, and thus it can be visualized on radiographs.

HINDBRAIN

The **pons** is situated on the anterior surface of the cerebellum below the midbrain and above the medulla oblongata. It is composed mainly of nerve fibers, which connect the two halves of the cerebellum. It also contains ascending and descending fibers connecting the forebrain, the midbrain, and the spinal cord. Some of the nerve cells within the pons serve as relay stations, whereas others form cranial nerve nuclei.

The **medulla oblongata** is conical in shape and connects the pons above to the spinal cord below. A **median fissure** is present on the anterior surface of medulla, and on each side of this is a swelling called **pyramid**. The pyramids are composed of bundles of nerve fibers that originate in large nerve cells in the precentral gyrus of the cerebral cortex. The pyramids taper below, and here most of the descending fibers cross over to the opposite side, forming the **decussation of the pyramids**.

Posterior to the pyramids are the **olives**, which are oval elevations, produced by the underlying **olivary nuclei**. Behind the olives are the **inferior cerebellar peduncles**, which connect the medulla to the cerebellum.

On the posterior surface of the inferior part of the medulla oblongata are the **gracile** and **cuneate tubercles**, produced by the medially placed underlying **nucleus gracilis** and the laterally placed underlying **nucleus cuneatus**.

The **cerebellum** lies within the posterior cranial fossa beneath the tentorium cerebelli. It is situated posterior to the pons and medulla oblongata. It is consists of of two hemispheres connected by a median portion, the **vermis**. The cerebellum is connected to the midbrain by the **superior cerebellar peduncles**, to the pons by the **middle cerebellar peduncles**, and to the medulla by the **inferior cerebellar peduncles**.

The surface layer of each cerebellar hemisphere, called the **cortex**, is composed of gray matter. The cerebellar cortex is thrown into folds, or **folia**, separated by closely se transverse fissures. Certain masses of gray matter are fount in the interior of the cerebellum, embedded in the white matter; the largest of these is known as the **dentate nucleus**.

The cerebellum plays an important role in the control of muscle tone and the coordination of muscle movement of muscle movements on the same side of the body.

The cavity of the hindbrain is the fourth ventricle. This is bounded in front by the pons and the medulla oblongata and behind by the **superior** and **inferior medullary vela** and the cerebellum. The fourth ventricle is connected above to the third ventricle by the cerebral aqueduct, and below it is continuous with the central canal of the spinal cord. It communicates with the subarachnoid space through three openings in the lower part of the roof: a median and two lateral openings.

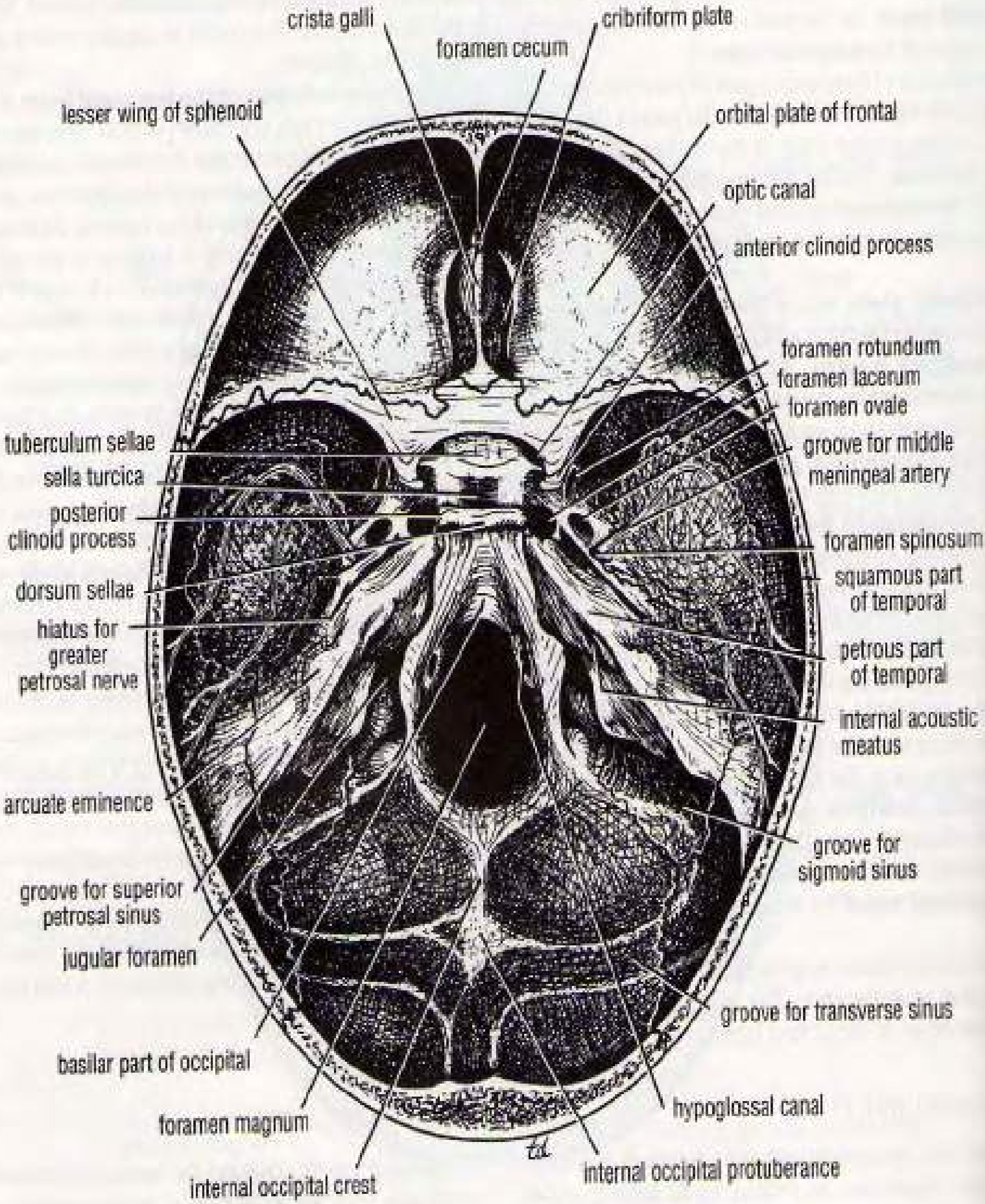


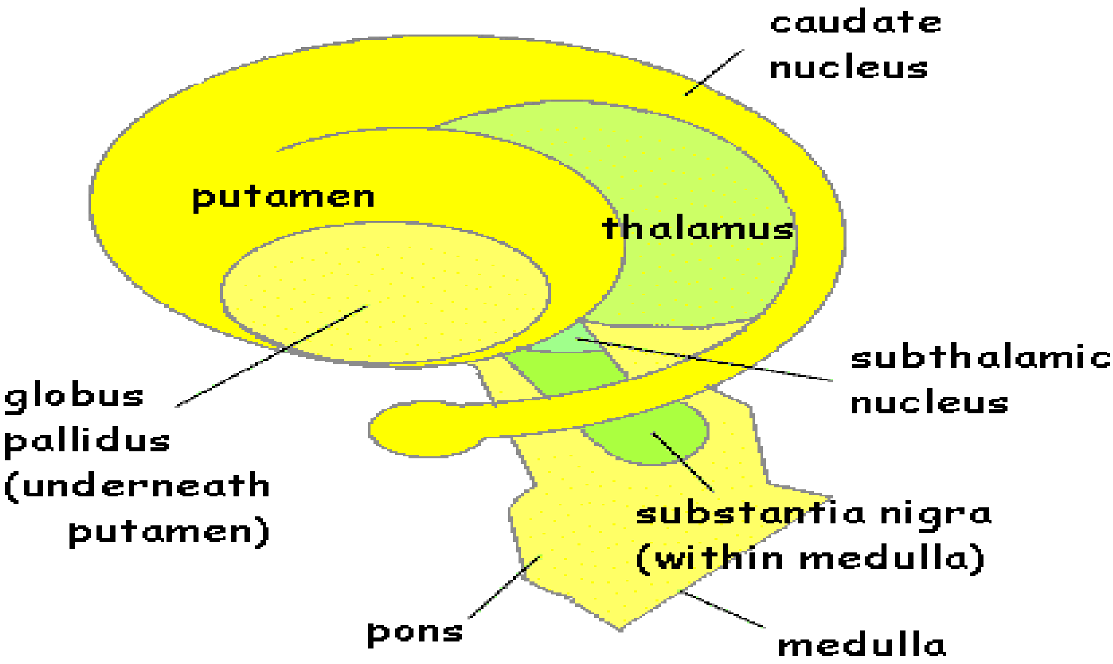
Figure 11-34 Internal surface of the base of the skull.

The Basal Ganglia

Dr. Mohammad Ahmad Abdulla

The **basal ganglia** are a collection of nuclei found on both sides of the thalamus, outside and above the limbic system, but below the cingulate gyrus and within the temporal lobes. Although glutamate is the most common neurotransmitter here as everywhere in the brain, the inhibitory neurotransmitter GABA plays the most important role in the basal ganglia.

1- The largest group of these nuclei are called the ***corpus striatum*** ("striped body"), made up of:
A- the **caudate nucleus** ("tail"), **B-** the **lentiform nucleus** that itself composed of two parts; the **putamen** ("shell"),and the **globus pallidus** ("pale ball"), All of these structures a double ones, one set on each side of the central septum.



The **caudate** begins just behind the frontal lobe and curves back towards the occipital lobe. It is an elongated C-shaped mass of gray matter with large rounded head, curved body and long slender tail. It is closely related to the lateral ventricle. Around the rostral border of the internal capsule, it is fused with the putamen of the lentiform nucleus while its tail terminates in close relationship to the amygdala. It sends its messages to the frontal lobe (especially the orbital cortex, just above the eyes), and appears to be responsible **for informing us that something is not right and we should do something about it**: Wash your hands! Lock your door! As these examples are meant to suggest, **obsessive compulsive disorder** (OCD) is likely to involve an **overactive** caudate. On the other hand, an **underactive** caudate may be involved in various disorders, **depression**, and **lethargy**.

The **putamen** lies just below and behind the front of the caudate. It appears to be involved in **coordinating automatic behaviors** such as riding a bike, driving a car.

The **globus pallidus** is located just inside the putamen, with an outer part and an inner part. It receives inputs from the caudate and putamen and provides outputs to the substantia nigra. Responsible for **regulation of muscle tone required for body movements**.

2- Another nucleus of the basal ganglia is the ***substantia nigra*** ("black substance"). Located in the upper portions of the midbrain, below the thalamus, it gets its color from neuromelanin, a close relative of the skin pigment. The exact function isn't known, but is believed to involve **reward circuits**. Also, **Parkinson's disease** is due to the death of dopamine neurons here.

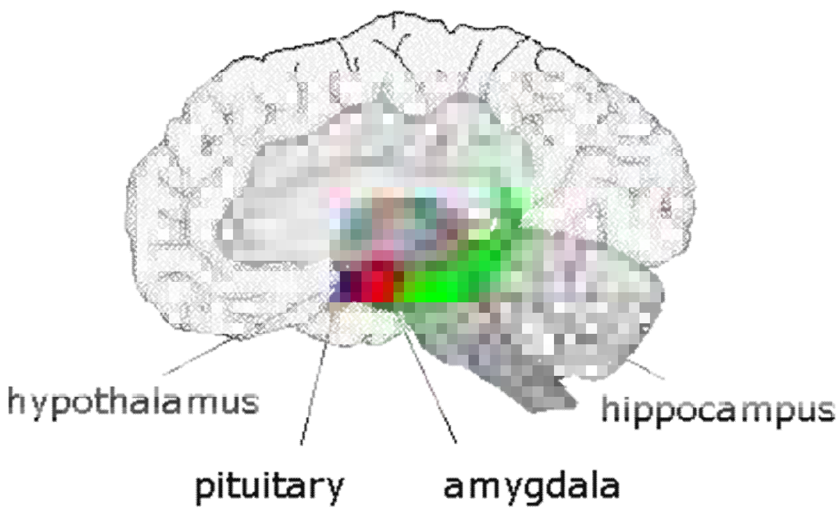
3- *Subthalamic nucleus*: present in thalamus. Damage of it result in **hemiballismus (Half jumping)** which is characterized by involuntary purposeless movements suddenly occurred with force and rapidly.

4- *Red nucleus*:-present in tegmentum of midbrain concerned with **muscle activity.**

5- *Claustrum*: means 'hidden away', it is a thin, irregular sheet of grey matter, concealed between the inner surface of the cerebral cortex. It lies below the general region of the insula, and above the outer surface of the putamen, with a fibre tract on each side of it (external capsule). The claustrum is **not** located everywhere beneath the cerebral cortex. It is mainly, but not entirely, in the general region of the insular cortex. The claustrum may contain specialized mechanisms that permit information to travel widely **to synchronize different perceptual, cognitive and motor modalities**.

The Limbic System

It is also called the (Emotional Nervous System). The limbic system consists of an odd collection of separate parts. 'Limbic' comes from the Latin word for 'belt'. Most parts of the limbic system are within the telencephalon. The limbic system is a complex set of structures that lies on both sides of the thalamus, just under the cerebrum. It includes the hypothalamus, the hippocampus, the amygdala, and several others nearby areas. It appears to be primarily responsible for our **emotional life**, and has a lot to do with **the formation of memories**.



1- Hypothalamus:

The hypothalamus is a small part of the brain located just below the thalamus on both sides of the third ventricle. (The ventricles are areas within the cerebrum that are filled with cerebrospinal fluid, and connect to the fluid in the spine.) It sits just inside the two tracts of the optic nerve, and just above (and intimately connected with) the pituitary gland.

The hypothalamus is one of the busiest parts of the brain, and is mainly concerned with **homeostasis**. Homeostasis is the process of returning something to some “set point.” It works like a thermostat: When a room gets too cold, the thermostat conveys that information to the furnace and

turns it on. As the room warms up and the temperature gets beyond a certain point, it sends a signal that tells the furnace to turn off.

The hypothalamus is responsible for **regulating the degree of hunger, thirst, response to pain, levels of pleasure, sexual satisfaction, anger and aggressive behavior, and more**. It also regulates the functioning of the **autonomic nervous system**, which in turn means it regulates things like pulse, blood pressure, breathing, and arousal in response to emotional circumstances.

The hypothalamus receives inputs from a number of sources:- From the **vagus nerve**, it gets information about blood pressure and the distension of the gut (that is, how full your stomach is). From the **reticular formation in the brainstem**, it gets information about skin temperature. From the **optic nerve**, it gets information about light and darkness. From the **neurons lining the ventricles**, it gets information about the contents of the cerebrospinal fluid, including toxins that lead to vomiting. And from the other parts of the limbic system and the **olfactory** (smell) **nerves**, it gets information that helps regulate eating and sexuality. The hypothalamus also has some receptors of its own, that provide information about **ion balance and temperature of the blood**.

The hypothalamus sends instructions to the rest of the body in two ways:- The first is to the **autonomic nervous system**. This allows the hypothalamus to have ultimate control of things like blood pressure, heart rate, breathing, digestion, sweating, and all the sympathetic and parasympathetic functions.

The second way the hypothalamus controls things is via the **pituitary gland**. It is neurally and chemically connected to the pituitary, which in turn pumps hormones called releasing factors into the bloodstream. As the pituitary is called "master gland," and these hormones are vitally important in regulating growth and metabolism.

2- Hippocampus:

The hippocampus consists of two "horns" that curve back from the amygdala. It appears to be very important in converting things that are at the moment (in short-term memory) into things that you will remember for the long time (long-term memory). If the hippocampus is damaged, a person cannot build new memories and lives instead in a strange world where everything they experience just fades away, even while older memories from the time before the damage are untouched. The hippocampus becomes damaged in Alzheimer's disease.

3- Amygdala:

The amygdalas are two almond-shaped masses of neurons on either side of the thalamus at the lower end of the hippocampus, also called the amygdaloid complex. It is a large composite nucleus in the anterior temporal lobe beneath the uncus. When it is stimulated electrically, respond with **aggression**. And if the amygdala is removed, no longer respond to things that would have caused rage before. But there is more to it than just anger: When removed, also become **indifferent to stimuli** that would have otherwise have caused fear and even sexual responses.

4- Related areas of Limbic system:-

Besides the hypothalamus, hippocampus, and amygdala, there are other areas in the structures near to the limbic system that are intimately connected to it:

A- **The limbic cortex (gyrus) or lobe** that composed of parahippocampal gyrus, hippocampus and cingulate gyrus.

The **cingulate gyrus** is the part of the cerebrum that lies closest to the limbic system, just above the corpus collosum. The cingulate gyrus provides a pathway from the thalamus to the hippocampus, seems to be responsible for **focusing attention on emotionally significant events**, and **for associating memories to smells and to pain.**

B- The **dentate gyrus** is present between the hippocampus and the parahippocampal gyrus, is involved in **creating new memories** and is one of the few areas in the adult brain where there is neurogenesis (birth of neurons). It is also involved in stress and depression.

C- The **ventral tegmental area** of the brain stem (just below the thalamus) consists of dopamine pathways that seem to be responsible for **pleasure**. People with damage here tend to have difficulty getting pleasure in life, and often turn to alcohol, drugs, sweets, and gambling.

D- Parts from the **basal ganglia** lie over and to the sides of the limbic system, and are tightly connected with the cortex above them. They are responsible for **repetitive behaviors, reward experiences, and focusing attention**.

E- The **prefrontal cortex**, which is the part of the frontal lobe which lies in front of the motor area, is also closely linked to the limbic system. Besides apparently being involved in **thinking about the future, making plans, and taking action**, it also appears to be involved in the same dopamine pathways as the ventral tegmental area, and **plays a part in pleasure and addiction**.

G- Mammillary bodies: are two small structures (that look like breasts), located in the lower limbic system, near the anterior arches of the fornix. They are considered to a part of the hypothalamus and act as a relay for signals from the amygdala and hippocampus to the thalamus.

H- The **anterior thalamic nuclei**: **modulate alertness and are involved in learning and memory.**

I- The **septal nuclei; under the corpus collosum.**

J- Olfactory Bulb: about smell.

The Reticular Formation

- It's a '**diffuse net**' which is formed by nerve cells & fibers
- It extends from the **neuroaxis spinal cord through medulla, pons, midbrain, subthalamus, hypothalamus & thalamus** (Spinal cord is relayed superiorly to the cerebral cortex)
- Many afferent & efferent pathways project in & out of the RF **from most parts of the CNS**
- Reticular formation can be divided into 3 columns : **Median, Medial & Lateral** columns
- Functions of the reticular formation

1. Control of skeletal muscles
    - Modulate muscle tone & reflex activities (Via **reticulospinal & reticulo bulbar** tracts)
    - Important in controlling muscles of facial expression when associated with emotions
2. Control somatic & visceral sensation (Influence can be **excitatory or inhibitory**)
3. Control of autonomic nervous system
4. Control of endocrine nervous system (Hypothalamus & the pituitary)
5. Influence on the biological clock (Rhythm)
6. The reticular activating system (Arousal & level of consciousness are controlled by the RF)

Lecture 4 in Anatomy of CNS

By

Dr. Mohammad Ahmad Abdulla

THALAMUS

The thalamus is a large, egg-shaped mass of gray matter that forms the major part of the diencephalon. There are two thalami and one is situated on each side of the third ventricle. The anterior end of the thalamus is narrow and rounded and forms the posterior boundary of the interventricular foramen. The posterior end is expanded to form the **pulvinar**, which overhangs the superior colliculus. The inferior surface is continuous with the tegmentum of the midbrain. The medial surface of the thalamus forms part of the lateral wall of the third ventricle and is usually connected to the opposite thalamus by a band of gray matter, the **interthalamic connection** (interthalamic adhesion).

SUBDIVISIONS OF THE THALAMUS

The thalamus is covered on its superior surface by a thin layer of white matter, called the **stratum zonale** , and on its lateral surface by another layer, the **external medullary lamina** . The gray matter of the thalamus is divided by a vertical sheet of white matter, the **internal medullary lamina**, into medial and lateral halves.

Each of the three parts of the thalamus contains a group of thalamic nuclei. Moreover, smaller nuclear groups are situated within the internal medullary lamina, and some are located on the medial and lateral surfaces of the thalamus.

I- Anterior Part

This part of the thalamus contains the **anterior thalamic nuclei**. They receive the mammillothalamic tract from the mammillary nuclei. These anterior thalamic nuclei also receive reciprocal connections with the cingulate gyrus and hypothalamus. The function of the anterior thalamic nuclei is closely associated with that of the limbic system and is concerned with emotional tone and the mechanisms of recent memory.

II- Medial Part

This part of the thalamus contains the **large dorsomedial nucleus and several smaller nuclei**. The dorsomedial nucleus has two-way connections with the whole prefrontal cortex of the frontal lobe of the cerebral hemisphere. It is interconnected with all other groups of thalamic nuclei. The medial part of the thalamus is responsible for the integration of a large variety of sensory information, including somatic, visceral, and olfactory information, and the relation of this information to one's emotional feelings and subjective states.

III- Lateral Part

The nuclei are subdivided into a dorsal tier and a ventral tier:-

A- Dorsal tier of the nuclei

This tier includes the **lateral dorsal nucleus,** the **lateral posterior nucleus,** and the **pulvinar**. The details of the connections of these nuclei are not clear. They are known, however, to have interconnections with other thalamic nuclei, and with the parietal lobe, cingulate gyrus, and occipital and temporal lobes.

B- Ventral tier of the nuclei

This tier consists of the following in a craniocaudal sequence:

1. **Ventral anterior nucleus**. This nucleus is connected to the reticular formation, the substantia nigra, the corpus striatum, and the premotor cortex as well as to many of the other thalamic nuclei. Since this nucleus lies on the pathway between the corpus striatum and the motor areas of the frontal cortex, it probably influences the activities of the motor cortex.
2. **Ventral lateral nucleus**. This nucleus has connections similar to those of the ventral anterior nucleus but, in addition, has a major input from the cerebellum and a minor input from the red nucleus. Its main projections pass to the motor and premotor regions of the cerebral cortex. Here again this thalamic nucleus probably influences motor activity.
3. **Ventral posterior nucleus**. This nucleus is subdivided into the **ventral posteromedial nucleus** and the **ventral posterolateral nucleus**. The ventral posteromedial nucleus receives the ascending trigeminal and gustatory pathways, while the ventral posterolateral nucleus receives the important ascending sensory tracts, the medial and spinal lemnisci. The thalamocortical projections from these important nuclei pass through the posterior limb of the internal capsule and corona radiata to the primary somatic sensory areas of the cerebral cortex in the postcentral gyrus (areas 3, 1, and 2).

IV- Other Nuclei of the Thalamus

These nuclei include the intralaminar nuclei, the midline nuclei, the reticular nucleus, and the medial and lateral geniculate bodies.

1-The intralaminar nuclei are small collections of nerve cells within the internal medullary lamina. The nuclei are believed to influence the levels of consciousness and alertness in an individual.

2-The midline nuclei consist of groups of nerve cells adjacent to the third ventricle and in the interthalamic connection. They receive afferent fibers from the reticular formation. Their precise functions are unknown.

3-The reticular nucleus is a thin layer of nerve cells sandwiched between the external medullary lamina and the posterior limb of the internal capsule. The function of this nucleus is not fully understood, but it may be concerned with a mechanism by which the cerebral cortex regulates thalamic activity.

4-The medial geniculate body forms part of the auditory pathway and is a swelling on the posterior surface of the thalamus beneath the pulvinar. Afferent fibers to the medial geniculate body form the **inferior brachium** and come from the inferior colliculus. It will be remembered that the inferior colliculus receives the termination of the fibers of the lateral lemniscus. The medial geniculate body receives auditory information from both ears but predominantly from the opposite ear.

The efferent fibers leave the medial geniculate body to form the auditory radiation, which passes to the auditory cortex of the superior temporal gyrus.

5-The lateral geniculate body forms part of the visual pathway and is a swelling on the undersurface of the pulvinar of the thalamus. The nucleus consists of six layers of nerve cells and is the terminus of all but a few fibers of the optic tract (except the fibers passing to the pretectal nucleus). The fibers are the axons of the ganglion cell layer of the retina and come from the temporal half of the ipsilateral eye and from the nasal half of the contralateral eye, the latter fibers crossing the midline in the optic chiasma. Each lateral geniculate body therefore, receives visual information from the opposite field of vision.

The efferent fibers leave the lateral geniculate body to form the visual radiation, which passes to the visual cortex of the occipital lobe.

HYPOTHALAMUS

The hypothalamus, although small (0.3% of the total brain), is a very important part of the central nervous system. **It controls the autonomic nervous system and the endocrine system and thus indirectly controls body homeostasis**. The hypothalamus is well placed for this purpose, lying in the center of the limbic system. It is the site of numerous converging and diverging neuronal pathways and through its adequate blood supply it is able to sample the blood chemistry. The hypothalamus makes appropriate controlling responses following the integration of its nervous and chemical inputs.

The hypothalamus is that part of the diencephalon that extends from the region of the optic chiasma to the caudal border of the mammillary bodies. It lies below the thalamus and forms the floor and the inferior part of the lateral walls of the third ventricle. Anterior to the hypothalamus is an area that for functional reasons is often included in the hypothalamus. Because it extends forward from the optic chiasma to the lamina terminalis and the anterior commissure, it is referred to as the preoptic area. Caudally, the hypothalamus merges into the tegmentum of the midbrain. The lateral boundary of the hypothalamus is formed by the internal capsule.

When observed from below, the hypothalamus is seen to be related to the following structures, from anterior to posterior (1) the optic chiasma, (2) the tuber cinereum and the infundibulum, and (3) the mammillary bodies.

HYPOTHALAMIC NUCLEI

For purposes of description, the nuclei are divided by an imaginary parasagittal plane into medial and lateral zones. Lying within the plane are the columns of the fornix and the mammillothalamic tract, which serve as markers.

Medial Zone

In the medial zone, the following hypothalamic nuclei can be recognized, <u>from anterior to posterior</u>**:** **(1) part of the preoptic nucleus; (2) the anterior nucleus, which merges with the preoptic nucleus; (3) part of the suprachiasmatic nucleus; (4) the paraventricular nucleus; (5) the dorsomedial nucleus; (6) the ventromedial nucleus; (7) the infundibular (arcuate) nucleus; and (8) the posterior nucleus**.

Lateral Zone

In the lateral zone, the following hypothalamic nuclei can be recognized, <u>from anterior to posterior</u>: **(1) part of the preoptic nucleus, (2) part of the suprachiasmatic nucleus, (3) the supraoptic nucleus, (4) the lateral nucleus, (5) the tuberomamillary nucleus, and (6) the lateral tuberal nuclei.**

Some of the nuclei, for example, the preoptic nucleus, the suprachiasmatic nucleus, and the mammillary nuclei, overlap both zones. It should be emphasized that most of the hypothalamic nuclei have ill-defined boundaries.

Hypothalamic Lines of Communication

The hypothalamus receives information from the rest of the body through (1) Nervous connections, (2) Bloodstream, and (3) Cerebrospinal fluid. The neurons of the hypothalamic nuclei respond and exert their control via the same routes. The cerebrospinal fluid may serve as a conduit between the neurosecretory cells of the hypothalamus and distant sites of the brain.

AFFERENT NERVOUS CONNECTIONS OF THE HYPOTHALAMUS

The hypothalamus, which lies in the center of the limbic system, receives many afferent fibers from the viscera, the olfactory mucous membrane, the cerebral cortex, and the limbic system.

The afferent connections are numerous and complex; the main pathways are as follows:

1.Somatic and Visceral afferents. General somatic sensation, gustatory and visceral sensations, reach the hypothalamus through collateral branches of the lemniscal afferent fibers and the tractus solitarius, and through the reticular formation**.**

2.Visual afferents leave the optic chiasma and pass to the suprachiasmatic nucleus.

3.Olfaction travels through the medial forebrain bundle.

4.Auditory afferents have not been identified but since auditory stimuli can influence the activities of the hypothalamus they must exist.

5.Cortico-hypothalamic fibers arise from the frontal lobe of the cerebral cortex and pass directly to the hypothalamus.

6.Hippocampo-hypothalamic fibers pass from the hippocampus through the fornix to the mammillary body. Many neurophysiologists regard the hypothalamus as the main output pathway of the limbic system.

7.Amygdalo-hypothalamic fibers pass from the amygdaloid complex to the hypothalamus through the stria terminalis and by a route that passes inferior to the lentiform nucleus.

8.Thalamo-hypothalamic fibers arise from the dorsomedial and midline thalamic nuclei.

9.Tegmental fibers arise from the midbrain.

EFFERENT NERVOUS CONNECTIONS OF THE HYPOTHALAMUS

The efferent connections of the hypothalamus are also numerous and complex, and only the main pathways are described here:

1. **Descending fibers to the brainstem and spinal cord**: influence the peripheral neurons of the autonomic nervous system. They descend through a series of neurons in the reticular formation. The hypothalamus is connected to the parasympathetic nuclei of the oculomotor, facial, glossopharyngeal, and vagus nerves in the brainstem. In a similar manner, the reticulospinal fibers connect the hypothalamus with sympathetic cells of origin in the lateral gray horns of the first thoracic segment to the second lumbar segment of the spinal cord and the sacral parasympathetic outflow at the level of the second, third, and fourth sacral segments of the spinal cord.

2. The mammillothalamic tract arises in the mammillary body and terminates in the anterior nucleus of the thalamus. Here the pathway is relayed to the cingulate gyrus.

3. The mammillotegmental tract arises from the mammillary body and terminates in the cells of the reticular formation in the tegmentum of the midbrain.

4. Multiple pathways to the **limbic system.**

CONNECTIONS OF THE HYPOTHALAMUS WITH THE HYPOPHYSIS CEREBRI

The hypothalamus is connected to the hypophysis cerebri (pituitary gland) by two pathways: (1) nerve fibers that travel from the supraoptic and paraventricular nuclei to the posterior lobe of the hypophysis, and (2) long and short portal blood vessels that connect sinusoids in the median eminence and infundibulum with capillary plexuses in the anterior lobe of the hypophysis. These pathways enable the hypothalamus to influence the activities of the endocrine glands.

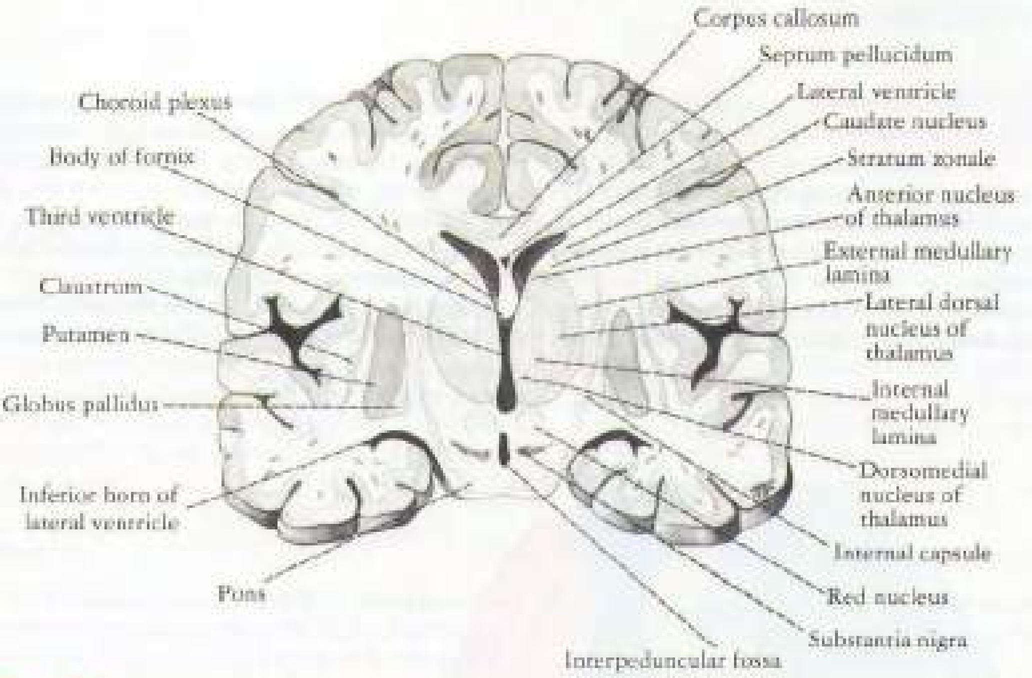


Figure 12-1 Coronal section of the cerebral hemispheres, showing the position and relations of the thalamus.

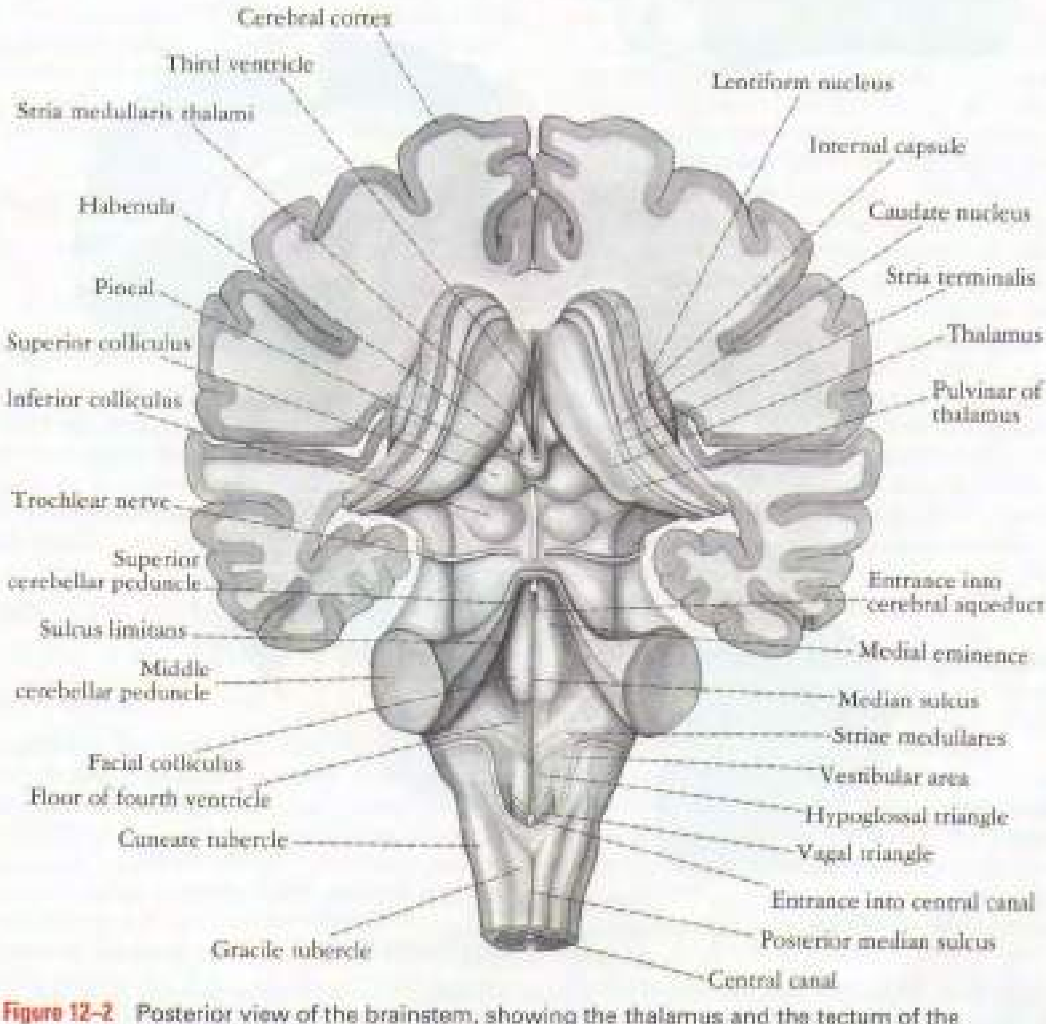


Figure 12-2 Posterior view of the brainstem, showing the thalamus and the tectum of the midbrain.

Table 12-1 The Various Thalamic Nuclei, Their Nervous Connections, and Their Functions

Thalamic Nucleus	Afferent Neuronal Loop	Efferent Neuronal Loop	Function
Anterior	Mammillothalamic tract, cingulate gyrus, hypothalamus	Cingulate gyrus, hypothalamus	Emotional tone, mechanisms of recent memory
Dorsomedial	Prefrontal cortex, hypothalamus, other thalamic nuclei	Prefrontal cortex, hypothalamus, other thalamic nuclei	Integration of somatic, visceral, and olfactory information and relation to emotional feelings and subjective states
Lateral dorsal, lateral posterior, pulvinar	Cerebral cortex, other thalamic nuclei	Cerebral cortex, other thalamic nuclei	Unknown
Ventral anterior	Reticular formation, substantia nigra, corpus striatum, premotor cortex, other thalamic nuclei	Reticular formation, substantia nigra, corpus striatum, premotor cortex, other thalamic nuclei	Influences activity of motor cortex
Ventral lateral	As in ventral anterior nucleus but also major input from cerebellum and minor input from red nucleus		Influences motor activity of motor cortex
Ventral posteromedial (VPM)	Trigeminal lemniscus, gustatory fibers	Primary somatic sensory (areas 3, 1, and 2) cortex	Relays common sensations to consciousness
Ventral posterolateral (VPL)	Medial and spinal lemnisci	Primary somatic sensory (areas 3, 1, and 2) cortex	Relays common sensations to consciousness
Intralaminar	Reticular formation, spinothalamic and trigeminothalamic tracts	To cerebral cortex via other thalamic nuclei, corpus striatum	Influences levels of consciousness and alertness
Midline	Reticular formation	Unknown	Unknown
Reticular	Cerebral cortex, reticular formation	Other thalamic nuclei	? Cerebral cortex regulates thalamus
Medial geniculate body	Inferior colliculus, lateral lemniscus from both ears but predominantly the contralateral ear	Auditory radiation to superior temporal gyrus	Hearing
Lateral geniculate body	Optic tract	Optic radiation to visual cortex of occipital lobe	Visual information from opposite field of vision

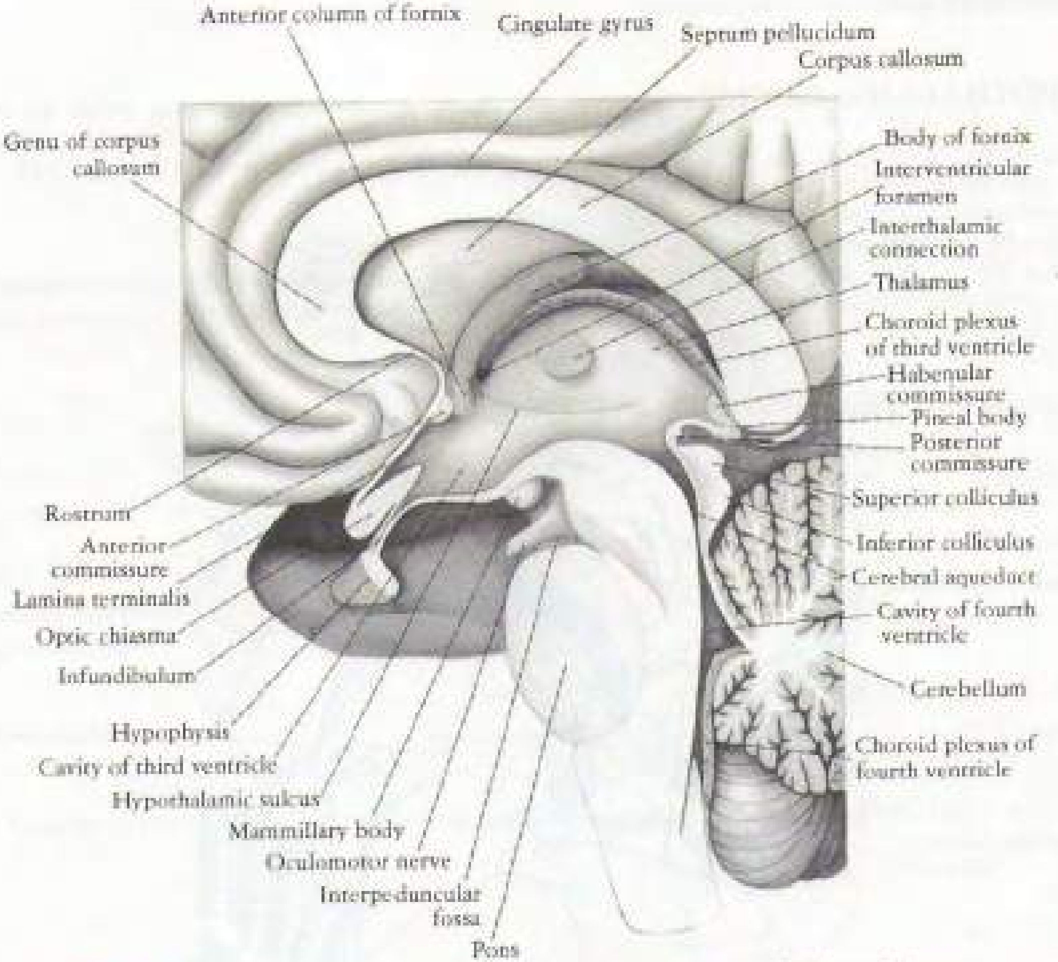


Figure 13–1 Sagittal section of the brain, showing the position of the hypothalamus.

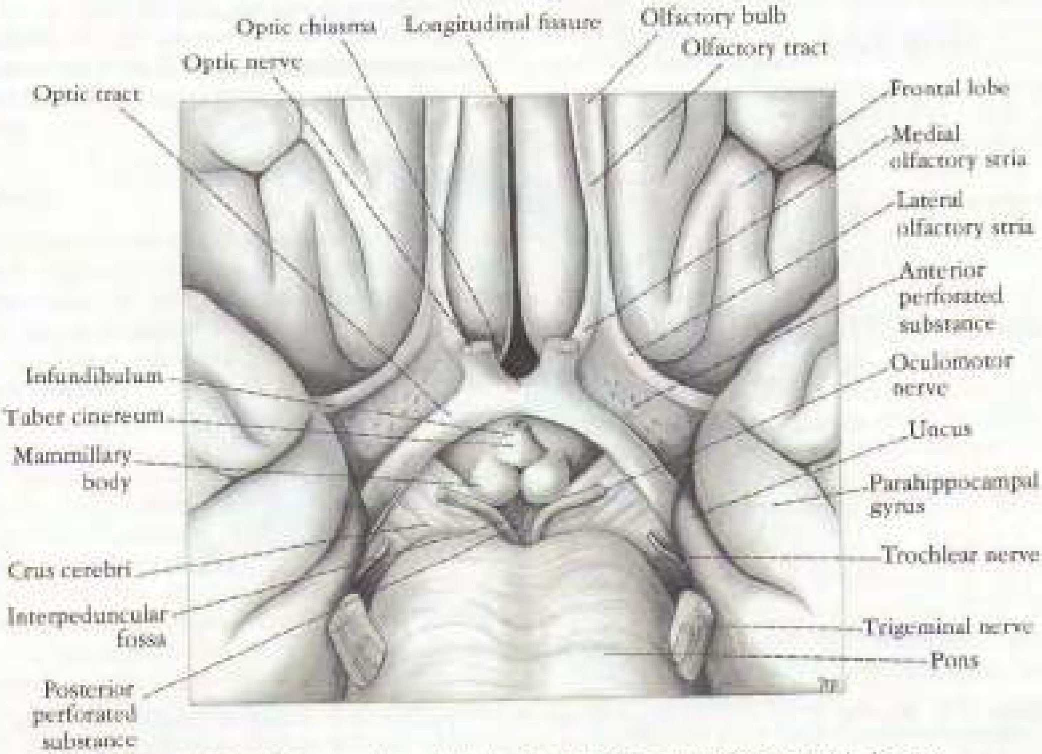


Figure 13–2 Inferior surface of the brain, showing parts of the hypothalamus.

Lecture 5 in Anatomy of CNS

By

Dr. Mohammad Ahmad Abdulla

The Brainstem

The brainstem is made up of the medulla oblongata, the pons, and the midbrain and occupies the posterior cranial fossa of the skull. It is stalk-like in shape and connects the narrow spinal cord with the expanded forebrain.

The brainstem has three broad functions:

1. It serves as a conduit for the ascending tracts and descending tracts connecting the spinal cord to the different parts of the higher centers in the forebrain.
2. It contains important reflex centers associated with the control of respiration and the cardiovascular system; it also is associated with the control of consciousness.
3. It contains the important nuclei of cranial nerves III through XII.

Midbrain

Gross Appearance of the Midbrain

The midbrain measures about 0.8 inch (2 cm) in length and connects the pons and cerebellum with the forebrain. Its long axis inclines anteriorly as it ascends through the opening in the tentorium cerebelli. The midbrain is traversed by a narrow channel, the **cerebral aqueduct**, which is filled with cerebrospinal fluid.

On the posterior surface are four colliculi (corpora quadrigemina). These are rounded eminences that are divided into superior and inferior pairs by a vertical and a transverse groove. The superior colliculi are centers for visual reflexes, and the inferior are lower auditory centers. In the midline below the inferior colliculi the **trochlear nerves** emerge.

On the lateral aspect of the midbrain, the superior and inferior brachia ascend in an anterolateral direction. The **superior brachium** passes from the superior colliculus to the lateral geniculate body and the optic tract. The **inferior brachium** connects the inferior colliculus to the **medial geniculate body**.

On the anterior aspect of the midbrain there is a deep depression in the midline, the **interpeduncular fossa**, which is bounded on either side by the **crus cerebri**. Many small blood vessels perforate the floor of the interpeduncular fossa and this region is termed the **posterior perforated substance**. The oculomotor nerve emerges from a groove on the medial side of the crus cerebri and passes forward in the lateral wall of the cavernous sinus.

Internal Structure of the Midbrain

The midbrain comprises two lateral halves, called the **cerebral peduncles**; each of these is divided into an anterior part, the **crus cerebri**, and a posterior part, the **tegmentum**, by a pigmented band of gray matter, the **substantia nigra**. The narrow cavity of the midbrain is the **cerebral aqueduct**, which connects the third and fourth ventricles. The **tectum** is the part of the midbrain posterior to the cerebral aqueduct; it has four small surface swellings referred to previously: the **two superior** and **two inferior colliculi**. The **cerebral aqueduct** is lined by ependyma and is surrounded by the central gray matter. On transverse sections of the midbrain the interpeduncular fossa can be seen to separate the crura cerebri, whereas the tegmentum is continuous across the median plane.

The important structures of Midbrain includes the following:-

1- The **inferior colliculus**, consisting of a large nucleus of gray matter, lies beneath the corresponding surface elevation and forms part of the auditory pathway. It receives many of the terminal fibers of the lateral lemniscus. The pathway then continues through the inferior brachium to the medial geniculate body.
2- The **superior colliculus**, a large nucleus of gray matter that lies beneath the corresponding surface elevation, forms part of the visual reflexes. It is connected to the lateral geniculate body by the superior brachium. It receives afferent fibers from the optic nerve, the visual cortex, and the spinotectal tract. The efferent fibers form the tectospinal and tectobulbar tracts, which are probably responsible for the reflex movements of the eyes, head, and neck in response to visual stimuli.
3- The **pretectal nucleus** which is the afferent pathway for the **light reflex** ends in it; this nucleus situated close to the lateral part of the superior colliculus. After relaying in the pretectal nucleus, the fibers pass to parasympathetic nucleus of the oculomotor nerve.
4- **The parasympathetic nucleus of the oculomotor nerve (Edinger-Westphal nucleus)**. The emerging fibers then pass to the oculomotor nerve.
5- The **oculomotor nucleus** is situated in the central gray matter close to the median plane, just posterior to the medial longitudinal fasciculus. The fibers of the oculomotor nucleus pass anteriorly through the red nucleus to emerge on the medial side of the crus cerebri in the interpeduncular fossa.
6- The **trochlear nerve nucleus** is situated in the central gray matter close to the median plane just posterior to the medial longitudinal fasciculus. The trochlear nerve leave the midbrain just below the inferior colliculi and its fibers decussate completely in the superior medullary velum.
7- The **mesencephalic nuclei of the trigeminal nerve** are lateral to the cerebral aqueduct.
8- The **substantia nigra** is a large motor nucleus situated between the tegmentum and the crus cerebri and is found throughout the midbrain. The nucleus is composed of neurons that possess inclusion granules of melanin pigment within their cytoplasm. The substantia nigra is concerned with muscle tone and is connected to the cerebral cortex, spinal cord, hypothalamus, and basal nuclei.
9- The **red nucleus** is a rounded mass of gray matter situated between the cerebral aqueduct and the substantia nigra. Its reddish, seen in fresh specimens, is due to its vascularity and the presence of an iron-containing pigment in the cytoplasm of many of its neurons.
   Afferent fibers reach the red nucleus from:-
   - **A-** the cerebral cortex through the corticospinal fibers.
   - **B-** the cerebellum through the superior cerebellar peduncle.
   - **C-** the lentiform nucleus, subthalamic and hypothalamic nuclei, substantia nigra, and spinal cord.

   Efferent fibers leave the red nucleus and pass to;-
   - **A-** the spinal cord through the rubrospinal tract.
   - **B-** the reticular formation through the rubroreticular tract.
   - **C-** the thalamus.
   - **D-** the substantia nigra.
10- The **lemnisci** which includes the followings:-
   - **A-** The **medial lemniscus** ascends posterior to the substantia nigra.
   - **B-** The **spinal** and **trigeminal lemnisci** are situated lateral to the medial lemniscus.
   - **C-** The **lateral lemniscus** is located posterior to the trigeminal lemniscus
11- The **important descending tracts** that present in crus cerebri; the corticospinal, corticonuclear, frontopontine and temporopontine. These descending tracts connect the

cerebral cortex to the anterior gray column cells of the spinal cord, the cranial nerve nuclei, the pons, and the cerebellum.

12- The **decussation of the superior cerebellar peduncles** occupies the central part of the tegmentum anterior to the cerebral aqueduct.

13- The **reticular formation** is smaller than that of the pons and is situated lateral to the decussation.

The Pons

Gross Appearance of the Pons:-

The pons is anterior to the cerebellum and connects the medulla oblongata to the midbrain. It is about 1 inch (2.5 cm) long and owes its name to the appearance presented on the anterior surface, which is that of a bridge connecting the right and left cerebellar hemispheres.

The anterior surface is convex from side to side and shows many transverse fibers that converge on each side to form the **middle cerebellar peduncle**. There is a shallow groove in the midline, the **basilar groove**, which lodges the basilar artery. On the anterolateral surface of the pons the **trigeminal nerve** emerges on each side. Each nerve consists of a smaller, medial part—the **motor root**— and a larger, lateral part—the **sensory root**. In the groove between the pons and the medulla oblongata there emerge, from medial to lateral, the **abducent, facial,** and **vestibu-locochlear nerves.**

The posterior surface of the pons is hidden from view by the cerebellum. It forms the upper half of the floor of the fourth ventricle and is triangular in shape. The posterior surface is limited laterally by the **superior cerebellar peduncles** and is divided into symmetrical halves by a **median sulcus**. Lateral to this sulcus is an elongated elevation, the **medial eminence**, which is bounded laterally by a sulcus, the **sulcus limitans**. The inferior end of the medial eminence is slightly expanded to form the **facial colliculus**, which is produced by the root of the facial nerve winding around the nucleus of the abducent nerve. The floor of the superior part of the sulcus limitans is bluish-gray in color and is called the **substantia ferruginea**; it owes its color to a group of deeply pigmented nerve cells. Lateral to the sulcus limitans is the **area vestibuli** produced by the underlying vestibular nuclei.

Internal Structure of the Pons:-

For purposes of description, the pons is commonly divided into a posterior part, the **tegmentum**, and an anterior **basal part** by the transversely running fibers of the **trapezoid body**.

The important structures of Pons includes the following:-

1- The **spinal nucleus of the trigeminal nerve** and **its tract** lie on the anteromedial aspect of the inferior cerebellar peduncle.

2- The **motor nucleus of the trigeminal nerve** is situated beneath the lateral part of the fourth ventricle within the reticular formation. The emerging motor fibers travel anteriorly through the substance of the pons and exit on its anterior surface.

3- The **principal sensory nucleus of the trigeminal nerve** is situated on the lateral side of the motor nucleus; it is continuous interiorly with the nucleus of the spinal tract. The entering sensory fibers travel through the substance of the pons and lie lateral to the motor fibers.

4- The **abducent nerve nucleus**.

5- The **facial nerve nucleus** lies posterior to the lateral part of the medial lemniscus. The fibers of the facial nerve wind around the nucleus of the abducent nerve, producing the **facial colliculus**.

6- The vestibulocochlear nerves nuclei which includes:-

- **A-** The **medial vestibular nucleus** is situated lateral to the abducent nucleus and is in close relationship to the inferior cerebellar peduncle.
- **B-** The **lateral vestibular nucleus.**
- **C-** The **superior vestibular nucleus.**.
- **D-** The **anterior cochlear nucleus**.
- **E-** The **posterior cochlear nucleus**.

7- The **medial longitudinal fasciculus** is situated beneath the floor of the fourth ventricle on either side of the midline. The medial longitudinal fasciculus is the main pathway that connects the vestibular and cochlear nuclei with the nuclei controlling the extraocular muscles (oculomotor, trochlear, and abducent nuclei).

8- The basilar part of the pons, contains small masses of nerve cells called **pontine nuclei**. The **corticopontine fibers** of the crus cerebri of the midbrain terminate in the pontine nuclei. The axons of these cells give origin to the **transverse fibers** of the pons, which cross the midline and intersect the corticospinal and corticonuclear tracts, breaking them up into small bundles.

9- The transverse fibers of the pons enter the **middle cerebellar peduncle** and are distributed to the cerebellar hemisphere. This connection forms the main pathway linking the cerebral cortex to the cerebellum.

10- The **lemnisci** which includes the followings:-

- **A-** The **medial lemniscus** rotates as it passes from the medulla into the pons. It is situated in the most anterior part of the tegmentum with its long axis running transversely.
- **B-** The medial lemniscus is accompanied by the **spinal** and **lateral lemnisci.**

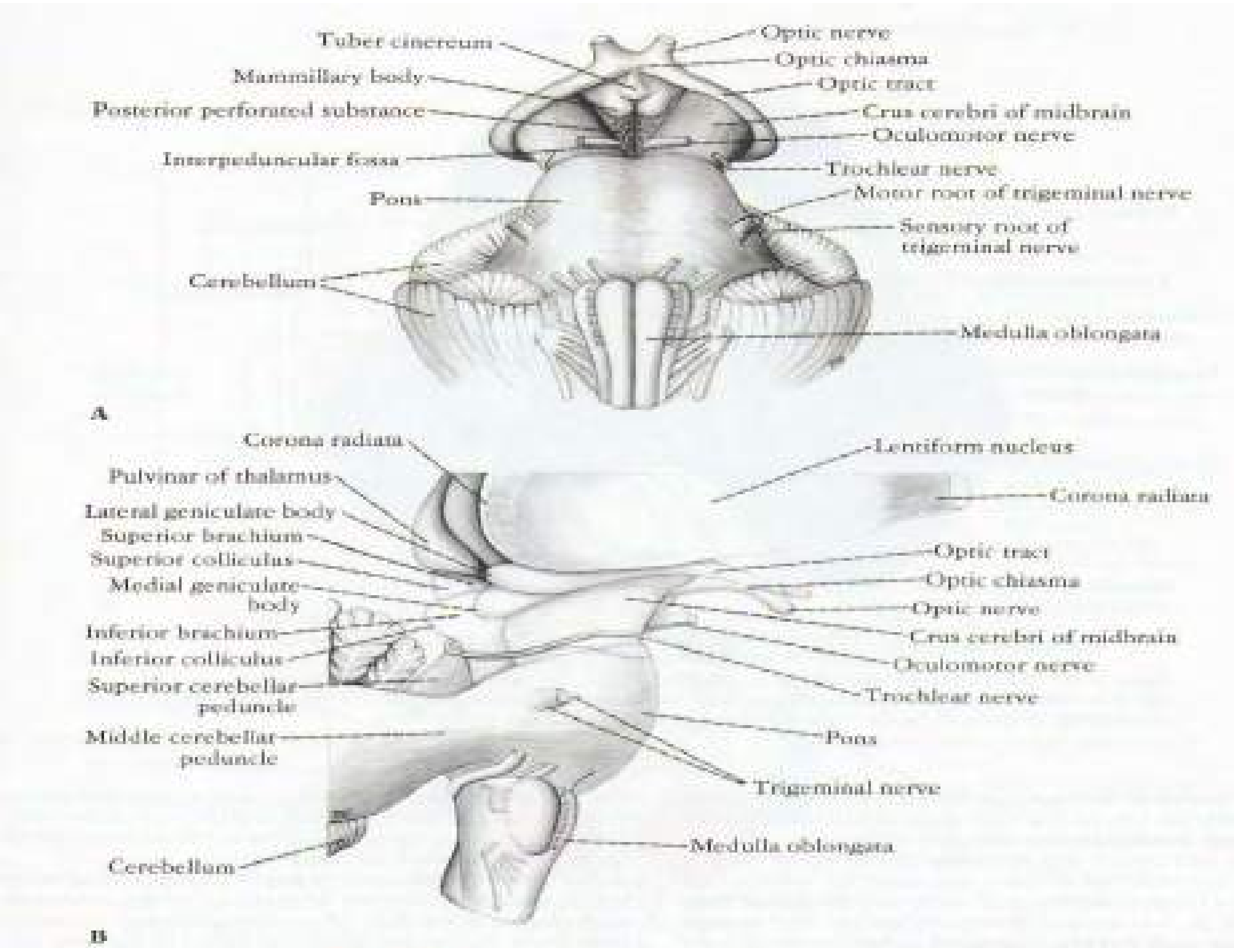


Figure 5-16 The midbrain. A. Anterior view. B. Lateral view.

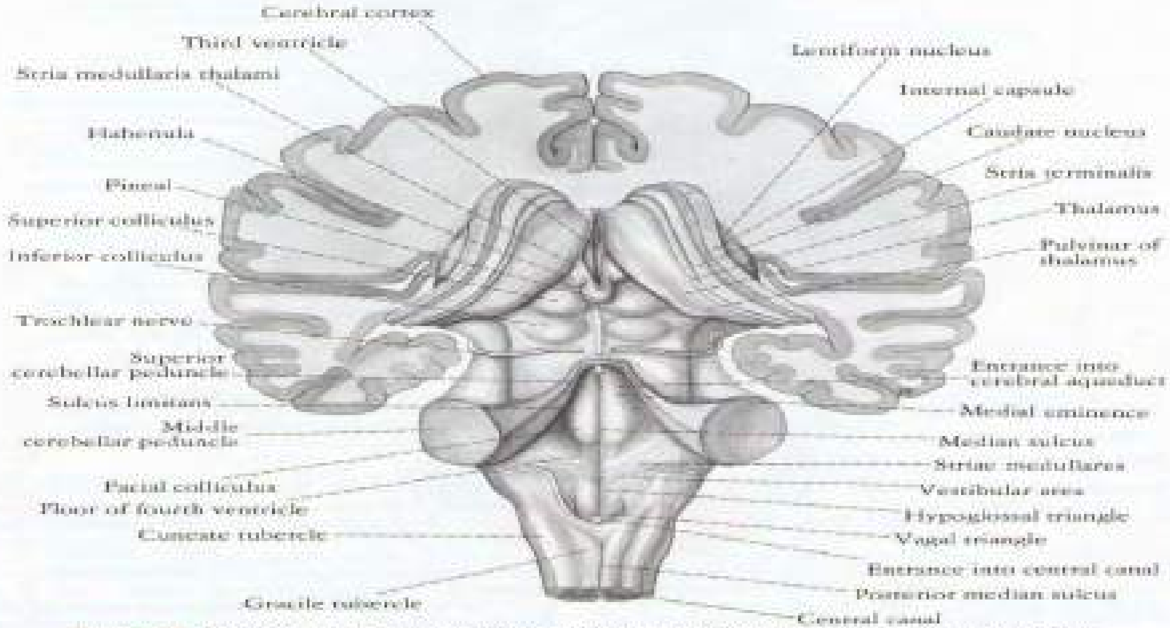


Figure 5–10 Posterior view of the brainstem showing the two superior and the two inferior colliculi of the tectum.

Figure 5–11 Posterior surface of the brainstem showing the pons. The cerebellum has been removed.

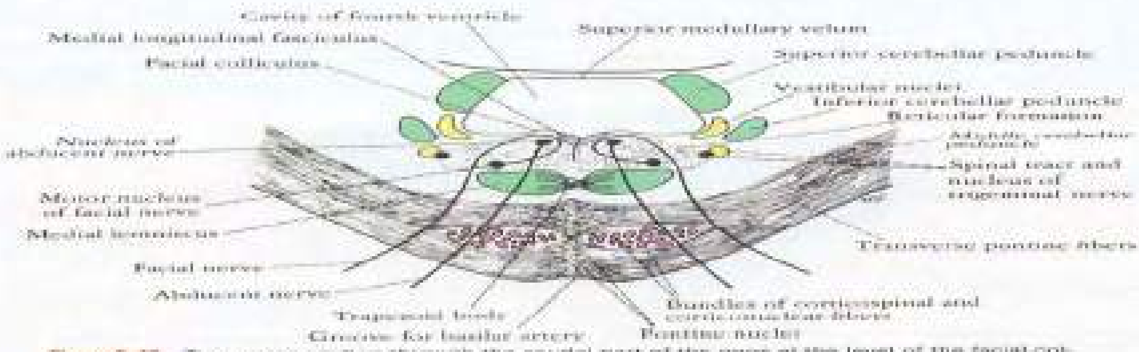


Figure 5–12 Transverse section through the caudal part of the pons at the level of the facial colliculus.

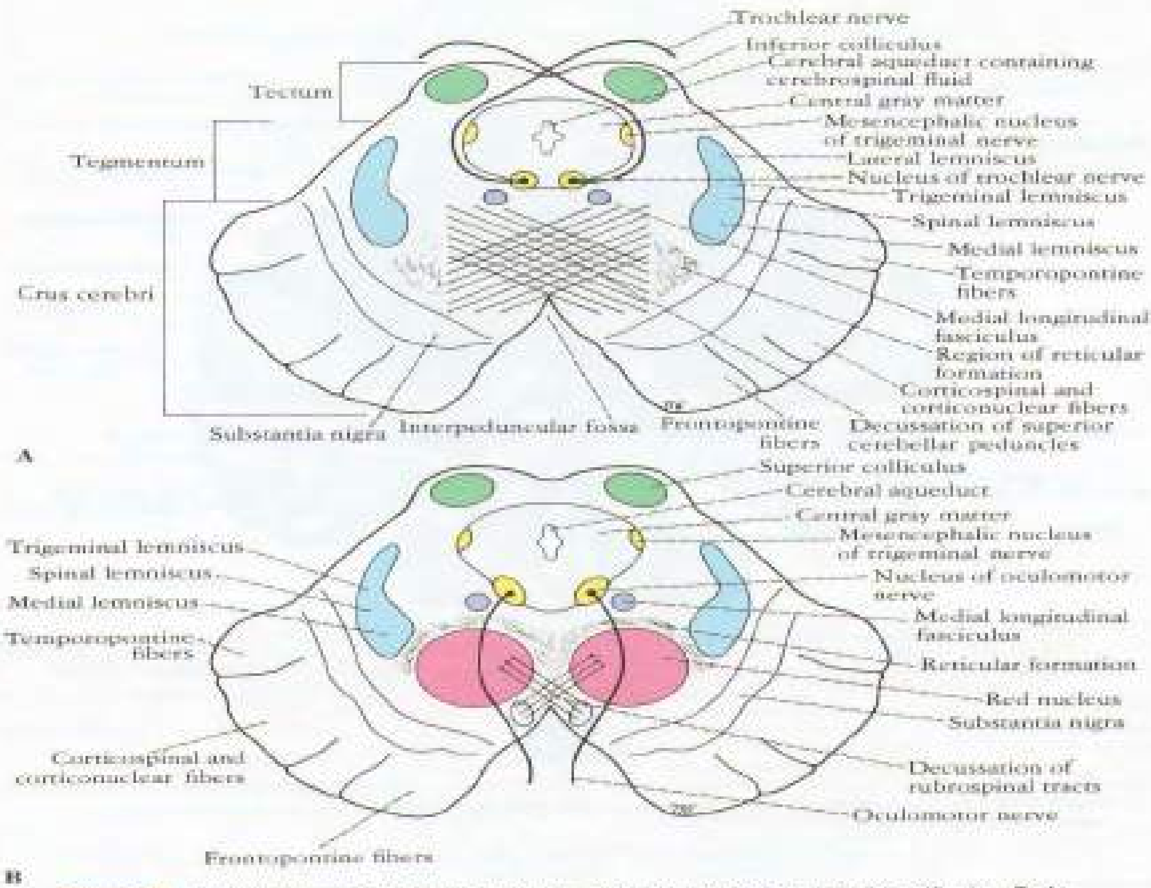


Figure 5-18 Transverse sections of the midbrain. **A.** At the level of the inferior colliculus. **B.** At the level of the superior colliculus. Note that trochlear nerves completely decussate within the superior medullary velum.

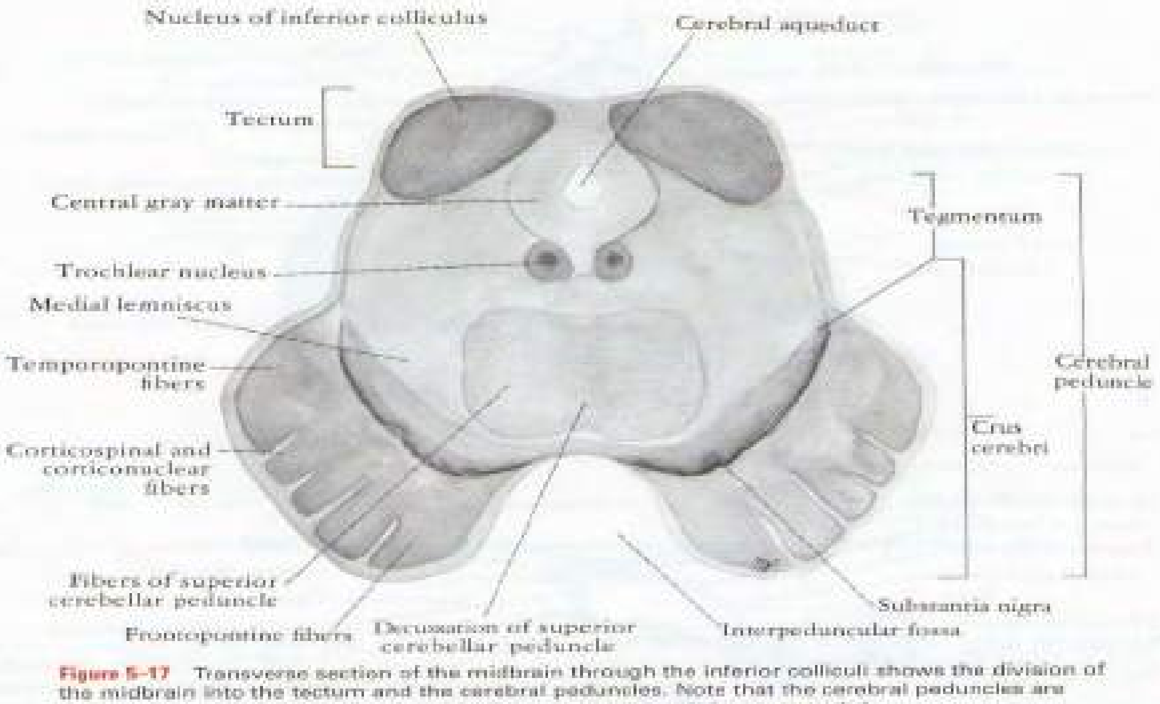


Figure 5-17 Transverse section of the midbrain through the inferior colliculi shows the division of the midbrain into the tectum and the cerebral peduncles. Note that the cerebral peduncles are subdivided by the substantia nigra into the tegmentum and the crus cerebri.

Lecture 6 in Anatomy of CNS

By

Dr. Mohammad Ahmad Abdulla

Medulla Oblongata & Cerebellum

Medulla Oblongata

Gross appearance of the Medulla Oblongata

The medulla oblongata connects the pons superiorly with the spinal cord inferiorly. The junction of the medulla and spinal cord corresponds approximately to the level of the foramen magnum. The medulla oblongata is conical in shape, its broad extremity being directed superiorly. The **central canal** of the spinal cord continues upward into the lower half of the medulla; in the upper half of the medulla it expands as the **cavity of the fourth ventricle**.

<u>On the anterior surface</u> of the medulla is the anterior median fissure, which is continuous inferiorly with the **anterior median fissure** of the spinal cord. On each side of the median fissure there is a swelling called the **pyramid.** The pyramids are composed of bundles of nerve-fibers, corticospinal fibers, which originate in large nerve cells in the precentral gyrus of the cerebral cortex. The pyramids taper inferiorly and it is here that the majority of the descending fibers cross over to the opposite side, forming the **decussation of the pyramids**.

Posterolateral to the pyramids are the **olives,** which are oval elevations produced by the underlying **inferior olivary nuclei.** In the groove between the pyramid and the olive emerge the rootlets of the hypoglossal nerve. Posterior to the olives are the **inferior cerebellar peduncles**, which connect the medulla to the cerebellum. In the groove between the olive and the inferior cerebellar peduncle emerge the roots of the glossopharyngeal nerve, vagus nerve and the cranial roots of the accessory nerve.

<u>The posterior surface</u> of the superior half of the medulla oblongata forms the lower part of the **floor of the fourth ventricle**. The posterior surface of the inferior half of the medulla is continuous with the posterior aspect of the spinal cord and possesses a **posterior median sulcus.** On each side of the median sulcus there is an elongated swelling, the gracile tubercle, produced by the underlying **gracile nucleus**. Lateral to the gracile tubercle is a similar swelling, the **cuneate tubercle,** produced by the underlying **cuneate nucleus.**

Internal structure of the Medulla Oblongata:-

1- The **pyramids** containing the corticospinal and some corticonuclear fibers are situated in the anterior part of the medulla separated by the anterior median fissure; the corticospinal fibers descend to the spinal cord and the corticonuclear fibers are distributed to the motor nuclei of the cranial nerves situated within the medulla.

2- The **decussation of the pyramids**, the great motor decussation. In the superior part of the medulla the corticospinal fibers occupy and form the pyramid, but interiorly about three-fourths of the fibers cross the median plane and continue down the spinal cord in the lateral white column as the **lateral corticospinal tract**.

3- The **fasciculus gracilis** and the **fasciculus cuneatus** continue to ascend superiorly posterior to the central gray matter. The nucleus gracilis and the nucleus cuneatus appear as posterior extensions of the central gray matter.

4- The **nucleus of the spinal tract of the trigeminal nerve** and **its tract** continuous with the **substantia gelatinosa** in the posterior gray column of the spinal cord.

5- Olivary Nuclear Complex:-

- **A-** The largest nucleus of this complex is the **inferior olivary nucleus**. It is shape like a crumpled bag with its mouth directed medially; it is responsible for the elevation on the surface of the medulla called the **olive**.
- **B-** Smaller **dorsal** and **medial accessory olivary nuclei** also are present.

The function of the olivary nuclei is associated with voluntary muscle movement.

6- Vestibulocochlear Nuclei:-

The **vestibular nuclear complex** is made up of the following nuclei:

- **A- Medial vestibular nucleus**
- **B- Lateral vestibular nucleus**
- **C- Superior vestibular nucleus.**
- **D- Inferior vestibular nucleus**

The **cochlear nuclei** are two in number:-

- **A-** The **anterior cochlear nucleus** is situated on the anterolateral aspect of the inferior cerebellar peduncle.
- **B-** The **posterior cochlear nucleus** is situated on the posterior aspect of the peduncle lateral to the floor of the fourth ventricle.

7- The Nucleus Ambiguus:- consists of large motor neurons and is situated deep within the reticular formation. The emerging nerve fibers join the glossopharyngeal, vagus, and cranial part of the accessory nerve and are **distributed to voluntary skeletal muscle**.

8- Some cranial nerve nuclei includes:-

- **A-** The **hypoglossal nucleus**
- **B-** The **dorsal nucleus of the vagus**
- **C-** The **nucleus of the tractus solitaries.**

9- The **glossopharyngeal, vagus,** and **cranial part of the accessory nerves** can be seen through the reticular formation. The nerve fibers emerge between the olives and the inferior cerebellar peduncles. The **hypoglossal nerves** also run anteriorly and laterally through the reticular formation and emerge between the pyramids and the olives.

10- The **decussation of lemnisci**, the great sensory decussation. It takes place anterior to the central gray matter and posterior to the pyramids. the lemnisci have been formed from the **internal arcuate fibers**, which have emerged from the anterior aspects of the nucleus gracilis and nucleus cuneatus. These includes:-

- **A- Spinal lemniscus** consisting of the **anterior spinothalamic,** the **lateral spinothalamic,** and **spinotectal tracts** is deeply placed.
- **B-** The **medial lemniscus** forms a flattened tract on each side of the midline posterior to the pyramid. These fibers emerge from the decussation of the lemnisci and convey sensory information to the thalamus.

11- The **medial longitudinal fasciculus** forms a small tract of nerve fibers situated on each side of the midline posterior to the medial lemniscus and anterior to the hypoglossal nucleus. It consists of ascending and descending fibers.

12- The **tracts which includes:-**

A- **Lateral** and **anterior spinothalamic tracts** and the **spinotectal tracts** occupy an area lateral to the decussation of the lemnisci.

B- The **spinocerebellar, vestibulospinal,** and the **rubrospinal tracts** are situated in the anterolateral region of the medulla oblongata.

C- The **anterior spinocerebellar tract** is situated near the surface in the interval between the inferior olivary nucleus and the nucleus of the spinal tract of the trigeminal nerve.

13- The **inferior cerebellar peduncle** is situated in the posterolateral corner of the section on the lateral side of the fourth ventricle.

14- The **reticular formation,** consisting of a diffuse mixture of nerve fibers and small groups of nerve cells, is deeply placed posterior to the olivary nucleus. The reticular formation represents, only a small part of this system, which is also present in the pons and midbrain.

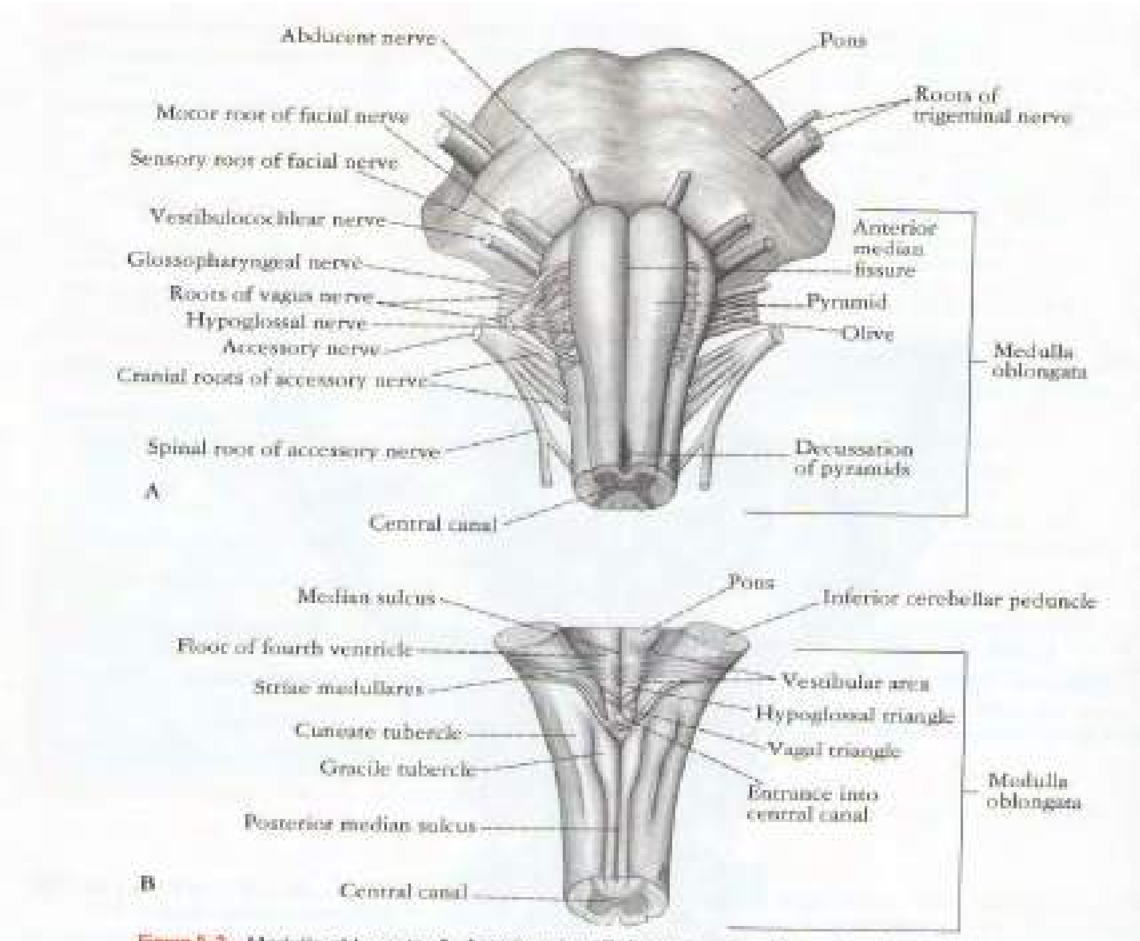


Figure 5-2 Medulla oblongata. **A.** Anterior view. **B.** Posterior view. Note that the roof of the fourth ventricle and the cerebellum have been removed.

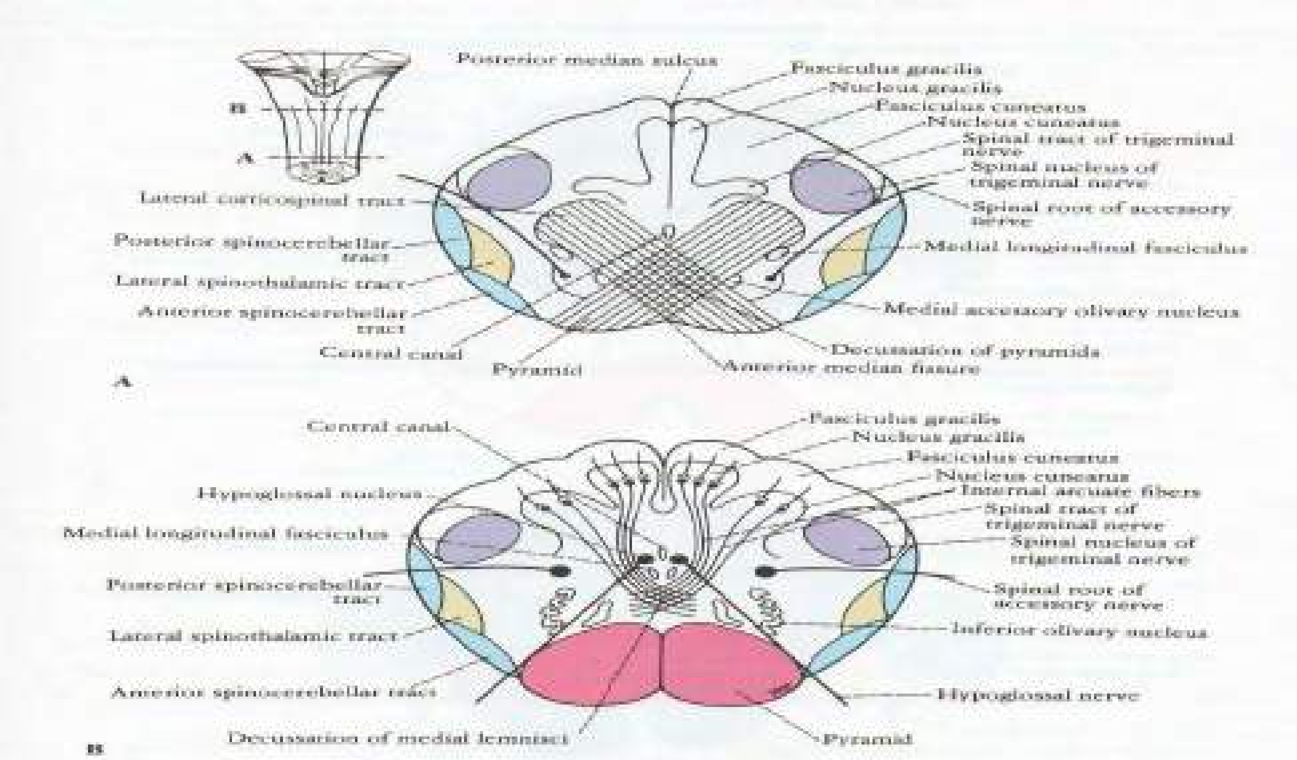


Figure 5–4 Transverse sections of the medulla oblongata. **A.** Level of decussation of the pyramids. **B.** Level of decussation of the medial lemnisci.

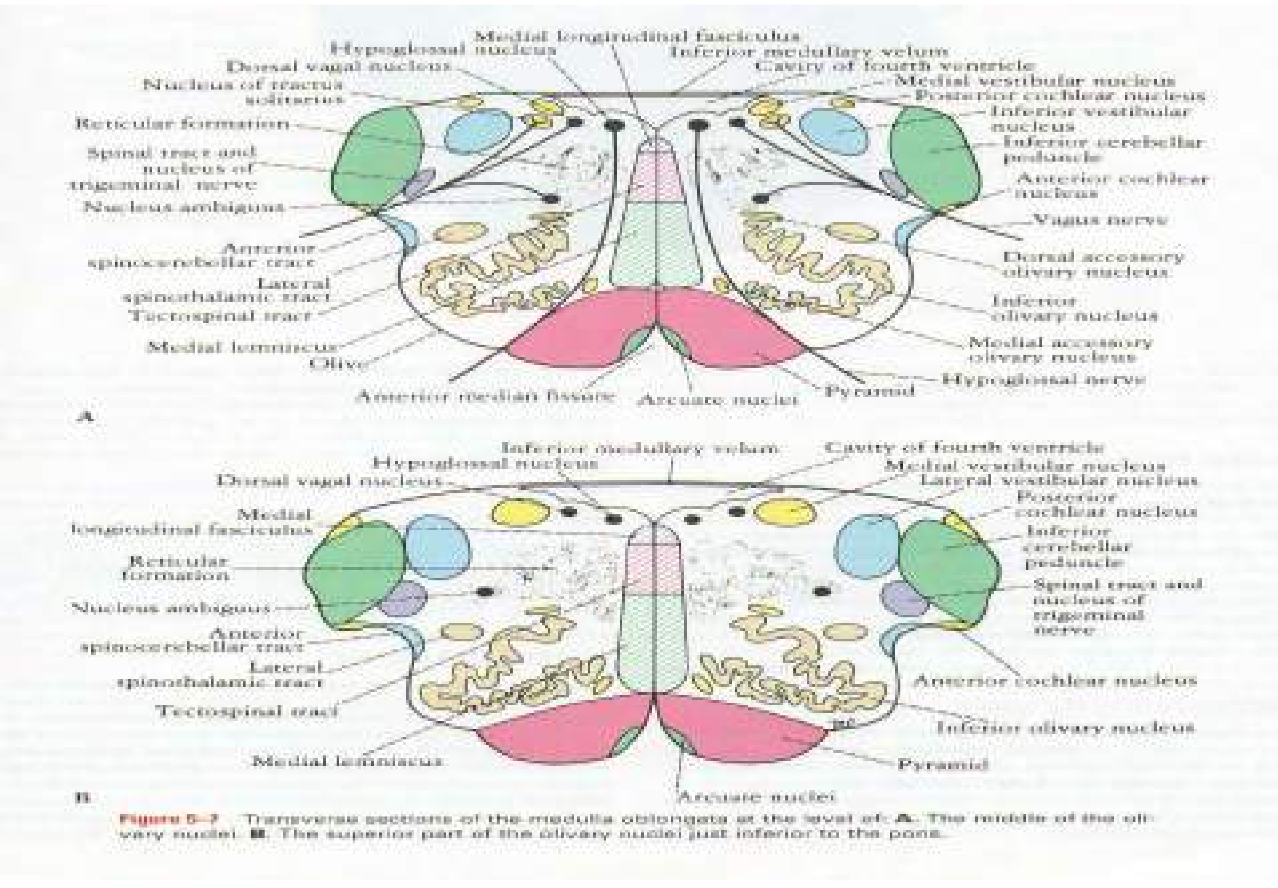


Figure 5–7 Transverse sections of the medulla oblongata at the level of: **A.** The middle of the olivary nuclei. **B.** The superior part of the olivary nuclei just inferior to the pons.

The Cerebellum

Gross Appearance of the Cerebellum

The cerebellum is situated in the posterior cranial fossa and covered superiorly by the tentorium cerebelli. It is the largest part of the hindbrain and lies posterior to the fourth ventricle, the pons and the medulla oblongata. The cerebellum is somewhat ovoid in shape and constricted in its median part. It consists of two **cerebellar hemispheres** joined by a narrow median **vermis.** The cerebellum is connected to the posterior aspect of the brainstem by three symmetrical bundles of nerve fibers called the **superior, middle,** and **inferior cerebellar peduncles.**

The cerebellum is divided into three main lobes: the **anterior lobe,** the **middle lobe,** and the **flocculonodular lobe.** The **anterior lobe** may be seen on the superior surface of the cerebellum and is separated from the middle lobe by a wide V-shaped fissure called the **primary fissure**. The **middle lobe** (sometimes called the posterior lobe), which is the largest part of the cerebellum, is situated between the primary and **uvulonodular fissures.** The **flocculonodular lobe** is situated posterior to the uvulonodular fissure. A deep **horizontal fissure** that is found along the margin of the cerebellum separates the superior from the inferior surfaces; it is of no morphological or functional significance.

The cerebellum is composed of an outer covering of gray matter called the **cortex** that can be regarded as a large sheet with folds lying in the coronal or transverse plane. Each fold or folium contains a core of white matter covered superficially by gray matter.

A section made through the cerebellum parallel with the median plane divides the folia at right angles, and the cut surface has a branched appearance, called the **arbor vitae**.

Internal structure of the Cerebellum:-

1- Intracerebellar Nuclei:-

A- The **dentate nucleus** is the largest of the cerebellar nuclei. It has the shape of a crumpled bag with the opening facing medially. The efferent fibers that leave the nucleus through the opening to form a large part of the superior cerebellar peduncle.

B- The **emboliform nucleus** is ovoid and is situated medial to the dentate nucleus, partially covering its hilus.

C- The **globose nucleus** consists of one or more rounded cell groups that lie medial to the emboliform nucleus.

D- The **fastigial nucleus** lies near the midline in the vermis and close to the roof of the fourth ventricle; it is larger than the globose nucleus.

The Intracerebellar Nuclei axons form the cerebellar outflow in the superior and inferior cerebellar peduncles.

2- White Matter of cerebellum:-

There is a small amount of white matter in the vermis and it closely resembles the trunk and branches of a tree—the **arbor vitae**. There is a large amount of white matter in each cerebellar hemisphere.

The white matter is made up of three groups of fibers:

A- The **intrinsic fibers** do not leave the cerebellum but connect different regions of the organ. Some interconnect folia of the cerebellar cortex and vermis on the same side; others connect the two cerebellar hemispheres together.

B- The **afferent fibers** form the greater part of the white matter and proceed to the cerebellar cortex. They enter the cerebellum mainly through the inferior and middle cerebellar peduncles.

C- The **efferent fibers** constitute the output of the cerebellum and commence as the axons of the Purkinje cells of the cerebellar cortex.

Fibers from the dentate, emboliform, and globose nuclei leave the cerebellum through the superior cerebellar peduncle. Fibers from the fastigial nucleus leave through the inferior cerebellar peduncle.

3- **Cerebellar Peduncles:-** The cerebellum is linked to other parts of the central nervous system by numerous efferent and afferent fibers that are grouped together on each side into three large bundles, or peduncles. The superior cerebellar peduncles connect the cerebellum to the midbrain, the middle cerebellar peduncles connect the cerebellum to the pons, and the inferior cerebellar peduncles connect the cerebellum to the medulla oblongata.

4- Cerebellar Afferent Fibers:-

A- Cerebellar Afferent Fibers from the Cerebral Cortex

The cerebral cortex sends information to the cerebellum by three pathways:

- **i.** The Cortico-ponto-cerebellar pathway.
- **ii.** The cerebro-olivo-cerebellar pathway.
- **iii.** The cerebro-reticulo-cerebellar pathway.

B- Cerebellar Afferent Fibers From The Spinal Cord:-

The spinal cord sends information to the cerebellum from somatosensory receptors by three pathways:

(I) Anterior Spinocerebellar Tract:-

The anterior spinocerebellar tract is found at all segments of the spinal cord and its fibers convey muscle joint information from the muscle spindles, tendon organs, and joint receptors of the upper and lower limbs. It is also believed that the cerebellum receives information from the skin and superficial fascia by this tract.

(II) Posterior Spinocerebellar Tract:-

The posterior spinocerebellar tract receives muscle joint information from the muscle spindles, tendon organs, and joint receptors of the trunk and lower limbs.

(III) Cuneocerebellar Tract:-

The cuneocerebellar tract receives muscle joint information from the muscle spindles, tendon organs, and joint receptors of the upper limb and upper part of the thorax.

C- Cerebellar Afferent Fibers from the Vestibular Nerve:

The vestibular nerve receives information from the inner ear concerning **motion** from the semicircular canals and **position** relative to gravity from the utricle and saccule. They enter the cerebellum through the inferior cerebellar peduncle on the same side. All the afferent fibers from the inner ear terminate in the flocculonodular lobe of the cerebellum.

D- Other Afferent Fibers

In addition, the cerebellum receives small bundles of afferent fibers from the red nucleus and the tectum.

5- Cerebellar Efferent Fibers:-

The efferent fibers from the cerebellum connect with the red nucleus, thalamus, vestibular complex, and reticular formation.

A- Globose-Emboliform-Rubral Pathway:-

By this means, the globose and emboliform nuclei influence motor activity on the same side of the body.

B- Dentothalamic Pathway:-

By this pathway, the dentate nucleus can influence motor activity by acting upon the motor neurons of the opposite cerebral cortex.

C- Fastigial Vestibular Pathway:-

The fastigial nucleus exerts a facilitatory influence mainly on the ipsilateral extensor muscle tone.

D- Fastigial Reticular Pathway

Axons of these neurons influence spinal segmental motor activity through the reticulospinal tract.

Functions of the Cerebellum

1- The cerebellum receives afferent information concerning **voluntary movement** from the cerebral cortex and from the muscles, tendons, and joints.

2- It also receives information concerning **balance** from the vestibular nerve and possibly concerning **sight** through the tectocerebellar tract.

3- The cerebellar output is conducted to the sites of origin of the descending pathways that **influence motor activity** at the segmental spinal level. In this respect, the cerebellum has no direct neuronal connections with the lower motor neurons, but exerts its influence indirectly through the cerebral cortex and brainstem.

4- Physiologists have postulated that the cerebellum functions **as a coordinator of precise movements by continually comparing the output of the motor area of the cerebral cortex with the proprioceptive information received from the site of muscle action; it is then able to bring about the necessary adjustments by influencing the activity of the lower motor neurons**.

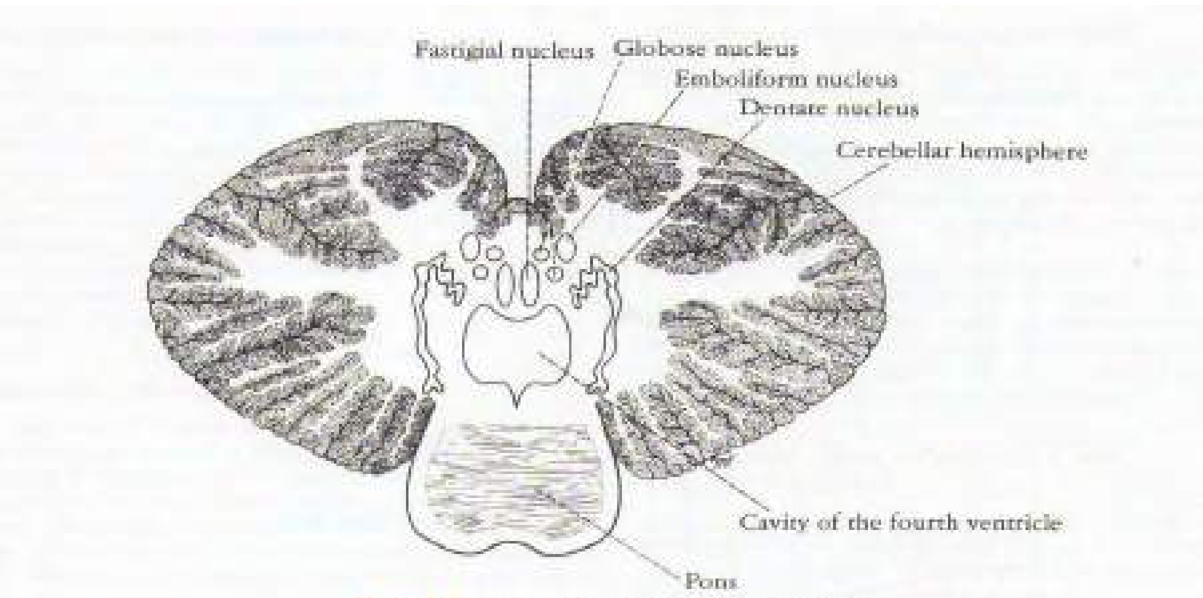


Figure 6–7 Position of the intracerebellar nuclei.

Lecture 7 in Anatomy of CNS

By

Dr. Mohammad Ahmad Abdulla

Meninges of The Brain

The brain and spinal cord are surrounded by three membranes, or meninges: the dura mater, the arachnoid mater, and the pia mater.

1- DURA MATER

The dura mater of the brain is conventionally described as two layers, the endosteal layer and the meningeal layer. These are closely united except along certain lines, where they separate to form **venous sinuses**.

The **endosteal layer** is nothing more than the periosteum covering the inner surface of the skull bones. At the foramen magnum it does **not** become continuous with the dura mater of the spinal cord.

The **meningeal layer** is the dura mater proper. It is a dense, strong fibrous membrane covering the brain and is continuous through the foramen magnum with the dura mater of the spinal cord.

The meningeal layer sends inward four septa, which divide the cranial cavity into freely communicating spaces that lodge the subdivisions of the brain. The function of these septa is to restrict the displacement of the brain associated with acceleration and deceleration, when the head is moved, and these septa are:-

1- The **falx cerebri** is a sickle-shaped fold of dura mater that lies in the midline between the two cerebral hemispheres. The **superior sagittal sinus** runs in its upper fixed margin; the **inferior sagittal sinus** runs in its lower concave free margin; and the **straight sinus** runs along its attachment to the tentorium cerebelli.
2- The **tentorium cerebelli** is a crescent-shaped fold of dura mater that roofs over the posterior cranial fossa. It covers the upper surface of the cerebellum and supports the occipital lobes of the cerebral hemispheres.
3- The **falx cerebelli**, a small, sickle-shaped fold of dura mater attached to the internal occipital crest, projects forward between the two cerebellar hemispheres. Its posterior fixed margin contains the **occipital sinus**.
4- The **diaphragma sellae** is a small, circular fold of dura mater that forms the roof for the sella turcica. A small opening in its center allows passage of the stalk of the **hypophysis cerebri**.

Dural Venous Sinuses

The venous sinuses of the cranial cavity are situated between the layers of the dura mater. Their main function is to receive blood from the brain through the cerebral veins and the cerebrospinal fluid from the subarachnoid space through the **arachnoid villi**. The blood in the dural sinuses ultimately drains into the internal jugular veins in the neck. They have no valves. **Emissary veins,** which are also valveless, connect the dural venous sinuses with the **diploic veins** of the skull and with the veins of the scalp. **<u>The important venous sinuses are</u>**:-

1- The **superior sagittal sinus** occupies the upper fixed border of the falx cerebri. It begins anteriorly at the foramen cecum, where it occasionally receives a vein from the nasal cavity. It becomes continuous with the corresponding **transverse sinus.**
   The superior sagittal sinus receives in its course the **superior cerebral veins**. At the internal occipital protuberance it is dilated to form the **confluence of the sinuses**. Here, the superior sagittal sinus usually becomes continuous with the right transverse sinus; it is connected to the opposite transverse sinus and receives the **occipital sinus.**
2- The **inferior sagittal sinus** occupies the free lower margin of the falx cerebri. It runs backward and joins the **great cerebral vein** at the free margin of the tentorium cerebelli, to form the straight sinus.

3- The **straight sinus** occupies the line of junction of the falx cerebri with the tentorium cerebelli. It is formed by the union of the **inferior sagittal sinus** with the **great cerebral vein.** It ends by turning to the left (sometimes to the right) to form the **transverse sinus.**

4- The **transverse sinuses** are paired structures and they begin at the internal occipital protuberance. The right sinus is usually continuous with the superior sagittal sinus, and the left is continuous with the straight sinus. They receive the **superior petrosal sinuses,** the **inferior cerebral** and **cerebellar veins,** and the **diploic veins.** They end by turning downward as the **sigmoid sinuses**.

5- The **sigmoid sinuses** are a direct continuation of the transverse sinuses. Each sinus turns downward and medially and grooves the mastoid part of the temporal bone. The sinus then turns forward and then interiorly through the posterior part of the jugular foramen, to become continuous with the **superior bulb** of the **internal jugular vein.**

6- The **occipital sinus** is a small sinus occupying the attached margin of the falx cerebelli. It commences near the foramen magnum, where it communicates with the **vertebral veins** and drains into the **confluence of sinuses.**

7- The **cavernous sinuses** are situated in the middle cranial fossa on each side of the body of the sphenoid bone. **<u>It contains the following structures:-.</u>**

  a- The **internal carotid artery,** surrounded by its **sympathetic nerve plexus and t**he **abducent nerve** are pass through the sinus.

  b- The **third** and **fourth cranial nerves,** and the **ophthalmic** and **maxillary divisions of the trigeminal nerve,** run forward in the lateral wall of the sinus.

  <u>The tributaries of cavernous sinus:-</u> are the **superior ophthalmic vein**, **inferior ophthalmic vein,** the **inferior cerebral veins,** the **sphenoparietal sinus** and the **central vein of the retina.**

  <u>The sinus drains</u> posteriorly into the **superior** and **inferior petrosal sinuses,** and inferiorly into the **pterygoid venous plexus.**

  <u>The two sinuses communicate with each other</u> by means of the **anterior** and **posterior intercavernous sinuses,** which run in the diaphragma sellae anterior and posterior to the stalk of the hypophysis cerebri. Each sinus has an important communication with the facial vein through the superior ophthalmic vein. (This is a route by which infection can travel from the facial skin to the cavernous sinus.)

  The **superior** and **inferior petrosal sinuses** are small sinuses and each superior sinus drains the cavernous sinus into the transverse sinus, and each inferior sinus drains the cavernous sinus into the internal jugular vein.

2- ARACHNOID MATER

The arachnoid mater is a delicate, impermeable membrane covering the brain and lying between the pia mater internally and the dura mater externally. It is separated from the dura by a potential space, the **subdural space,** filled by a film of fluid; it is separated from the pia by the **subarachnoid space,** which is filled with **cerebrospinal fluid.**

In certain areas, the arachnoid projects into the venous sinuses to form **arachnoid villi.** The arachnoid villi are most numerous along the superior sagittal sinus. Aggregations of arachnoid villi are referred to as **arachnoid granulations**. Arachnoid villi serve as sites where the cerebrospinal fluid diffuses into the bloodstream.

The arachnoid is connected to the pia mater across the fluid-filled subarachnoid space by delicate strands of fibrous tissue.

3- PIA MATER

The pia mater is a vascular membrane covered by flattened mesothelial cells. It closely invests the brain, covering the gyri and descending into the deepest sulci. It extends out over the cranial nerves and fuses with their epineurium. The cerebral arteries entering the substance of the brain carry a sheath of pia with them.

The pia mater forms the **tela choroidea** of the roof of the third and fourth ventricles of the brain, and it fuses with the ependyma to form the choroid plexuses in the lateral, third, and fourth ventricles of the brain.

VENTRICULAR SYSTEM OF THE BRAIN

The ventricles of the brain are the lateral ventricles, the third ventricle, and the fourth ventricle. The two **lateral ventricles** communicate through the **interventricular foramina (of Monro)** with the **third ventricle**. The third ventricle is connected to the **fourth ventricle** by the **cerebral aqueduct (aqueduct of Sylvius)**. The fourth ventricle in turn is continuous with the narrow **central canal** of the spinal cord and, through the three foramina in its roof, with the subarachnoid space. The central canal has a small dilatation at its inferior end, referred to as the **terminal ventricle**.

1- LATERAL VENTRICLES

There are two lateral ventricles and one is present in each cerebral hemisphere. The ventricle is a roughly C-shaped cavity and may be divided into a **body**, which occupies the parietal lobe and from which **anterior, posterior,** and **inferior horns** extend into the frontal, occipital, and temporal lobes, respectively.

2- The interventricular foramen

The lateral ventricle communicates with the cavity of the third ventricle through the **interventricular foramen**. This opening, which lies in the anterior part of the medial wall of the ventricle, is bounded anteriorly by the anterior column of the fornix and posteriorly by the anterior end of the thalamus.

3-THIRD VENTRICLE

The third ventricle is a slitlike cleft between the two thalami. It communicates anteriorly with the lateral ventricles through the interventricular foramina (of Monro) and posteriorly with the fourth ventricle through the cerebral aqueduct (of Sylvius).

4-Cerebral Aqueduct (Aqueduct of Sylvius)

The cerebral aqueduct, a narrow channel about 3/4-inch (1.8-cm) long, connects the third with the fourth ventricle. The direction of flow of cerebrospinal fluid is from the third to the fourth ventricle. There is no choroid plexus in the cerebral aqueduct.

5-FOURTH VENTRICLE

The fourth ventricle is a tent-shaped cavity filled with cerebrospinal fluid. It is situated anterior to the cerebellum and posterior to the pons and the superior half of the medulla oblongata. The fourth ventricle possesses lateral boundaries, a roof, and a rhomboid-shaped floor.

Lateral Boundaries:-

The caudal part of each lateral boundary is formed by the inferior cerebellar peduncle. The cranial part of each lateral boundary is formed by the superior cerebellar peduncle.

Roof or Posterior Wall:-

The tent-shaped roof projects into the cerebellum. The superior part is formed by the medial borders of the two superior cerebellar peduncles and a connecting sheet of white matter called the s**uperior medullary velum**. The inferior part of the roof is formed by the **inferior medullary velum**, which consists of a thin sheet devoid of nervous tissue and formed by the ventricular ependyma and its posterior covering of pia mater. This part of the roof is pierced in the midline by a large aperture, the **median aperture** or **foramen of Magendie**.

Lateral recesses extend laterally around the sides of the medulla and open anteriorly as the **lateral openings of the fourth ventricle,** or the **foramina of Luschka**.

Floor or Rhomboid Fossa:-

The diamond-shaped floor is formed by the posterior surface of the pons and the cranial half of the medulla oblongata.

6-Central Canal of the Spinal Cord and Medulla Oblongata

The central canal opens superiorly into the fourth ventricle. Interiorly it extends through the inferior half of the medulla oblongata and through the entire length of the spinal cord. In the conus medullaris of the spinal cord, it expands to form the t**erminal ventricle**. The central canal is closed at its lower end, is filled with cerebrospinal fluid, and is lined with ependyma. The central canal is surrounded by gray matter, the **gray commissure**. There is no choroid plexus in the central canal.

CEREBROSPINAL FLUID

The cerebrospinal fluid is found in the ventricles of the brain and in the subarachnoid space around the brain and spinal cord. It is a clear, colorless fluid.

Functions:-

1.Cushions and protects the central nervous system from trauma
2.Provides mechanical buoyancy and support for the brain
3.Serves as a reservoir and assists in the regulation of the contents of the skull
4.Nourishes the central nervous system
5.Removes metabolites from the central nervous system
6.Serves as a pathway for pineal secretions to reach the pituitary gland

BLOOD SUPPLY TO THE BRAIN

ARTERIES OF THE BRAIN

The brain is supplied by the two internal carotid and the two vertebral arteries. The four arteries lie within the subarachnoid space, and their branches anastomose on the inferior surface of the brain to form the circle of Willis.

Internal Carotid Artery

The internal carotid artery begins at the bifurcation of the common carotid artery, where it usually possesses a localized dilatation, called the **carotid sinus.** It ascends the neck and perforates the base of the skull by passing through the carotid canal of the temporal bone. The artery then runs horizontally forward through the cavernous sinus and emerges on the medial side of the anterior clinoid process by perforating the dura mater. It now enters the subarachnoid space by piercing the arachnoid mater and turns posteriorly to the region of the medial end of the lateral cerebral sulcus. Here, it divides into the **anterior** and **middle cerebral arteries**.

Branches of The Cerebral Portion of Internal Carotid Artery:-

1. The **ophthalmic artery** arises as the internal carotid artery emerges from the cavernous sinus. It enters the orbit through the optic canal.
2. The **posterior communicating artery** is a small vessel that originates from the internal carotid artery close to its terminal bifurcation.

3. The **choroidal artery,** a small branch, enters the inferior horn of the lateral ventricle, and ends in the choroid plexus.
4. The **anterior cerebral artery** is the smaller terminal branch that joined to the opposite side by the **anterior communicating artery.**
5. The **middle cerebral artery,** the largest branch of the internal carotid, runs laterally in the lateral cerebral sulcus.

Vertebral Artery

The vertebral artery a branch of the first part of the subclavian artery, ascends the neck by passing through the foramina in the transverse processes of the upper six cervical vertebrae. It enters the skull through the foramen magnum and pierces the dura mater and arachnoid to enter the subarachnoid space. It then passes upward, forward, and medially on the medulla oblongata. At the lower border of the pons, it joins the vessel of the opposite side to form the **basilar artery**.

Branches of The Cranial Portion of The Vertebral Artery:-

1- The **meningeal branches** are small and supply the bone and dura in the posterior cranial fossa.
2- The **posterior spinal artery** It descends on the posterior surface of the spinal cord close to the posterior roots of the spinal nerves.
3- The **anterior spinal artery**. The single artery descends on the anterior surface of the medulla oblongata and spinal cord and is embedded in the pia mater along the anterior median fissure.
4- The **posterior inferior cerebellar artery**, the largest branch of the vertebral artery passes on an irregular course between the medulla and the cerebellum.
5- The **medullary arteries** are very small branches that are distributed to the medulla oblongata.

Basilar Artery

The basilar artery, formed by the union of the two vertebral arteries, ascends in a groove on the anterior surface of the pons. At the upper border of the pons, it divides into the two posterior cerebral arteries.

Branches of The Basilar Artery:-

1- The **pontine arteries** are numerous small vessels that enter the substance of the pons.
2- The **labyrinthine artery** is a long, narrow artery that accompanies the facial and the vestibulocochlear nerves into the internal acoustic meatus and supplies the internal ear.
3- The **anterior inferior cerebellar artery** passes posteriorly and laterally and supplies the anterior and inferior parts of the cerebellum. A few branches pass to the pons and the upper part of the medulla oblongata.
4- The **superior cerebellar artery** arises close to the termination of the basilar artery.
5- The **posterior cerebral artery** curves laterally and backward around the midbrain and is joined by the posterior communicating branch of the internal carotid artery.

Circle of Willis

The circle of Willis lies in the interpeduncular fossa at the base of the brain. It is formed by the anastomosis between the two internal carotid arteries and the two vertebral arteries. The anterior communicating, anterior cerebral, internal carotid, posterior communicating, posterior cerebral, and basilar arteries all contribute to the circle. The circle of Willis allows blood that enters by either internal carotid or vertebral arteries to be distributed to any part of both cerebral hemispheres. Cortical and central branches arise from the circle and supply the brain substance.

Variations in the sizes of the arteries forming the circle are common and the absence of one or both posterior communicating arteries has been reported.

VEINS OF THE BRAIN

The veins of the brain have no muscular tissue in their very thin walls, and they possess no valves. They emerge from the brain and lie in the subarachnoid space. They pierce the arachnoid mater and the meningeal layer of the dura and drain into the cranial venous sinuses.

External Cerebral Veins:-

1- The **superior cerebral veins** pass upward over the lateral surface of the cerebral hemisphere and empty into the superior sagittal sinus.
2- The **superficial middle cerebral vein** drains the lateral surface of the cerebral hemisphere. It runs inferiorly in the lateral sulcus and empties into the cavernous sinus.
3- The **deep middle cerebral vein** drains the insula and is joined by the **anterior cerebral** and **striate veins** to form the **basal vein**. The basal vein ultimately joins the great cerebral vein, which in turn drains into the straight sinus.

Internal Cerebral Veins:-

There are two internal cerebral veins and they are formed by the union of the **thalamostriate vein** and the **choroid vein** at the interventricular foramen. The two veins run posteriorly in the tela choroidea of the third ventricle and unite beneath the splenium of the corpus callosum to form the great cerebral vein, which empties into the straight sinus..

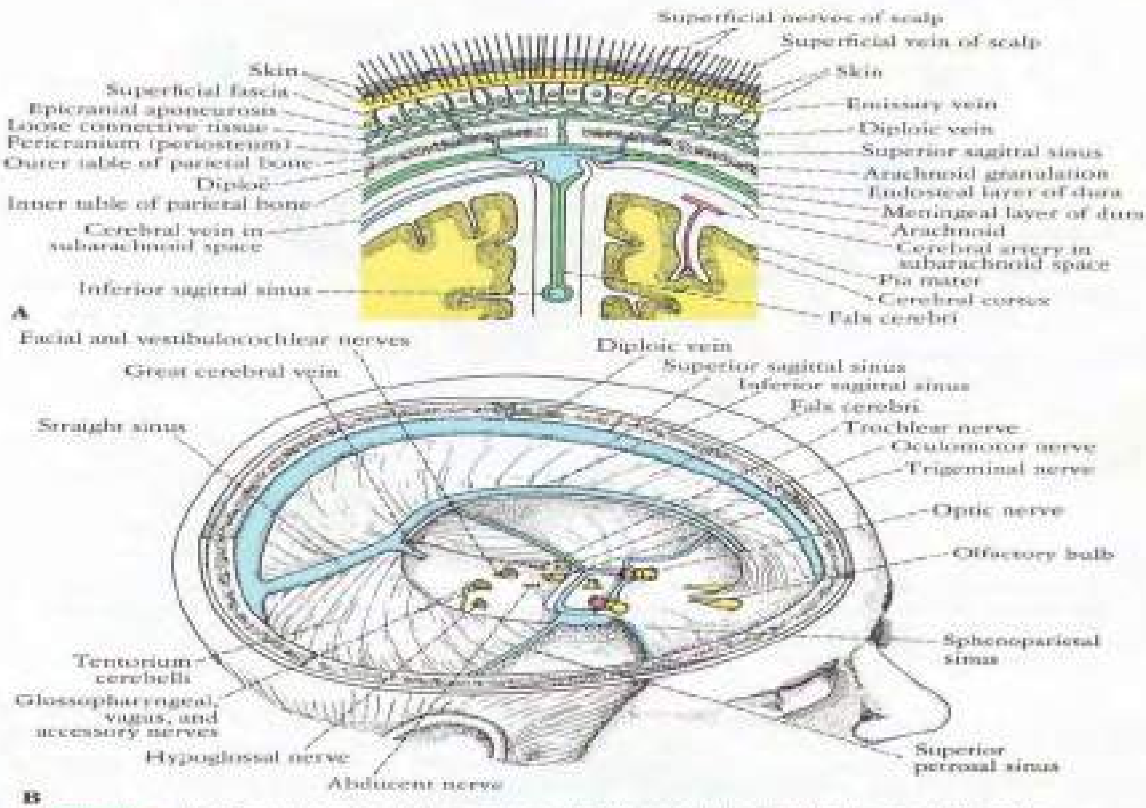


Figure 15-1 **A.** Coronal section of the upper part of the head showing the layers of the scalp, sagittal suture of the skull, falx cerebri, venous sinuses, arachnoid granulations, emissary veins, and relation of the cerebral blood vessels to the subarachnoid space. **B.** Interior of the skull, showing the dura mater and its contained venous sinuses.

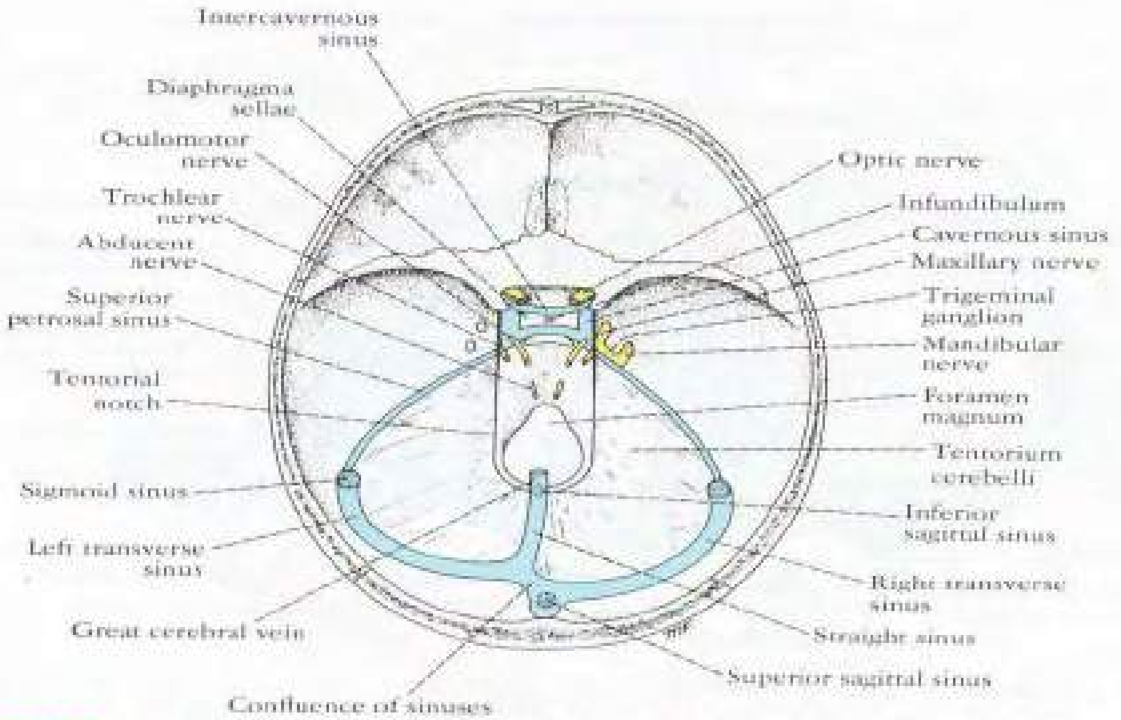


Figure 15-4 Superior view of the diaphragma sellae and tentorium cerebelli. Note the position of the cranial nerves and venous sinuses.

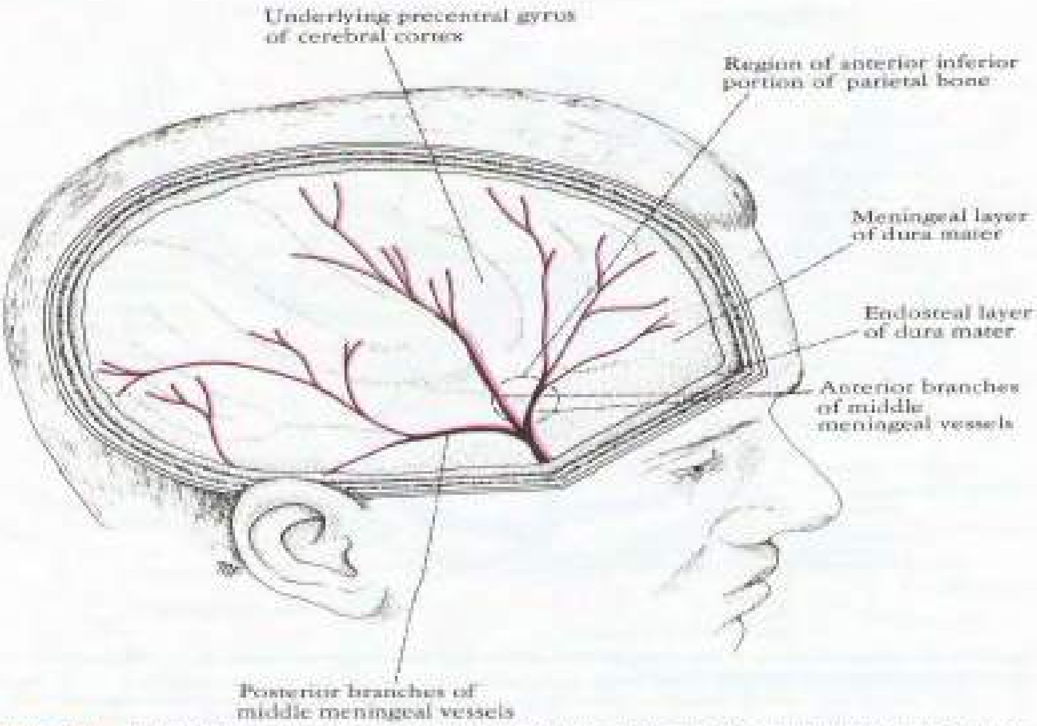


Figure 15-5 Right side of the head, showing the relations of the middle meningeal vessels to the layers of the dura mater and the skull.

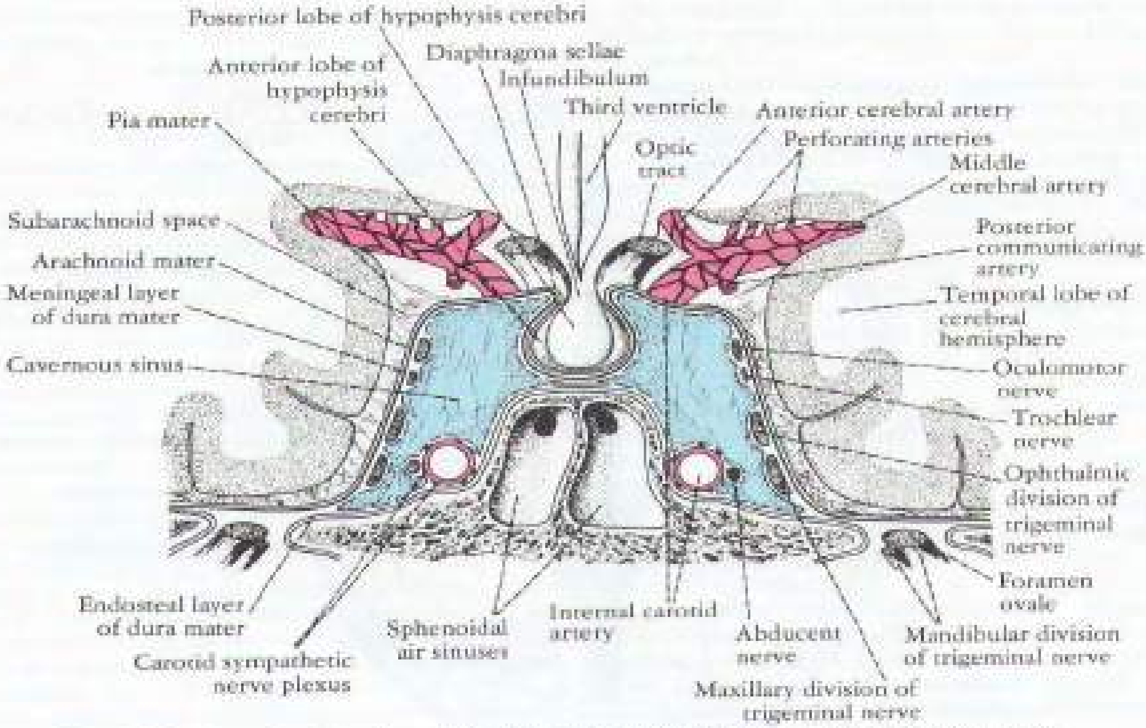


Figure 15–6 Coronal section through the body of the sphenoid bone, showing the hypophysis cerebri and cavernous sinuses. Note the position of the internal carotid artery and the cranial nerves.

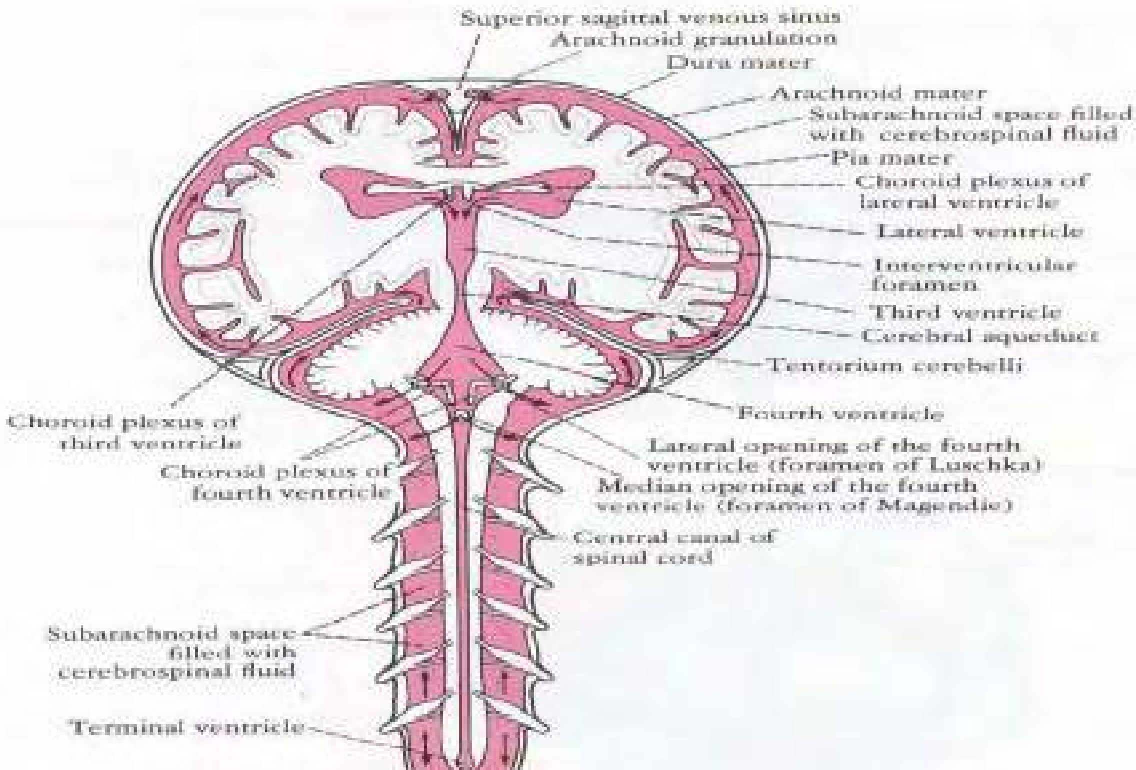


Figure 16–1 Origin and circulation of the cerebrospinal fluid.

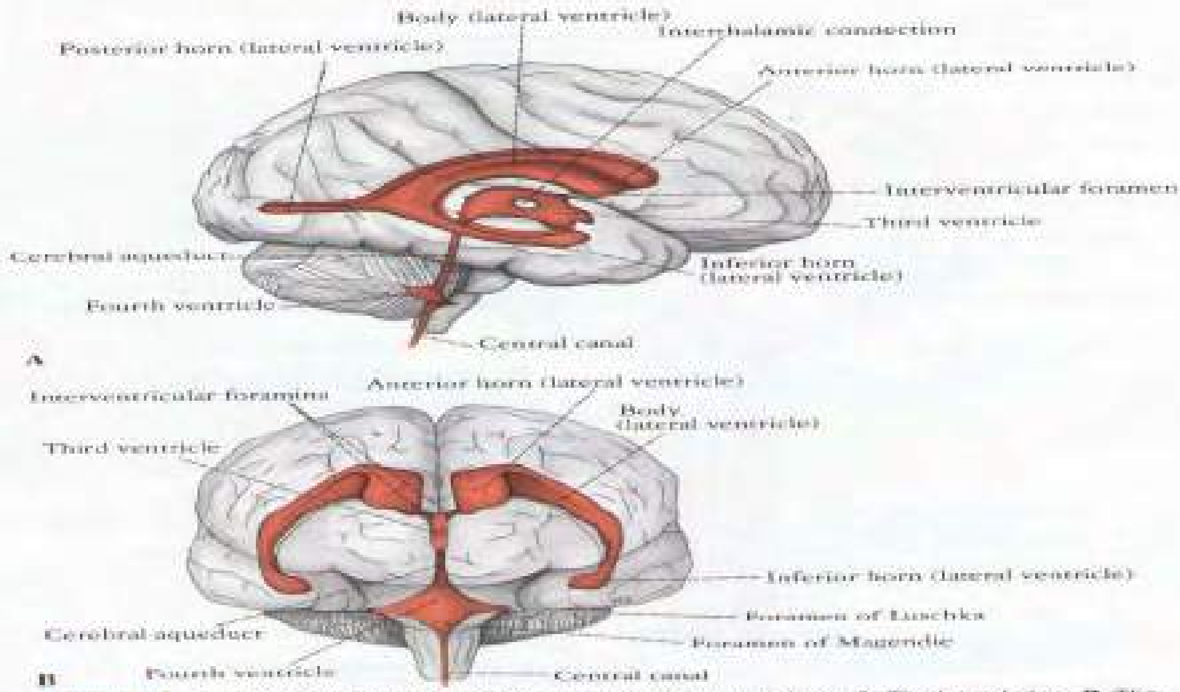


Figure 18-2 Cast of the ventricular cavities of the brain as seen from: **A.** The lateral view. **B.** The anterior view.

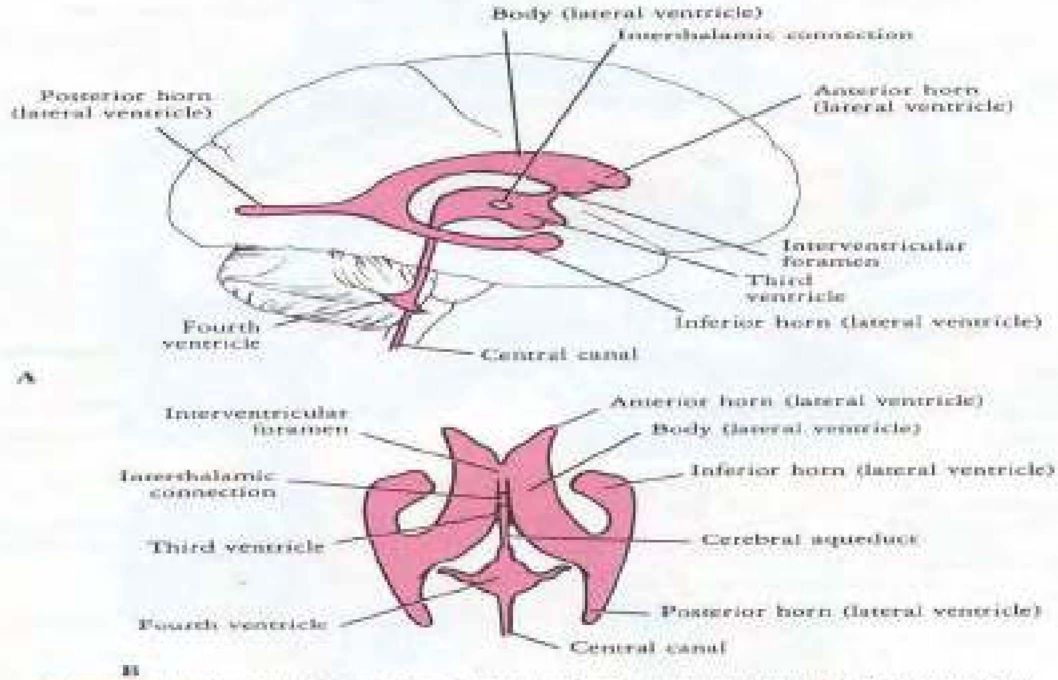


Figure 18-3 Ventricular cavities of the brain. **A.** Lateral view. **B.** Superior view.

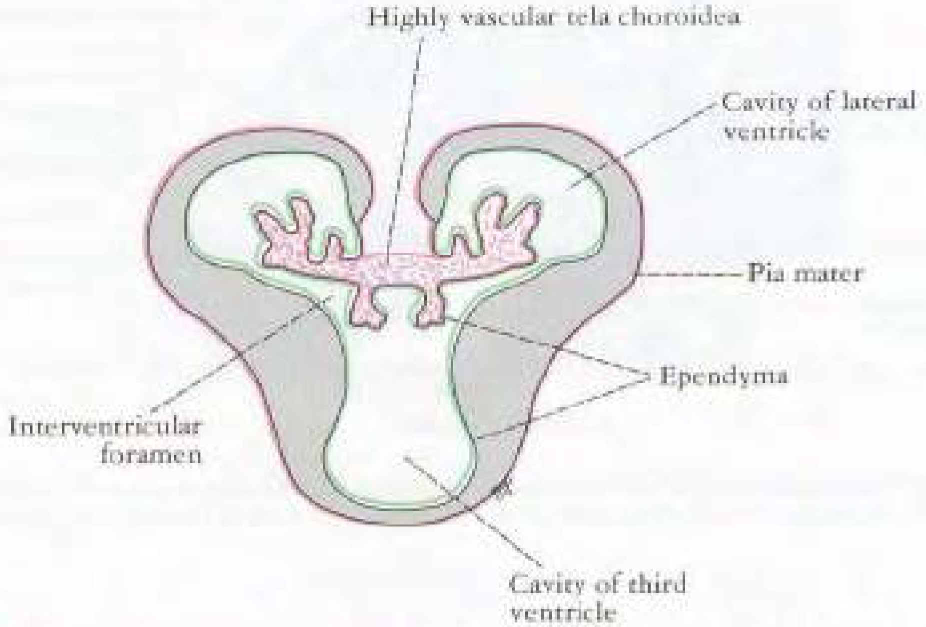


Figure 16–6 Schematic diagram of a coronal section of the third and lateral ventricles at the site of the interventricular foramina, showing the structure of the tela choroidea and its relationship with the ependyma and pia mater.

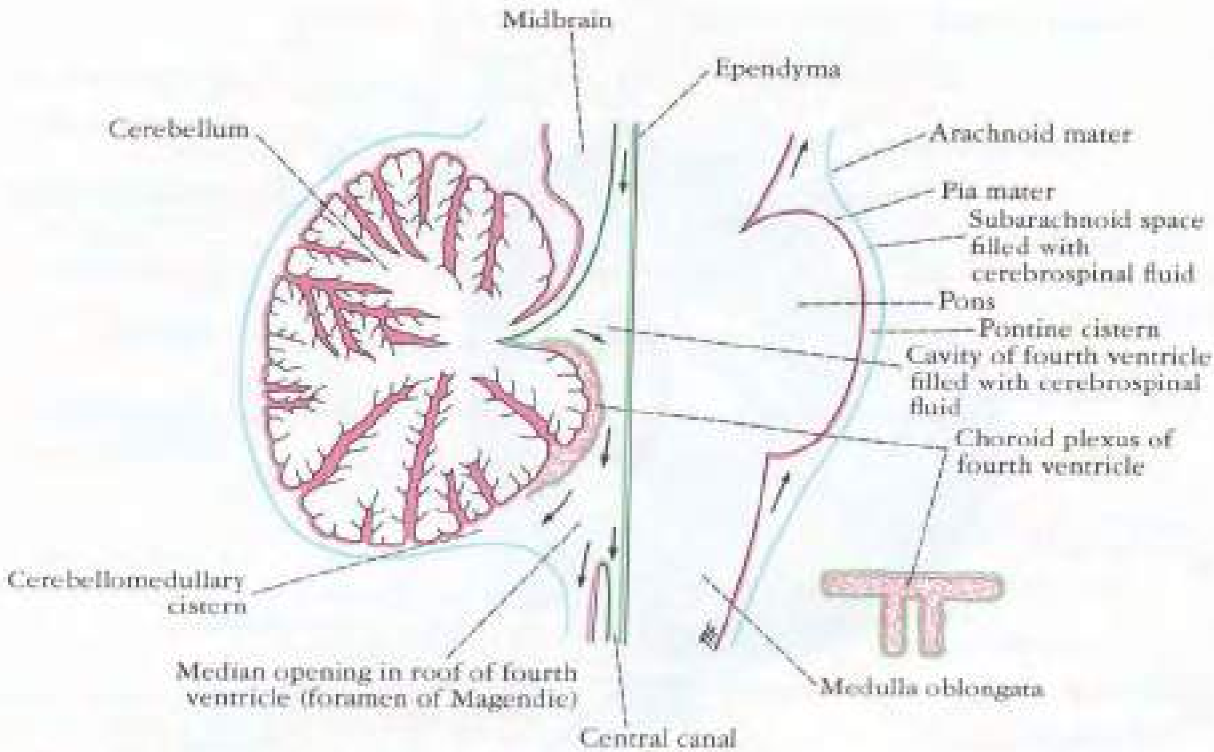


Figure 16–7 Sagittal section of the fourth ventricle, showing the origin and circulation of the cerebrospinal fluid. Note the position of the foramen of Magendie.

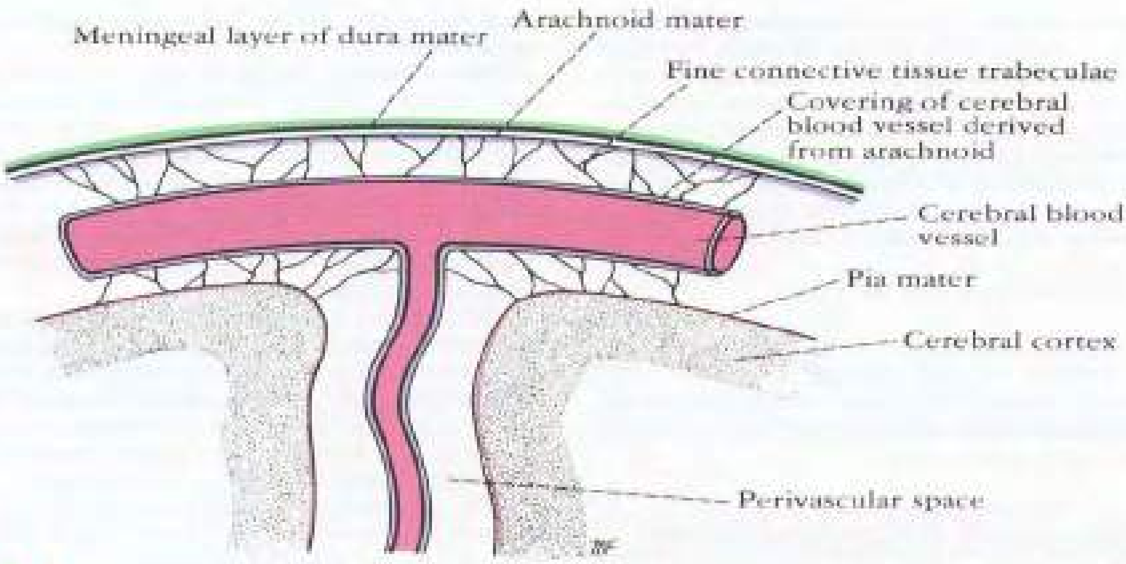


Figure 16–15 Diagram of the subarachnoid space around the cerebral hemisphere showing the relationship of the cerebral blood vessel to the meninges and cerebral cortex.

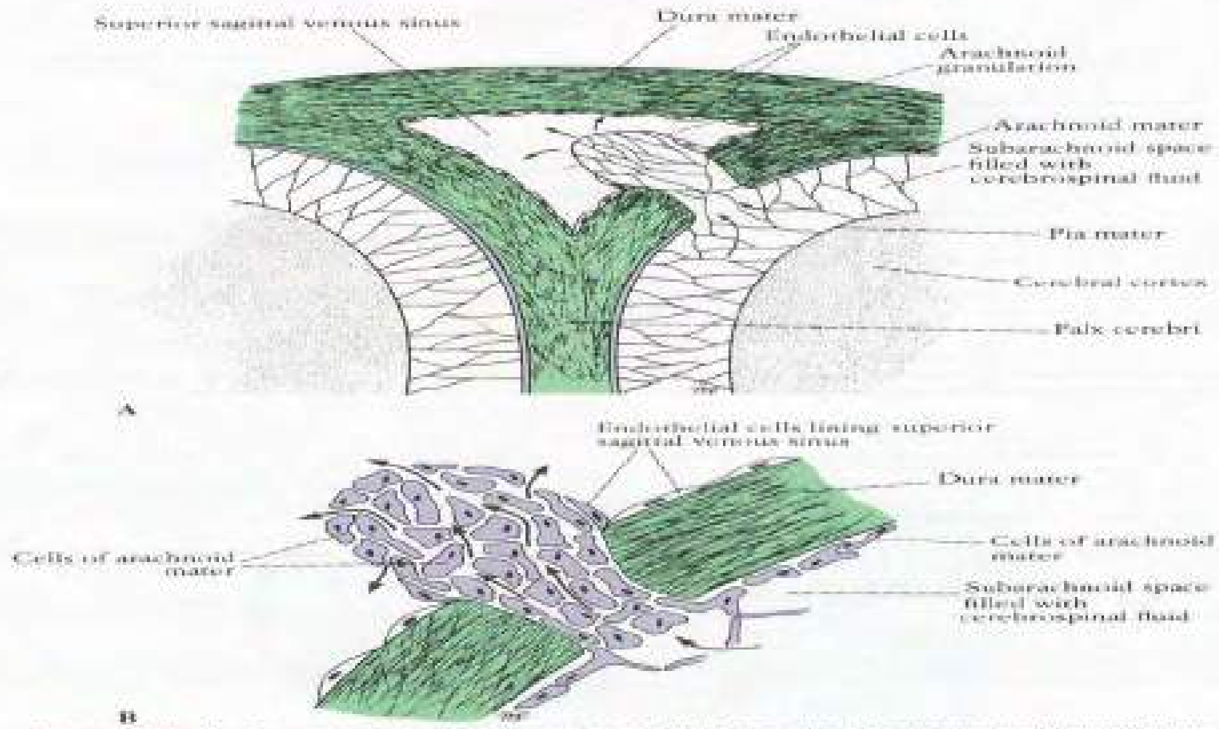


Figure 16–18 **A**. Coronal section of the superior sagittal sinus, showing an arachnoid granulation. **B**. Magnified view of an arachnoid granulation, showing the path taken by the cerebrospinal fluid into the venous system.

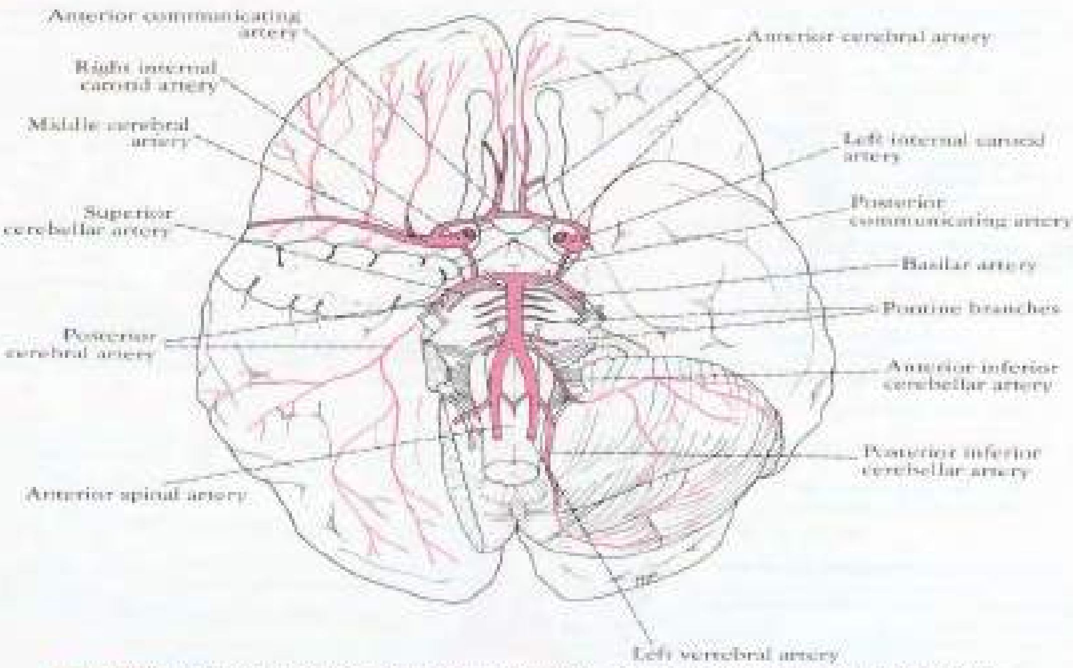


Figure 17–2 Arteries of the inferior surface of the brain. Note the formation of the circle of Willis. Part of the right temporal lobe has been removed to show the course of the middle cerebral artery.

Lecture 8 in Anatomy of CNS

By

Dr. Mohammad Ahmad Abdulla

THE CRANIAL NERVES

There are 12 pairs of cranial nerves, which leave the brain and pass through foramina and fissures in the skull. All the nerves are distributed in the head and neck, except the tenth, which also supplies structures in the thorax and abdomen.

Organization of The Cranial Nerves

The olfactory, optic, and vestibulocochlear nerves are **entirely sensory**. The oculomotor, trochlear, abducent, accessory, and hypoglossal nerves are **entirely motor**. The trigeminal, facial, glossopharyngeal, and vagus nerves are **both sensory and motor nerves**. The cranial nerves have central motor and /or sensory nuclei within the brain and peripheral nerve fibers that emerge from the brain and exit from the skull to reach their effector or sensory organs.

Motor Nuclei of the Cranial Nerves

The general visceral motor nuclei form the cranial outflow of the parasympathetic portion of the autonomic nervous system. They are the **Edinger-Westphal nucleus** of the oculomotor nerve, the **superior salivatory** and **lacrimal nuclei** of the facial nerve, the **inferior salivatory nucleus** of the glossopharyngeal nerve, and the **dorsal motor nucleus** of the vagus. These nuclei receive numerous afferent fibers including descending pathways from the hypothalamus.

Sensory Nuclei of the Cranial Nerves

These include somatic and visceral afferent nuclei. The sensory or afferent parts of a cranial nerve are the axons of nerve cells outside the brain and are situated in ganglia on the nerve trunks (equivalent to posterior root ganglion of a spinal nerve) or may be situated in a sensory organ, such as the nose, eye, or ear. These cells and their processes form the **first-order neuron**. The central processes of these cells enter the brain and terminate by synapsing with cells forming the sensory nuclei. These cells and their processes form the **second-order neuron**. Axons from these nuclear cells now cross the midline and ascend to other sensory nuclei, such as the thalamus, where they synapse. The nerve cells of these nuclei form the **third-order neuron** and their axons terminate in the cerebral cortex.

Olfactory Nerve (Cranial Nerve I)

The olfactory nerves arise from the olfactory receptor nerve cells in the olfactory mucous membrane located in the upper part of the nasal cavity. The **olfactory receptor cells** are consists of a small bipolar nerve cell that have a number of short cilia arise, the **olfactory hairs**, which project into the mucus covering the surface of the mucous membrane. These projecting hairs react to odors in the air and stimulate the olfactory cells. The **olfactory nerve fibers** that pass through the openings of the cribriform plate of the ethmoid bone to enter the olfactory bulb.

Olfactory Bulb:- This ovoid structure possesses several types of nerve cells, receives axons from the contralateral olfactory bulb through the olfactory tract.

Olfactory Tract:- This narrow band of white matter runs from the posterior end of the olfactory bulb beneath the inferior surface of the frontal lobe of the brain. It consists of the central axons of the same side and some fibers from the opposite olfactory bulb.As the olfactory tract reaches the **anterior perforated substance**, it divides into **medial** and **lateral olfactory striae**. The lateral stria carries the axons to the **olfactory area of the cerebral cortex (primary olfactory cortex).** The medial olfactory stria carries the fibers that cross the median plane in the anterior commissure to pass to the olfactory bulb of the opposite side. The **(area 28)** of the parahippocampal gyrus, which receives numerous connections from the primary olfactory cortex, is called the **secondary olfactory cortex**. These areas

of the cortex are responsible for the appreciation of olfactory sensations. Note that, in contrast to all other sensory pathways, the olfactory afferent pathway has only two neurons and reaches the cerebral cortex **without synapsing in any thalamic nuclei**.

Optic Nerve(Cranial Nerve II)

Origin Of The Optic Nerve:- The fibers of the optic nerve are the axons of the cells in the **ganglionic layer** of the retina. They converge on the **optic disc** and exit from the eye. The optic nerve leaves the orbital cavity through the optic canal and unites with the optic nerve of the opposite side to form the **optic chiasma.**

Optic Chiasma:- It is situated at the junction of the anterior wall and floor of the third ventricle. In the chiasma, the fibers from the nasal (medial) half of each retina, including the nasal half of the **macula,** cross the midline and enter the optic tract of the opposite side, while the fibers from the temporal (lateral) half of each retina, including the temporal half of the **macula,** pass posteriorly in the optic tract of the same side.

Optic Tract:- It emerges from the optic chiasma and passes posterolaterally around the cerebral peduncle. Most of the fibers synapse with nerve cells in the **lateral geniculate body** of the thalamus. A few of the fibers pass to the **pretectal nucleus** and the **superior colliculus** of midbrain and are concerned with light reflexes.

Lateral Geniculate Body:- It is a small, oval swelling projecting from **pulvinar of the thalamus.** The axons within the geniculate body leave it to form the **optic radiation**.

Optic Radiation:- The fibers of it are the axons of the nerve cells of the lateral geniculate body. The tract passes posteriorly through part of the **internal capsule** and terminates in the **visual cortex (area 17**. The **visual association cortex (areas 18 and 19)** is responsible for recognition of objects and perception of color.

Oculomotor Nerve (Cranial Nerve III)

Oculomotor Nerve Nuclei:- The oculomotor nerve has two motor nuclei:-

1- The **main oculomotor nucleus** is situated in the anterior part of the gray matter that surrounds the **cerebral aqueduct of the midbrain**. It lies at the level of the **superior colliculus**. The nucleus supply all the extrinsic muscles of the eye except the superior oblique and the lateral rectus. The outgoing nerve fibers pass anteriorly through the red nucleus and emerge on the anterior surface of the midbrain in the **interpeduncular fossa**. The main oculomotor nucleus receives fibers from both cerebral hemispheres, from the superior colliculus and from the visual cortex. It also receives fibers from the medial longitudinal fasciculus, by which it is connected to the nuclei of the fourth, sixth, and eighth cranial nerves.

2- The **accessory parasympathetic nucleus (Edinger-Westphal nucleus)** is situated posterior to the main oculomotor nucleus. The axons of the nerve cells accompany the other oculomotor fibers to the orbit. Here they synapse in the **ciliary ganglion** and postganglionic fibers pass through the **short ciliary nerves** to the constrictor pupillae of the iris and the ciliary muscles.

Course of the Oculomotor Nerve:- The oculomotor nerve emerges on the anterior surface of the midbrain. It then continues into the middle cranial fossa in the lateral wall of the cavernous sinus and enter the orbital cavity through the superior orbital fissure. The oculomotor nerve supplies the following extrinsic muscles of the eye: the levator palpebrae superioris, superior rectus, medial rectus, inferior rectus, and inferior oblique. It also supplies through its branch to the ciliary ganglion and the short ciliary nerves parasympathetic nerve fibers to the following intrinsic muscles: the constrictor pupillae of the iris and ciliary muscles.

Trochlear Nerve (Cranial Nerve IV)

Trochlear Nerve Nucleus:- The trochlear nucleus is situated in the anterior part of the gray matter that surrounds the **cerebral aqueduct of the midbrain**. It lies inferior to the oculomotor

nucleus at the level of the **inferior colliculus**. The nerve fibers, after leaving the nucleus, pass posteriorly to reach the posterior surface of the midbrain.
The trochlear nucleus receives fibers from the same areas for the main oculomotor nucleus.

Course of the Trochlear Nerve:- The trochlear nerve, the most slender of the cranial nerves, and the only one to leave the posterior surface of the brainstem, emerges from the midbrain. The trochlear nerve passes forward through the middle cranial fossa in the lateral wall of the cavernous sinus and enters the orbit through the superior orbital fissure. The nerve supplies the superior oblique muscle of the eyeball. The trochlear nerve is entirely motor and assists in turning the eye downward and laterally.

Trigeminal Nerve (Cranial Nerve V)

The trigeminal nerve is the largest cranial nerve and contains both sensory and motor fibers. It is the sensory nerve to the greater part of the head and the motor nerve to several muscles, including the muscles of mastication.

Trigeminal Nerve Nuclei:- The trigeminal nerve has four nuclei:

1- **Main Sensory Nucleus:-** This nucleus lies in the posterior part of the pons, lateral to the motor nucleus. It is continuous below with the spinal nucleus.
2- **Spinal Nucleus:-** This nucleus is continuous superiorly with the main sensory nucleus in the pons and extends inferiorly through the whole length of the medulla oblongata and into the upper part of the spinal cord as far as the second cervical segment.
3- **Mesencephalic Nucleus:-** This nucleus is situated in the lateral part of the gray matter around the cerebral aqueduct. It extends inferiorly into the pons as far as the main sensory nucleus.
4- **Motor Nucleus:-** This nucleus is situated in the pons medial to the main sensory nucleus.

Sensory Components of the Trigeminal Nerve

The sensations of pain and temperature and touch and pressure from the skin of the face and mucous membranes travel along axons whose cell bodies are situated in the **trigeminal sensory ganglion**. The sensations of touch and pressure are conveyed by nerve fibers that terminate in the main sensory nucleus. The sensations of pain and temperature pass to the spinal nucleus. Proprioceptive impulses from the muscles of mastication and from the facial and extraocular muscles are carried by the mesencephalic nucleus. The axons of the neurons in the main sensory, spinal nuclei and the mesencephalic nucleus, now cross the median plane and ascend as the trigeminal lemniscus to terminate on the nerve cells of nucleus of the thalamus. The axons of these cells now travel through the internal capsule to the postcentral gyrus (areas 3, 1, and 2) of the cerebral cortex.

Motor Component of the Trigeminal Nerve

The motor nucleus receives corticonuclear fibers from both cerebral hemispheres, the reticular formation, the red nucleus, the tectum, the medial longitudinal fasciculus and from the mesencephalic nucleus. The motor nucleus supplies the **muscles of mastication,** the **tensor tympani,** the **tensor veli palatini,** and the **mylohyoid** and the **anterior belly of the digastric muscle.**

Course of the Trigeminal Nerve:- The trigeminal nerve leaves the anterior aspect of the pons as a small motor root and a large sensory root. The nerve passes forward out of the posterior cranial fossa and rests on the upper surface of the apex of the petrous part of the temporal bone in the middle cranial fossa. The large sensory root now expands to form the crescent-shaped **trigeminal ganglion.** The ophthalmic, maxillary, and mandibular nerves arise from the anterior border of the ganglion. The ophthalmic nerve (V1) contains only sensory fibers and leaves the skull through the superior orbital fissure to enter the orbital cavity. The maxillary nerve (V2) also contains only sensory fibers and leaves the skull through the foramen rotundum. The mandibular nerve (V3) contains both sensory and motor fibers and leaves the skull through the foramen ovale.

The sensory fibers to the skin of the face from each division supply a distinct zone, there being little or no overlap of the dermatomes.

Abducent Nerve (Cranial Nerve VI)

Abducent Nerve Nucleus:- The small motor nucleus is situated beneath the floor of the upper part of the fourth ventricle, close to the midline and beneath the **colliculus facialis**. The nucleus receives afferent from the same areas for the main oculomotor nucleus.

Course of the Abducent Nerve:- The fibers of the abducent nerve pass anteriorly through the pons and emerge in the groove between the lower border of the pons and the medulla oblongata. It passes forward through the cavernous sinus. The nerve then enters the orbit through the superior orbital fissure. The abducent nerve is entirely a motor nerve and supplies the lateral rectus muscle and is, therefore, responsible for turning the eye laterally.

Facial Nerve (Cranial Nerve VII)

Facial Nerve Nuclei:- The facial nerve has three nuclei:-

1- **Main Motor Nucleus:-** This lies deep in the reticular formation of the lower part of the pons. The part of the nucleus that supplies the muscles of the upper part of the face receives corticonuclear fibers from **both** cerebral hemispheres. The part of the nucleus that supplies the muscles of the lower part of the face receives only corticonuclear fibers from the **opposite** cerebral hemisphere.
2- **Parasympathetic Nuclei:-** These lie posterolateral to the main motor nucleus. They are the **superior salivatory** and **lacrimal nuclei**. The superior salivatory nucleus receives afferent fibers from the hypothalamus through the **descending autonomic pathways**. **The lacrimal nucleus** receives afferent fibers from the hypothalamus and from the sensory nuclei of the trigeminal nerve.
3- **Sensory Nucleus:-** This is the upper part of the **nucleus of the tractus solitarius** and lies close to the motor nucleus. Sensations of taste travel through the peripheral axons of nerve cells situated in the **geniculate ganglion** on the seventh cranial nerve.

Course of the Facial Nerve:- The facial nerve consists of a motor and a sensory root. The fibers of the motor root travel posteriorly around the medial side of the abducent nucleus. Then they pass around its nucleus beneath the **colliculus facialis** in the floor of the fourth ventricle and finally pass anteriorly to emerge from the brainstem. The sensory root is formed of the cells of the geniculate ganglion. It also contains the efferent preganglionic parasympathetic fibers from the parasympathetic nuclei. The two roots of the facial nerve emerge from the anterior surface of the brain between the pons and the medulla oblongata. They pass laterally in the posterior cranial fossa with the vestibulocochlear nerve and enter the internal acoustic meatus. At the bottom of the meatus, the nerve enters the facial canal and runs laterally through the inner ear. On reaching the medial wall of the tympanic cavity, the nerve expands to form the sensory **geniculate ganglion**. At the posterior wall of the tympanic cavity the facial nerve turns downward and emerges from the stylomastoid foramen.

Distribution of the Facial Nerve:- The **motor nucleus** supplies the muscles of facial expression, the auricular muscles, the stapedius, the posterior belly of the digastric, and the stylohyoid muscles. The **superior salivatory nucleus** supplies the submandibular and sublingual salivary glands and the nasal and palatine glands. The **lacrimal nucleus** supplies the lacrimal gland. The **sensory nucleus** receives taste fibers from the anterior two-thirds of the tongue, the floor of the mouth, and the palate.

Vestibulocochlear Nerve (Cranial Nerve VIII)

This nerve consists of two distinct parts, the vestibular nerve and the cochlear nerve, which are concerned with the transmission of afferent information from the internal ear to the central nervous system.

Vestibular Nerve

The vestibular nerve conducts nerve impulses from the utricle and saccule that provide information concerning the position of the head; the nerve also conducts impulses from the semicircular canals that provide information concerning movements of the head. The nerve fibers of the vestibular nerve are located in the **vestibular ganglion**, which is situated in the **internal acoustic meatus**. They enter the anterior surface of the brainstem in a groove between the lower border of the pons and the upper part of the medulla oblongata. When they enter the vestibular nuclear complex, a small number of fibers pass directly to the cerebellum through the inferior cerebellar peduncle, bypassing the vestibular nuclei.

The Vestibular Nuclear Complex:- This complex consists of a group of nuclei situated beneath the floor of the fourth ventricle. Four nuclei may be recognized: (1) the **lateral vestibular nucleus,** (2) the **superior vestibular nucleus,** (3) the **medial vestibular nucleus,** and (4) the **inferior vestibular nucleus**. The vestibular nuclei receive afferent fibers from the **utricle** and **saccule** and the **semicircular canals** through the vestibular nerve, and fibers from the cerebellum through the inferior cerebellar peduncle. Efferent fibers also descend uncrossed to the spinal cord from the lateral vestibular nucleus and form the **vestibulospinal tract**. In addition, efferent fibers pass to the nuclei of the oculomotor, trochlear, and abducent nerves through the medial longitudinal fasciculus. These connections enable the movements of the head and the eyes to be coordinated. In addition, information received from the internal ear can assist in maintaining balance by influencing the muscle tone of the limbs and trunk. Ascending fibers also pass upward from the vestibular nuclei to the vestibular area in the postcentral gyrus, just above the lateral fissure, which serves to orient the individual consciously in space.

Cochlear Nerve

The cochlear nerve conducts nerve impulses concerned with sound from the organ of Corti in the cochlea. The fibers of the cochlear nerve are located in the **spiral ganglion of the cochlea**. They enter the anterior surface of the brainstem at the lower border of the pons.

Cochlear Nuclei:- The anterior and posterior cochlear nuclei are situated on the surface of the inferior cerebellar peduncle. They receive afferent fibers from the cochlea through the cochlear nerve. The cochlear nuclei send axons that run medially through the pons to end in the **trapezoid body** and the olivary nucleus. The axons now ascend through the posterior part of the pons and midbrain and form a tract known as the **lateral lemniscus**. On reaching the midbrain, the fibers of the lateral lemniscus either terminate in the **nucleus of the inferior colliculus** or are relayed in the **medial geniculate body** and pass to the **auditory cortex** of the cerebral hemisphere through the **acoustic radiation of the internal capsule**. The primary auditory cortex (areas 41 and 42) on the upper surface of the superior temporal gyrus. The recognition and interpretation of sounds on the basis of past experience take place in the secondary auditory area.

Course of the Vestibulocochlear Nerve:- The vestibular and cochlear parts of the nerve leave the anterior surface of the brain between the lower border of the pons and the medulla oblongata**.** They run laterally in the posterior cranial fossa and enter the internal acoustic meatus with the facial nerve. The fibers are then distributed to the different parts of the internal ear.

Glossopharyngeal Nerve (Cranial Nerve IX)

Glossopharyngeal Nerve Nuclei:- The glossopharyngeal nerve has three nuclei:

1- Main Motor Nucleus:- This nucleus lies deep in the reticular formation of the medulla oblongata and is formed by the superior end of the nucleus ambiguus. It receives corticonuclear fibers from both cerebral hemispheres. The efferent fibers supply the **stylopharyngeus muscle.**

2- **Parasympathetic Nucleus:-** This nucleus is also called the **inferior salivatory nucleus**. It receives afferent fibers from the hypothalamus through the **descending autonomic pathways.** It also is thought to receive information from the olfactory system through the reticular formation. Information concerning taste also is received from the nucleus of the solitary tract from the mouth cavity. The efferent preganglionic parasympathetic fibers reach the otic ganglion.

3- **Sensory Nucleus:-** This is part of the **nucleus of the tractus solitarius**. Sensations of taste travel through the peripheral axons of nerve cells situated in the **ganglion** on the glossopharyngeal nerve. From the thalamus, the axons of the thalamic cells pass through the internal capsule and corona radiata to end in the lower part of the postcentral gyrus. Afferent information that concerns common sensation enters the brainstem through the superior ganglion of the glossopharyngeal nerve, but ends in the **spinal nucleus of the trigeminal nerve.** Afferent impulses from the **carotid sinus,** a baroreceptor situated at the bifurcation of the common carotid artery, also travel with the glossopharyngeal nerve that assists in the regulation of arterial blood pressure.

Course of the Glossopharyngeal Nerve:- The glossopharyngeal nerve leaves the anterolateral surface of the upper part of the medulla oblongata as a series of rootlets in a groove between the olive and the inferior cerebellar peduncle. It passes laterally in the posterior cranial fossa and leaves the skull through the jugular foramen. The superior and inferior glossopharyngeal sensory ganglia are situated on the nerve here. The nerve then descends through the upper part of the neck in company with the internal jugular vein and the internal carotid artery to reach the posterior border of the stylopharyngeus muscle, which it supplies. The nerve then passes forward between the superior and middle constrictor muscles of the pharynx to give sensory branches to the mucous membrane of the pharynx and the posterior third of the tongue.

Vagus Nerve (Cranial Nerve X)

Vagus Nerve Nuclei:- The vagus nerve has three nuclei:-

1- **Main Motor Nucleus:-**This nucleus lies deep in the reticular formation of the medulla oblongata and is formed by the nucleus ambiguus. It receives fibers from both cerebral hemispheres. The efferent fibers supply the constrictor muscles of the pharynx and the intrinsic muscles of the larynx.

2- **Parasympathetic Nucleus:-** This nucleus forms the dorsal nucleus of the vagus and lies beneath the floor of the lower part of the fourth ventricle. It receives afferent fibers from the hypothalamus through the descending autonomic pathways, and from the glossopharyngeal nerve (carotid sinus reflex). The efferent fibers are distributed to the involuntary muscle of the bronchi, heart, esophagus, stomach, small intestine, and large intestine as far as the distal one-third of the transverse colon.

3- **Sensory Nucleus:-** This nucleus is the lower part of the **nucleus of the tractus solitarius**. Sensations of taste travel through the peripheral axons of nerve cells situated in the **inferior ganglion on the vagus nerve**. From the thalamus, the axons of the thalamic cells pass through the internal capsule and corona radiata to end in the postcentral gyrus. Afferent information concerning common sensation enters the brainstem through the superior ganglion of the vagus nerve but ends in the **spinal nucleus of the trigeminal nerve**.

Course of the Vagus Nerve:- The vagus nerve leaves as a series of rootlets in a groove between the olive and the inferior cerebellar peduncle. It passes laterally through the posterior cranial fossa and leaves the skull through the jugular foramen. The vagus nerve possesses two sensory ganglia. Below the inferior ganglion the cranial root of the accessory nerve joins the vagus nerve and is distributed mainly in its pharyngeal and recurrent laryngeal branches. The vagus nerve descends vertically in the neck within the carotid sheath with the internal jugular vein and carotid arteries.

The **right vagus nerve** enters the thorax and passes posterior to the root of the right lung contributing to the pulmonary plexus. It then passes on to the posterior surface of the esophagus and contributes to the esophageal plexus. It enters the abdomen through the esophageal opening of the diaphragm. The posterior vagal trunk (the right vagus) is distributed to the stomach, duodenum, liver, kidneys, and small and large intestines as far as the distal third of the transverse colon. This wide distribution is accomplished through the celiac, superior mesenteric, and renal plexuses.
The **left vagus nerve** enters the thorax and crosses the left side of the aortic arch and descends behind the root of the left lung contributing to the pulmonary plexus. The left vagus then descends on the anterior surface of the esophagus contributing to the esophageal plexus. It enters the abdomen through the esophageal opening of the diaphragm. The anterior vagal trunk (the left vagus) divides into several branches, which are distributed to the stomach, liver, upper part of the duodenum, and head of the pancreas.

Accessory Nerve (Cranial Nerve XI)

Cranial Root (Part):- It is formed from the axons of nerve cells of the **nucleus ambiguous** which receives fibers from both cerebral hemispheres. The efferent fibers of the nucleus emerge from the anterior surface of the medulla oblongata between the olive and the inferior cerebellar peduncle.

Course Of The Cranial Root:- The nerve runs laterally in the posterior cranial fossa and joins the spinal root. The two roots unite and leave the skull through the jugular foramen. The roots then separate and the cranial root joins the vagus nerve and is distributed in its pharyngeal and recurrent laryngeal branches to the muscles of the soft palate, pharynx, and larynx.

Spinal Root (Part):- It is formed from axons of nerve cells in the **spinal nucleus,** which is situated in the anterior gray column of the spinal cord in the upper five cervical segments. The spinal nucleus is thought to receive corticospinal fibers from both cerebral hemispheres**.**

Course Of The Spinal Root:- The nerve fibers emerge from the spinal cord midway between the anterior and posterior nerve roots of the cervical spinal nerves. The fibers form a nerve trunk that ascends into the skull through the foramen magnum. The spinal root passes laterally and joins the cranial root as they pass through the jugular foramen. After a short distance, the spinal root separates from the cranial root and runs downward and laterally and enters the deep surface of the sternocliedomastoid muscle, which it supplies. The nerve then crosses the posterior triangle of the neck and passes beneath the trapezius muscle, which it supplies.
The accessory nerve thus brings about movements of the soft palate, pharynx, and larynx and controls the movement of two large muscles in the neck.

Hypoglossal Nerve (Cranial Nerve XII)

Hypoglossal Nucleus:- The hypoglossal nucleus is situated close to the midline immediately beneath the floor of the lower part of the fourth ventricle. It receives corticonuclear fibers from both cerebral hemispheres.

Course of the Hypoglossal Nerve:- The hypoglossal nerve fibers emerge between the pyramid and the olive. It crosses the posterior cranial fossa and leaves the skull through the hypoglossal canal. The nerve passes downward and forward in the neck between the internal carotid artery and the internal jugular vein until it reaches the lower border of the posterior belly of the digastric muscle. Here, it turns forward and crosses the internal and external carotid arteries and the loop of the lingual artery. It passes deep to the mylohyoid muscle lying on the lateral surface of the hyoglossus muscle. The nerve then sends branches to the muscles of the tongue. In the upper part of its course, the hypoglossal nerve is joined by CI fibers from the cervical plexus. The hypoglossal nerve thus controls the movements and shape of the tongue.

Lecture 9 in Anatomy of CNS

By

Dr. Mohammad Ahmad Abdulla

THE SPINAL CORD

GROSS APPEARANCE OF THE SPINAL CORD

The spinal cord is roughly cylindrical in shape. It begins superiorly at the foramen magnum in the skull, where it is continuous with the **medulla oblongata** of the brain, and it terminates inferiorly in the adult at the level of the **lower border of the first lumbar vertebra.** In the young child, it is relatively longer and usually ends at the upper border of the third lumbar vertebra. Thus it occupies the upper two-thirds of the **vertebral canal** of the vertebral column and is surrounded by the three meninges, the dura mater, the arachnoid mater, and the pia mater. Further protection is provided by the **cerebrospinal fluid,** which surrounds the spinal cord in the **subarachnoid space.**

In the cervical region, where it gives origin to the brachial plexus, and in the lower thoracic and lumbar regions, where it gives origin to the lumbosacral plexus, the spinal cord is fusiformly **enlarged**; the enlargements are referred to as the **cervical** and **lumbar enlargements**. Inferiorly, the spinal cord tapers off into the **conus medullaris,** from the apex of which a prolongation of the pia mater, the **filum terminale,** descends to be attached to the posterior surface of the coccyx. The cord possesses, in the midline anteriorly, a deep longitudinal fissure, the **anterior median fissure,** and on the posterior surface, a shallow furrow, the **posterior median sulcus**.

Along the entire length of the spinal cord are attached 31 pairs of spinal nerves by the **anterior** or **motor roots** and the **posterior** or **sensory roots**. Each root is attached to the cord by a series of rootlets, which extend the whole length of the corresponding segment of the cord.

Each posterior nerve root possesses a **posterior root ganglion,** the cells of which give rise to peripheral and central nerve fibers.

STRUCTURE OF THE SPINAL CORD

The spinal cord is composed of an inner core of gray matter, which is surrounded by an outer covering of white matter; there is no indication that the cord is segmented.

GRAY MATTER

On cross section, the gray matter is seen as an H-shaped pillar with **anterior** and **posterior gray columns,** or **horns,** united by a thin **gray commissure** containing the small **central canal**. A small **lateral gray column** or **horn** is present in the thoracic and upper lumbar segments of the cord. The amount of gray matter present at any given level of the spinal cord is related to the amount of muscle innervated at that level. Thus, its size is greatest within the cervical and lumbosacral enlargements of the cord, which innervate the muscles of the upper and lower limbs, respectively.

STRUCTURE OF GRAY MATTER

As in other regions of the central nervous system, the gray matter of the spinal cord consists of a mixture of nerve cells and their processes, neuroglia, and blood vessels. The nerve cells are multipolar and the neuroglia forms an intricate network around the nerve cell bodies and their neurites.

A- Nerve Cell Groups in the Anterior Gray Columns:-

Most nerve cells are large and multipolar, and their axons pass out in the anterior roots of the spinal nerves as **alpha efferents**, which innervate skeletal muscles. The smaller nerve cells are also multipolar and the axons of many of these pass out in the anterior roots of the spinal nerves as **gamma efferents**, which innervate the intrafusal muscle fibers of neuromuscular spindles.

For practical purposes, the nerve cells of the anterior gray column may be divided into three basic groups or columns—medial, central, and lateral:-

1- The **medial group** is present in most segments of the spinal cord and is responsible for innervating the skeletal muscles of the neck and trunk, including the intercostal and abdominal musculature.

2- The **central group** is the smallest and is present in some cervical and lumbosacral segments. In the cervical part of the cord some of these nerve cells (segments C3, 4, and 5) specifically innervate the diaphragm and are collectively referred to as the phrenic nucleus. In the upper five or six cervical segments, some of the nerve cells innervate the sternocleidomastoid and trapezius muscles and are referred to as the **accessory nucleus**.

3- The **lateral group** is present in the cervical and lumbosacral segments of the cord and is responsible for innervating the skeletal muscles of the limbs.

B- Nerve Cell Groups in the Posterior Gray Columns:-

There are four nerve cell groups of the posterior gray column, two that extend throughout the length of the cord and two that are restricted to the thoracic and lumbar segments:-

1- The **substantia gelatinosa group** is situated at the apex of the posterior gray column throughout the length of the spinal cord. It receives afferent fibers concerned with pain, temperature, and touch from the posterior root.

2- The **nucleus proprius** is a group of large nerve cells situated anterior to the substantia gelatinosa throughout the spinal cord. This nucleus receives fibers from the posterior white column that are associated with the senses of position and movement (proprioception), two-point discrimination, and vibration.

3- The **nucleus dorsalis (Clark's column)** is situated at the base of the posterior gray column and extending from the eighth cervical segment caudally to the third or fourth lumbar segment. This nucleus associated with proprioceptive endings (neuromuscular spindles and tendon spindles).

4- The **visceral afferent nucleus** is situated lateral to the nucleus dorsalis; it extends from the first thoracic to the third lumbar segment of the spinal cord. It is believed to be associated with receiving visceral afferent information.

C- Nerve Cell Groups in the Lateral Gray Columns:-

The intermediolateral group of cells form the small lateral gray column, which extends from the first thoracic to the second or third lumbar segment of the spinal cord. The cells give rise to pre-ganglionic sympathetic fibers. A similar group of cells found in the second, third, and fourth sacral segments of the spinal cord give rise to preganglionic parasympathetic fibers.

D- The Gray Commissure and Central Canal:-

In transverse sections of the spinal cord, the anterior and posterior gray columns on each side are connected by a transverse **gray commissure**, so that the gray matter resembles the letter H. In the center of the gray commissure is situated the **central canal**. The part of the gray commissure that is situated posterior to the central canal is often referred to as the **posterior gray commissure**; similarly, the part that lies anterior to the canal is called the **anterior gray commissure**.

The central canal is present throughout the spinal cord. Superiorly, it is continuous with the central canal of the caudal half of the medulla oblongata and above this it opens into the cavity of the fourth ventricle. Inferiorly in the conus medullaris, it expands into the fusiform **terminal ventricle** and terminates below within the root of the filum terminale. It is filled with cerebrospinal fluid, thus the central canal is closed inferiorly and opens superiorly into the fourth ventricle.

White Matter

The white matter, for purposes of description, may be divided into **anterior, lateral,** and **posterior white columns**. The anterior column on each side lies between the midline and the point of emergence of the anterior nerve roots; the lateral column lies between the emergence of the anterior nerve roots and the entry of the posterior nerve roots; the posterior column lies between the entry of the posterior nerve roots and the midline.

STRUCTURE OF WHITE MATTER

As in other regions of the central nervous system, the white matter of the spinal cord consists of a mixture of nerve fibers, neuroglia, and blood vessels. It surrounds the gray matter and its white color is due to the high proportion of myelinated nerve fibers.

Arrangement of Nerve Fiber Tracts

The arrangement of the nerve fiber tracts, are divided into ascending, descending, and intersegmental tracts and their relative positions in the white matter are described below.

A- The Ascending Tracts of The Spinal Cord:-

The ascending tracts conduct afferent information that divided into two main groups: (1) **exteroceptive** information, which originates from outside the body, such as pain, temperature, and touch, and (2) **proprioceptive** information, which originates from inside the body, for example, from muscles and joints.

ANATOMICAL ORGANIZATION

General information from the peripheral sensory endings is conducted through the nervous system by a series of neurons. In its simplest form, the ascending pathway to consciousness consists of three neurons. The first neuron, the **first-order neuron,** has its cell body in the **posterior root ganglion** of the spinal nerve. A peripheral process connects with a sensory receptor ending, whereas a central process enters the spinal cord through the posterior root to synapse on the second-order neuron. The **second-order neuron** gives rise to an axon that decussates (crosses to the opposite side) and ascends to a higher level of the central nervous system, where it synapses with the **third-order neuron**. The third-order neuron is usually in the thalamus and gives rise to a projection fiber that passes to a sensory region of the cerebral cortex. The three-neuron chain described is the most common arrangement, but some afferent pathways use more or fewer neurons. Many of the neurons in the ascending pathways branch and give a major input into the reticular formation, which in turn activates the cerebral cortex, maintaining wakefulness. Other branches pass to motor neurons and participate in reflex muscular activity.

The Ascending Tracts Includes:-

1- Lateral Spinothalamic Tract:- for Pain And Temperature Pathways.
2- Anterior Spinothalamic Tract:- for Light (Crude) Touch And Pressure Pathways.
3- Posterior White Column:- Fasciculus Gracilis and Fasciculus Cuneatus:- for Discriminative Touch, Vibratory Sense, and Conscious Muscle Joint Sense.
4- Anterior Spinocerebellar Tract, Posterior Spinocerebellar Tract and Cuneocerebellar Tract:- for Muscle Joint Sense Pathways To The Cerebellum.
5- Spinotectal Tract:- for spinovisual reflexes and brings about movements of the eyes and head toward the source of the stimulation.
6- Spinoreticular Tract:- pathway for the reticular formation, which plays an important role in influencing levels of consciousness.
7- Spino-Olivary Tract:- conveys information to the cerebellum from cutaneous and proprioceptive organs.
8- Visceral Sensory Tracts:- participate in reflex activity.

B-The Descending Tracts of The Spinal Cord:-

The motor neurons situated in the anterior gray columns of the spinal cord send axons to innervate skeletal muscle through the anterior roots of the spinal nerves. These motor neurons are sometimes referred to as the **lower motor neurons** and constitute the final common pathway to the muscles.
The lower motor neurons are constantly bombarded by nervous impulses that descend from the medulla, pons, midbrain, and cerebral cortex, as well as those that enter along sensory fibers from the posterior roots. The nerve fibers that descend in the white matter from different supraspinal nerve centers are segregated into nerve bundles called the **descending tracts**. These supraspinal neurons and their tracts are sometimes referred to as the **upper motor neurons** and they provide numerous separate pathways that can influence motor activity.

ANATOMICAL ORGANIZATION

Control of skeletal muscle activity from the cerebral cortex and other higher centers is conducted through the nervous system by a series of neurons. The descending pathway from the cerebral cortex is often made up of three neurons. The first neuron, the **first-order neuron**, has its cell body in the cerebral cortex. Its axon descends to synapse on the **second-order neuron**, an internuncial neuron, situated in the anterior gray column of the spinal cord. The axon of the second-order neuron is short and synapses with the **third-order neuron**, the lower motor neuron, in the anterior gray column. The axon of the third-order neuron innervates the skeletal muscle through the anterior root and spinal nerve. In some instances, the axon of the first-order neuron terminates directly on the third-order neuron (as in reflex arcs).

The Descending Tracts Includes:-

1- Anterior & Lateral Corticospinal Tracts:- originate from the primary motor cortex.
2- Reticulospinal Tracts:- Throughout the reticular formation, these tracts provide a pathway by which the hypothalamus can control the sympathetic outflow and the sacral parasympathetic outflow.
3- Tectospinal Tract:- concerned with reflex postural movements in response to visual stimuli.
4- Rubrospinal Tract:- facilitates the activity of the flexor muscles and inhibits the activity of the extensor or antigravity muscles.
5- Vestibulospinal Tract:- facilitate the activity of the extensor muscles and inhibit the activity of the flexor muscles in association with the maintenance of balance.
6- Olivospinal Tract:- influence the activity of the motor neurons in the anterior gray column.
7- Descending Autonomic Fibers:- associated with the control of autonomic activity.

C- Intersegmental Tracts:-

Short ascending and descending tracts that originate and end within the spinal cord exist in the anterior, lateral, and posterior white columns. The function of these pathways is to interconnect the neurons of different segmental levels, and they are particularly important in intersegmental spinal reflexes.