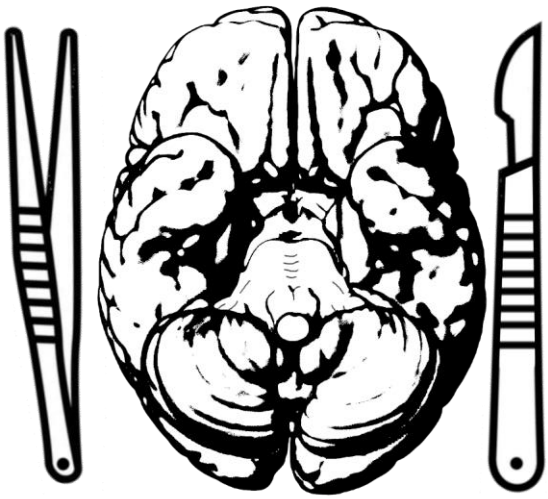
TEL AVIV UNIVERSITY

NEUROANATOMY

DISSECTION GUIDE



Sackler Faculty of Medicine
Tel Aviv University

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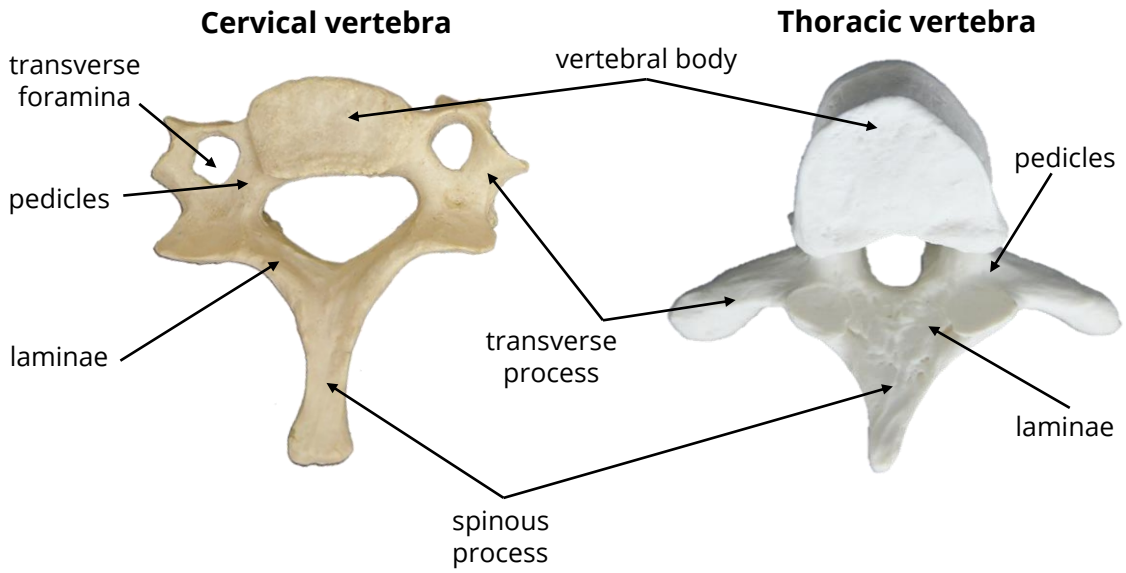
Spinal cord

Structure of the vertebra

The vertebra consists of the vertebral body, two pedicles (small foot) and two laminae (plate). The hole in the center of the vertebra is the vertebral foramen. Between each lamina and pedicle, find the transverse process. Between the two laminae, find the spinous process.

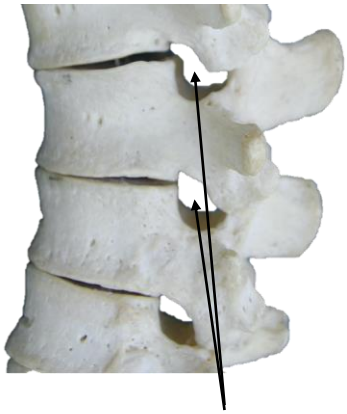
The cervical vertebrae (neck) are similar in structure to the other vertebrae. However, they also have holes in the transverse processes, the transverse foramina, through which the vertebral arteries pass.



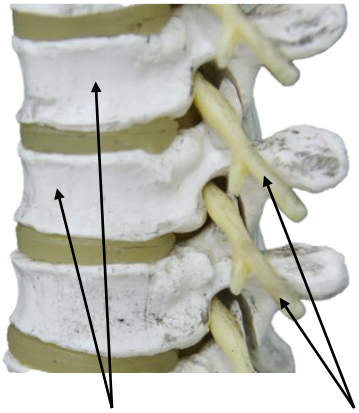
Structure of the vertebral column

Humans have 33 vertebrae that form the vertebral column. When the vertebrae are placed on top of each other, the vertebral foramina form the spinal canal that contains the spinal cord. On each side, a lateral hole is formed between each pair of vertebrae, the intervertebral foramen through which the spinal nerves pass. Intervertebral discs separate between the bodies of the vertebrae.

The vertebral column



intervertebral foramen



Intervertebral discs spinal nerves

vertebral column

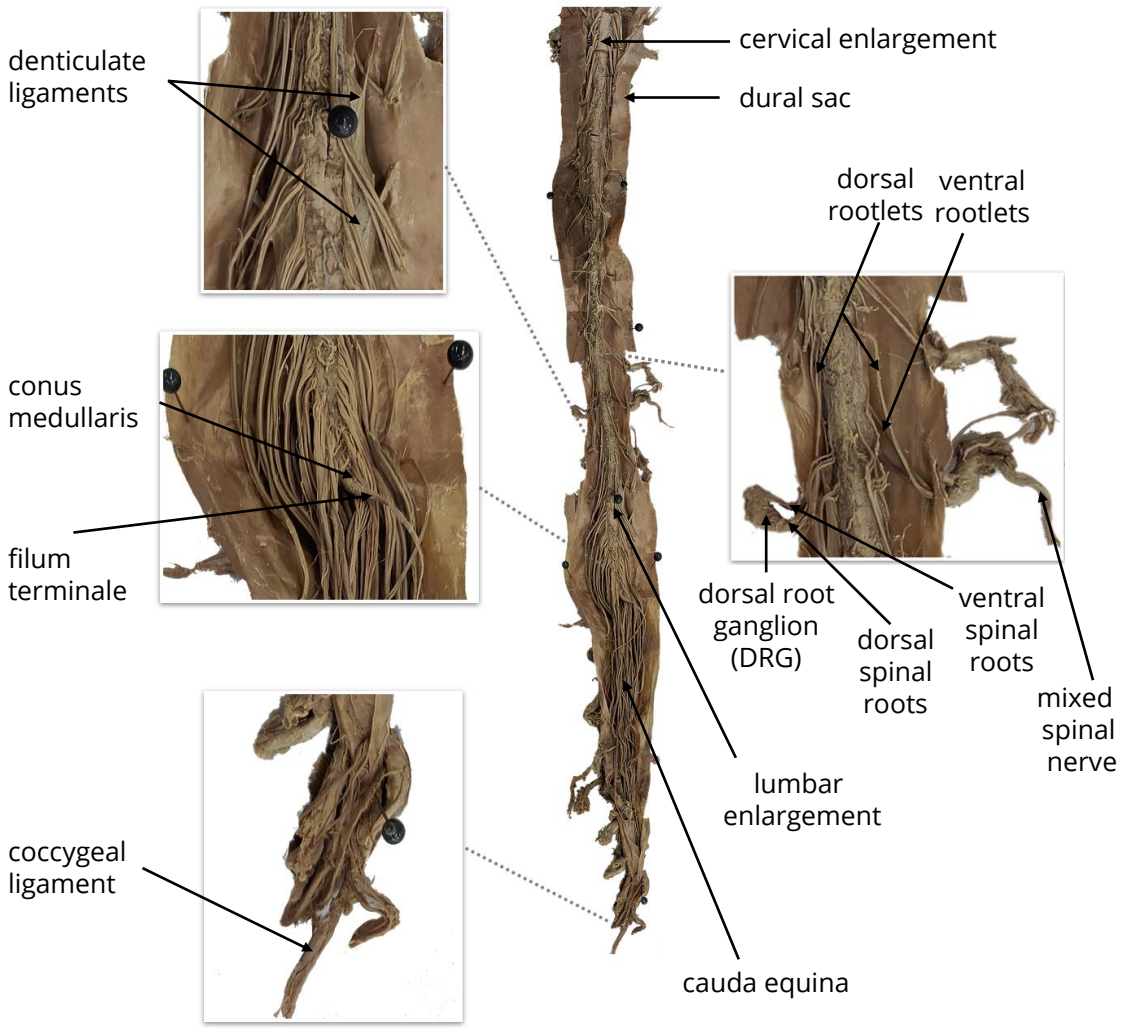
Spinal cord meninges

Three meninges cover the spinal cord and the brain. The most external meninx is the dura mater (hard). In the spinal cord, it creates the dural sac. While the dura around the brain is adjacent to the skull, the epidural space (between the dura and the vertebrae) is filled with blood vessels and fat. The dural sac terminates at the level of vertebra S2 and its extension, the coccygeal ligament, attaches to the coccyx bone.

Make a longitudinal incision to open the dural sac. The next meninx is the arachnoid mater (spider's web) that is attached to the inner part of the dura (in the brain it is more distinct and resembles a spider web). The innermost meninx that covers the spinal cord is the pia mater. The space between the pia and the arachnoid is the subarachnoid space that is filled with cerebrospinal fluid (CSF). Between segments C1 and L1, notice 21 pairs of pia extensions that leave the spinal cord, penetrate the arachnoid and fixate the spinal cord to the dura, the denticulate ligaments. The pia mater that covers the spinal cord continues caudally in a silvery structure called filum terminale that continues into the coccygeal ligament.

Structure of the spinal cord

Notice that the spinal cord is wider in two places, the cervical enlargement and the lumbar enlargement. These areas include the neural matter of the upper and lower limbs respectively. The spinal cord ends at the level of vertebra L2 in the conus medullaris. Along the length of the spinal cord, notice ventral rootlets and dorsal rootlets that join to create the ventral spinal roots and dorsal spinal roots. Immediately after exiting the dural sac, notice a bulge, the dorsal root ganglion (DRG), it contains the bodies of sensory neurons. Next to it, is the ventral root that contains the axons of motor neurons. The fibers of the dorsal root ganglion and the ventral root join to form the mixed spinal nerve. The dura mater also covers them and it is continuous with the epineurium of the peripheral nervous system. Notice that the rostral rootlets are shorter and horizontal, while the caudal rootlets are longer and diagonal. The lumbosacral and coccygeal spinal rootlets form a bundle that extend beyond the conus medullaris, the cauda equina (horse tail).

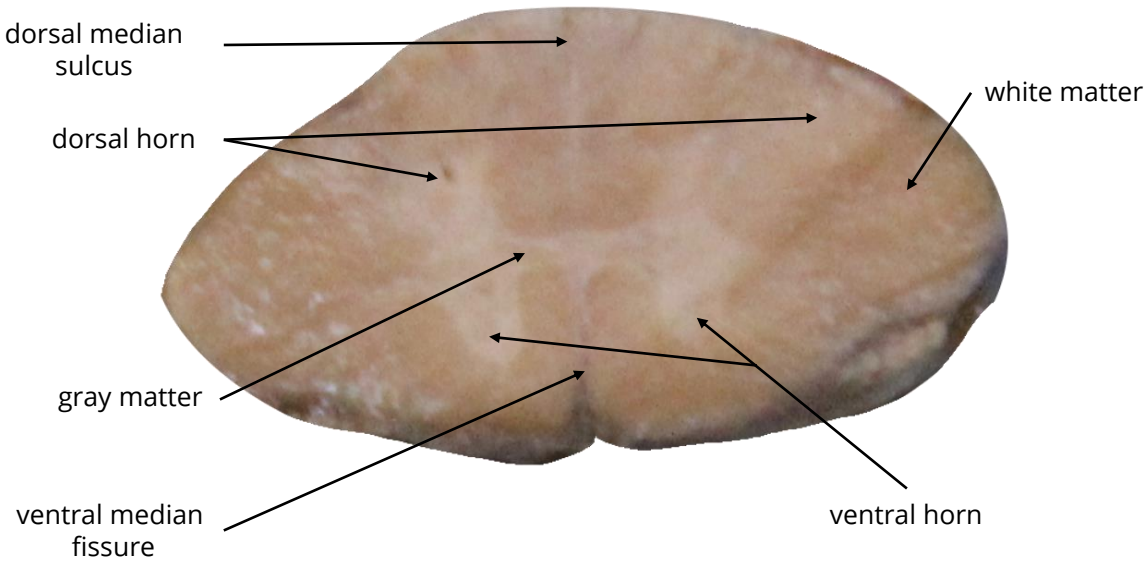


Cross section of the spinal cord

In the spinal cord, the butterfly-shaped gray matter is located in the center and the white matter surrounds it. As a result of the preservation procedures and the direction of the cut (perpendicular to the direction of the fibers), the white matter appears darker. The ventral horn of the spinal cord is slightly wider and it contains neural cell bodies that belong to the motor system. The dorsal horn of the spinal cord is narrower and it contains neural cell bodies that belong to the sensory system.

The ventral median fissure runs along the ventral aspect of the spinal cord and ventral to it, the anterior spinal artery.

The dorsal median sulcus runs along the dorsal aspect of the spinal cord and on both of its sides the two posterior spinal arteries can be found.

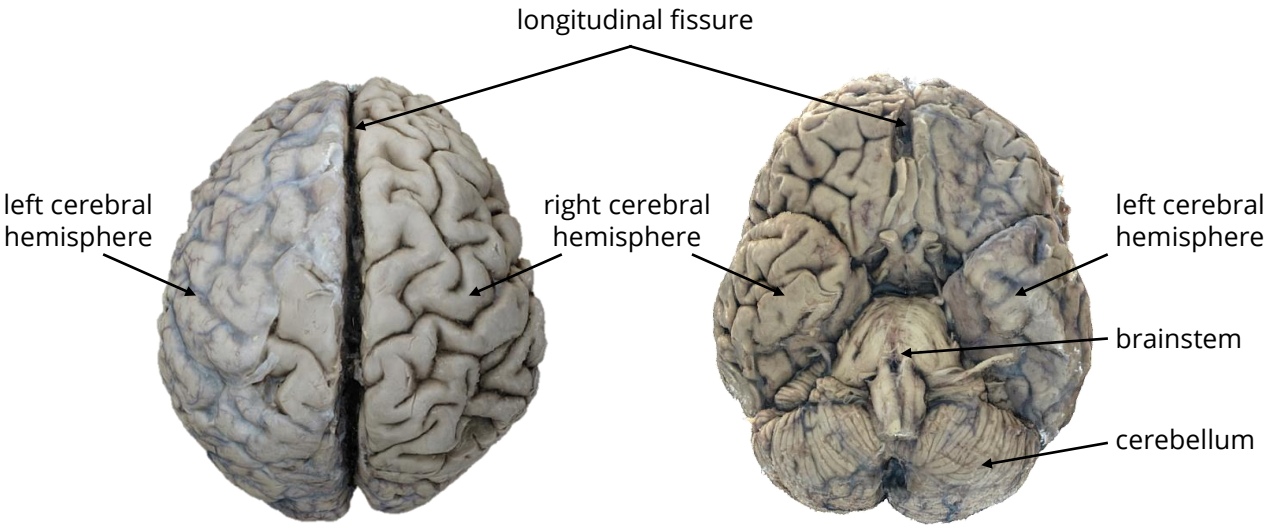


Surfaces of the cerebrum

In this lab we will study the different structures at the surface of the brain. We will look at a whole brain as well as a single hemisphere (brain cut in a mid-sagittal section).

Main regions of the central nervous system

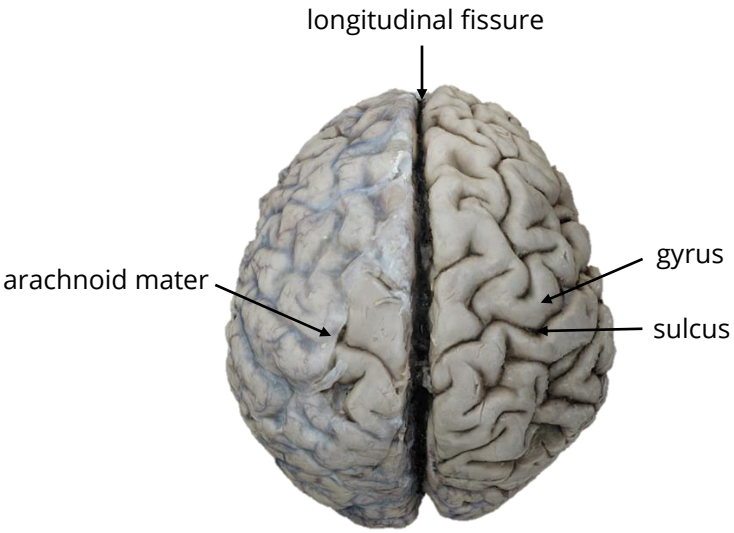
Examine the brain in front of you, it weighs about 1.5 kg and it is continuous with the spinal cord that we studied in the previous lab. Its main regions include the cerebrum which is divided by the longitudinal fissure to the right cerebral hemisphere and the left cerebral hemisphere, the cerebellum and the brainstem.



Meninges

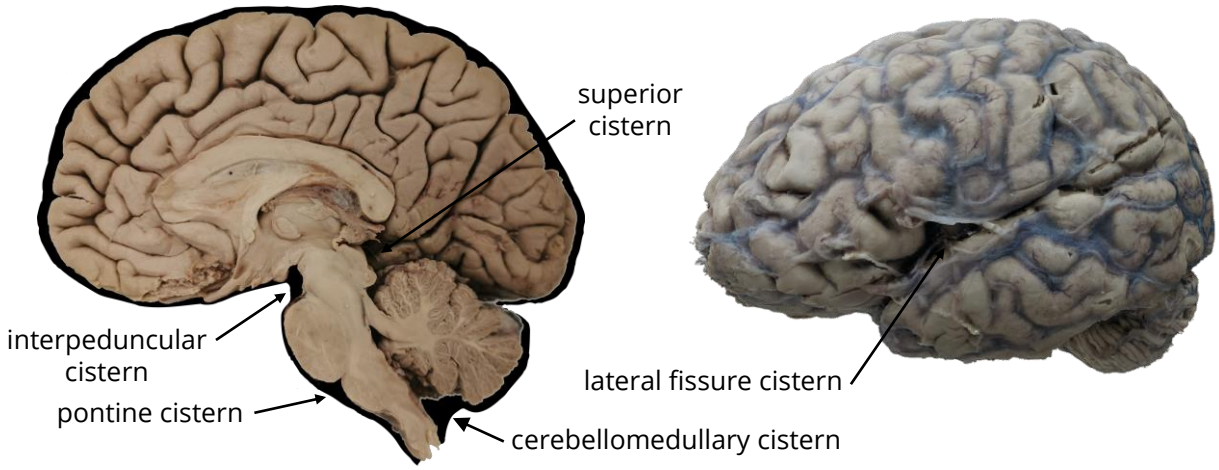
First, we will identify the three meninges that cover the brain: dura, arachnoid and pia. The dura mater (hard) is the most external meninx, it is a thick hard membrane that is located close to the skull. Within the longitudinal fissure, find a fold of dura that leaves the skull and enters it, the falx cerebri (sickle). When the brain is removed, most of the dura remains attached to the skull. The translucent meninx that covers the left hemisphere is the arachnoid mater (spider web). In the right hemisphere, the arachnoid is removed and you can see the gyri (folds) and sulci (grooves) of the cerebral cortex. The innermost meninx is the pia mater, it is a very thin membrane that closely follows the cerebral cortex. Unlike the spinal cord, it cannot be easily seen in the brain.

Structures in the surface of the cerebrum



Subarachnoid cisterns

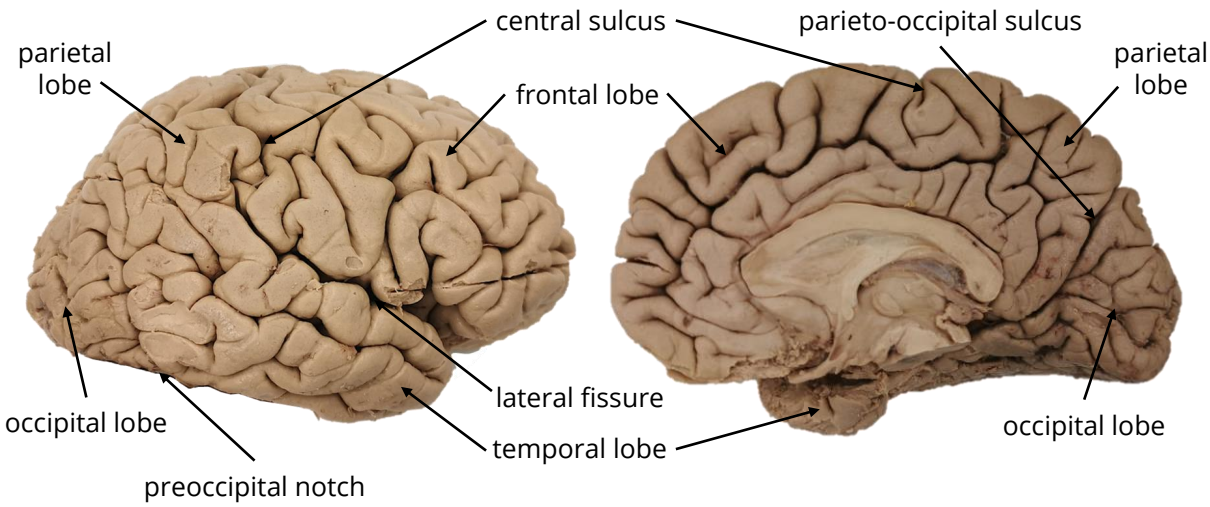
Notice that the arachnoid covers the brain superficially, it passes over the brain surfaces and does not enter into the sulci. In the living human the subarachnoid space is filled with cerebrospinal fluid (CSF). A cistern (reservoir), is an area where the arachnoid passes over a gap between structures and contains more CSF. Identify the cerebellomedullary cistern (cisterna magna), pontine cistern, interpeduncular cistern, superior cistern and lateral fissure cistern.



Hemispheric lobes (right hemisphere)

Clear the arachnoid from the hemisphere. Three main sulci divide the hemisphere into four lobes. In the lateral surface find the lateral fissure (lateral sulcus) and the central sulcus. In the medial surface find the parieto-occipital sulcus.

Anterior to the central sulcus is the frontal lobe. Inferior to the lateral fissure is the temporal lobe. Between the central sulcus and the parieto-occipital sulcus is the parietal lobe. Posterior to the parieto-occipital sulcus and the preoccipital notch is the occipital lobe.



Lateral surface of the hemisphere

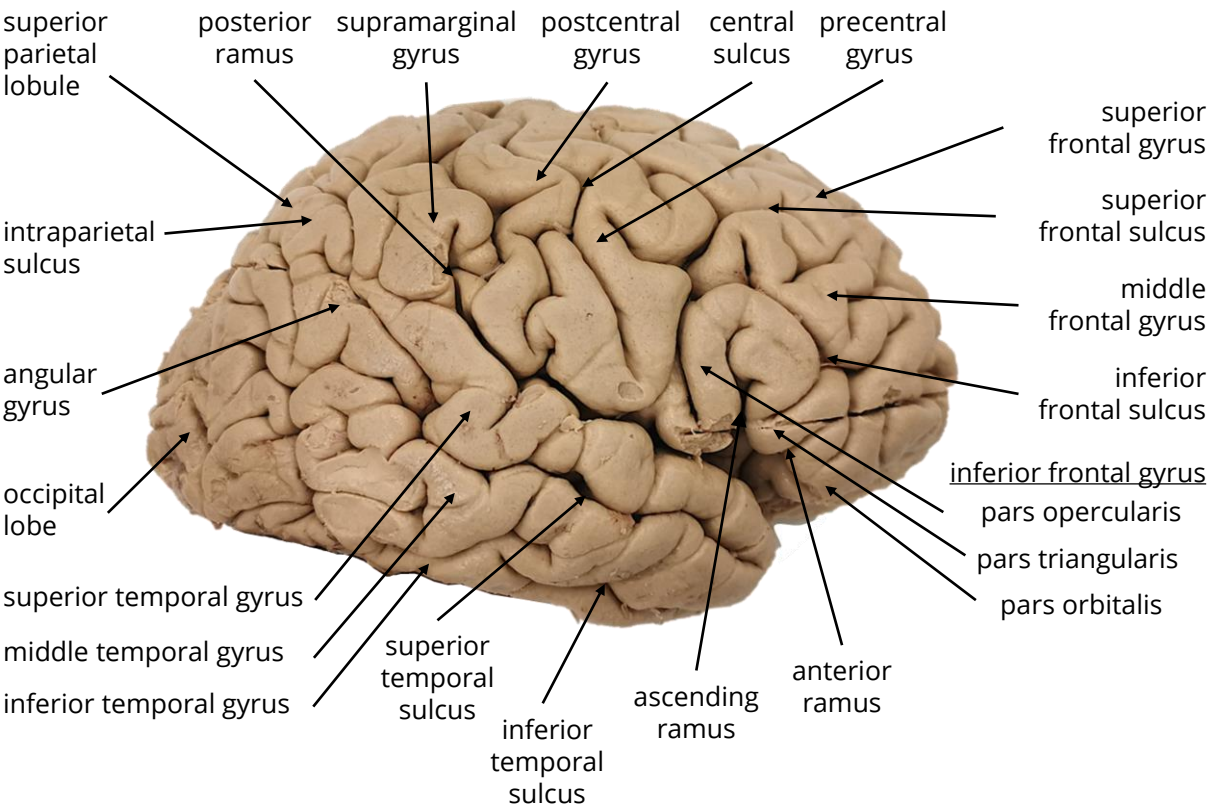
In the lateral surface, the frontal lobe is divided to four gyri. Anterior to the central sulcus is the precentral gyrus that contains the primary motor area. The superior frontal sulcus and the inferior frontal sulcus separate between the superior frontal gyrus, middle frontal gyrus and inferior frontal gyrus. The inferior frontal gyrus is further divided into three parts by two branches of the lateral fissure. The anterior ramus and the ascending ramus separate between the pars orbitalis, pars triangularis and pars opercularis.

Lateral surface of the hemisphere

The temporal lobe is divided to three gyri. The superior temporal sulcus and the inferior temporal sulcus separate between the superior temporal gyrus, middle temporal gyrus and inferior temporal gyrus.

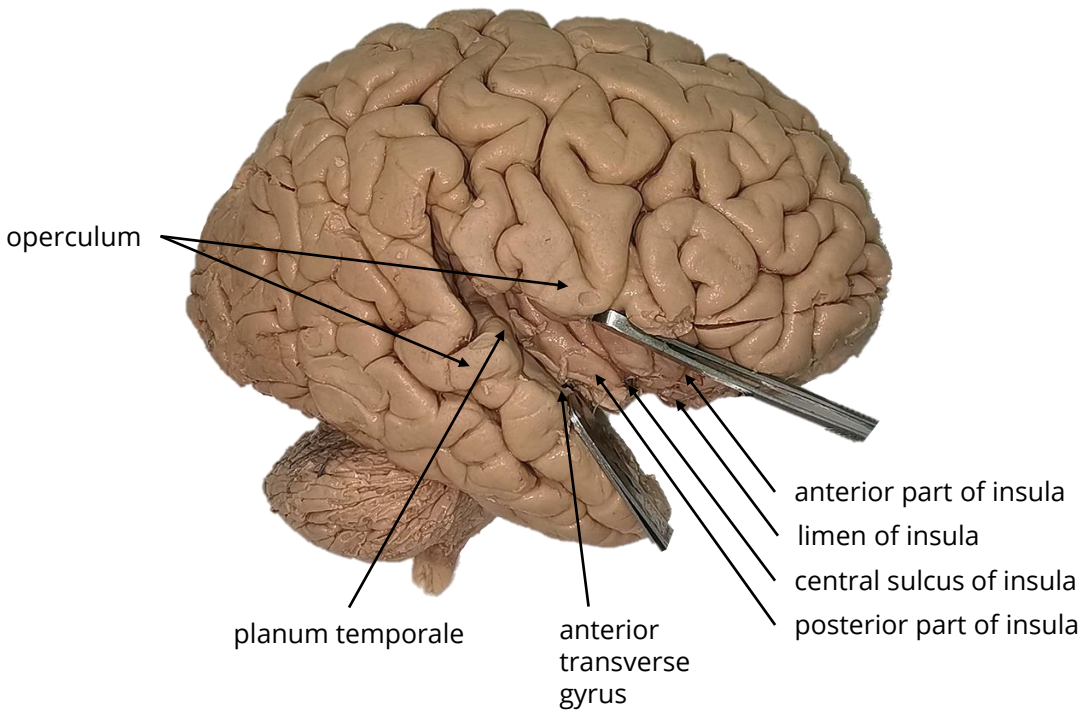
The parietal lobe is divided to four gyri. Posterior to the central sulcus is the postcentral gyrus that contains the primary sensory area. The supramarginal gyrus is located around the posterior ramus of the lateral fissure. The angular gyrus is located around the posterior part of the superior temporal sulcus. The intraparietal sulcus separates between the superior parietal lobule and the inferior parietal lobule (supra marginal gyrus and angular gyrus).

In the lateral surface, the occipital lobe is not further divided.



Structures in the lateral fissure

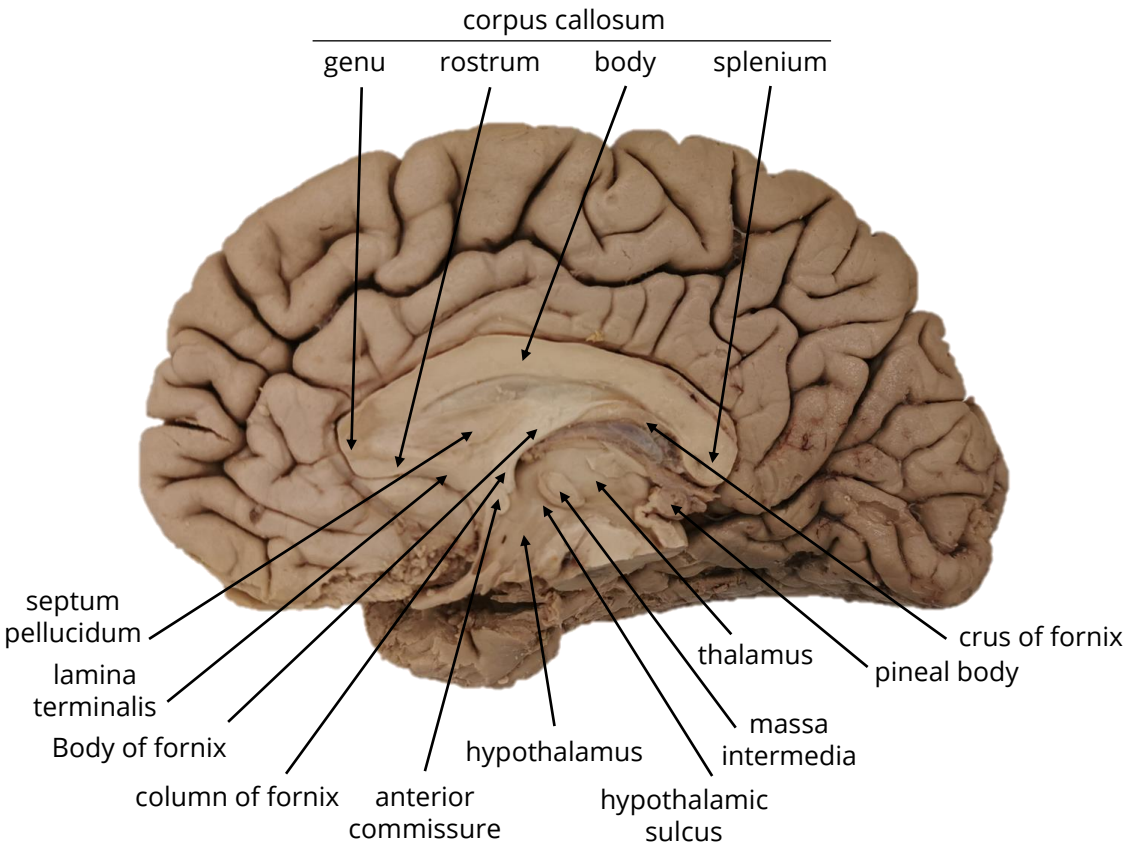
Gently spread apart the gyri on each side of the lateral fissure. Within it, find a part of the cortex that is covered by the neighboring gyri, the insula (island). Together, the gyri that cover it (inferior frontal gyrus, lower parts of the precentral and postcentral gyri and superior temporal gyrus) form the operculum (lid). The insula is divided by the central sulcus of insula into an anterior part that is composed of short gyri and a posterior part that is composed of long gyri. The anterior edge of the insula is the limen insulae (threshold). Within the lateral fissure, continuous with the superior temporal gyrus, find the planum temporale and the anterior transverse gyrus (heschl's convolution) that contains the primary auditory area.



Medial surface of the hemisphere

Subcortical structures

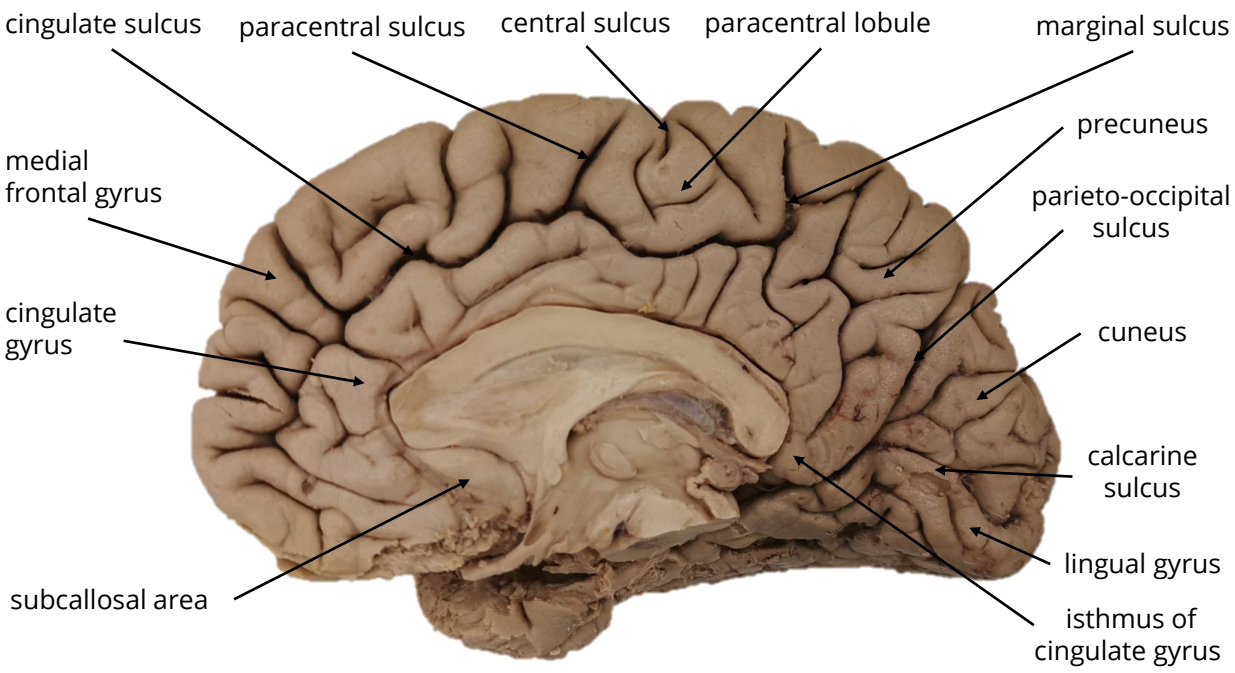
Identify the corpus callosum, it is a large structure of white matter that connects the two hemispheres. In the midsagittal section, it is divided to the rostrum (beak), genu (knee), body and splenium (bandage). Inferior to it, find the fornix (arch), it is a white matter structure of the hippocampus. The fornix is divided to the column, body and crus (leg). Between the corpus callosum and the fornix find the septum pellucidum. It is a thin sheet of neuroglial tissue that separates the frontal horns of the lateral ventricles. Continuing the line of the rostrum, find the lamina terminalis and posterior to it, the anterior commissure. Inferior to the fornix, find an oval structure, the thalamus (inner chamber) and in its center the interthalamic adhesion (massa intermedia). Inferior to the thalamus is the hypothalamus with the hypothalamic sulcus between them. Posterior to the thalamus find the pineal body.



Medial surface of the hemisphere

Cortical structures

In the medial surface, the cingulate sulcus divides the frontal lobe into the medial frontal gyrus and the cingulate gyrus (belt). Its two posterior branches, the paracentral sulcus and the marginal sulcus, define the paracentral lobule that surrounds the part of the central sulcus that slightly continues into the medial surface. The area of cortex below the genu of corpus callosum is also called the subcallosal area. Follow the cingulate gyrus posteriorly into the parietal lobe and notice how it becomes narrow posterior to the splenium of corpus callosum, this area is the isthmus of cingulate gyrus (neck). Anterior to the parieto-occipital sulcus is the precuneus and posterior to it, the occipital lobe. It is divided by the calcarine sulcus, that contains the primary visual area, to the cuneus and the lingual gyrus.



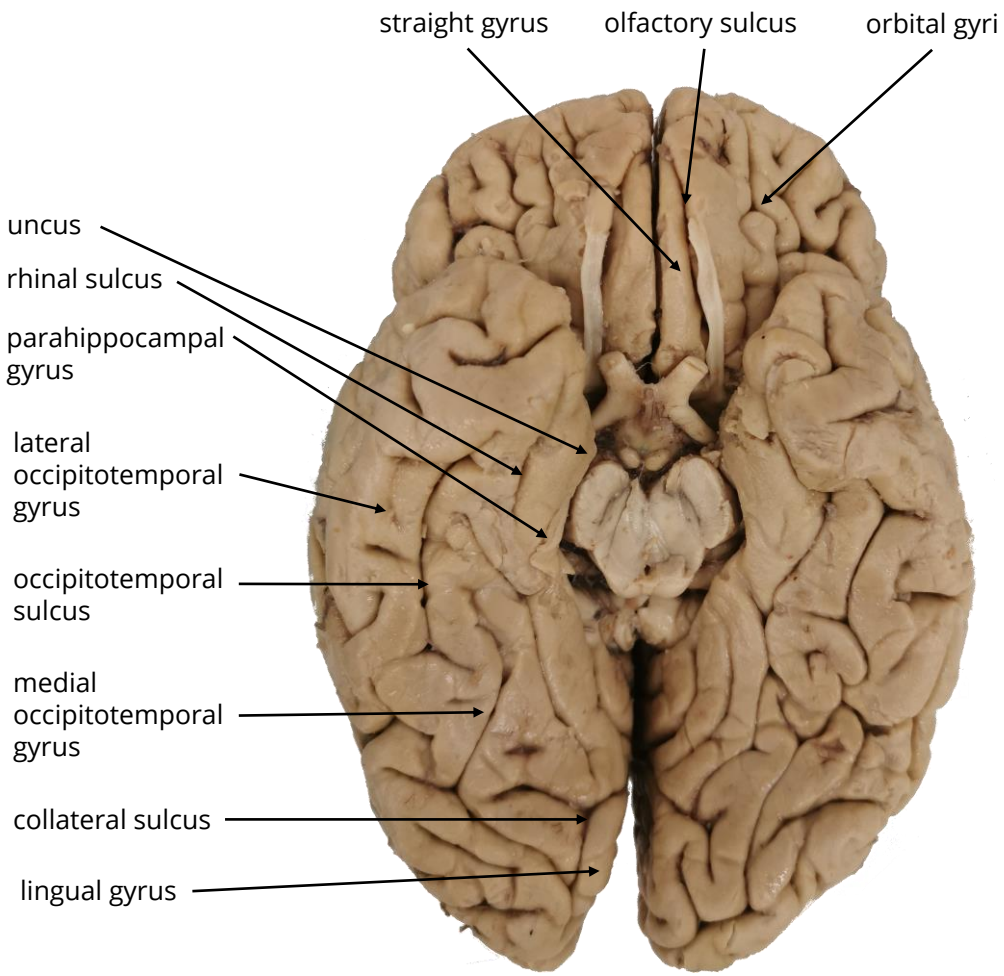
Inferior surface of the hemisphere

Cortical structures

In the inferior surface, the frontal lobe is divided by the olfactory sulcus into the straight gyrus (gyrus rectus) and the orbital gyri.

In the occipital lobe, the lingual gyrus is defined laterally by the collateral sulcus.

In the temporal lobe, the parahippocampal gyrus is defined laterally by the rhinal sulcus. Its curved anterior part, the uncus (hook), contains the primary olfactory area. The occipitotemporal sulcus divides between the medial occipitotemporal gyrus (fusiform gyrus) and the lateral occipitotemporal gyrus.

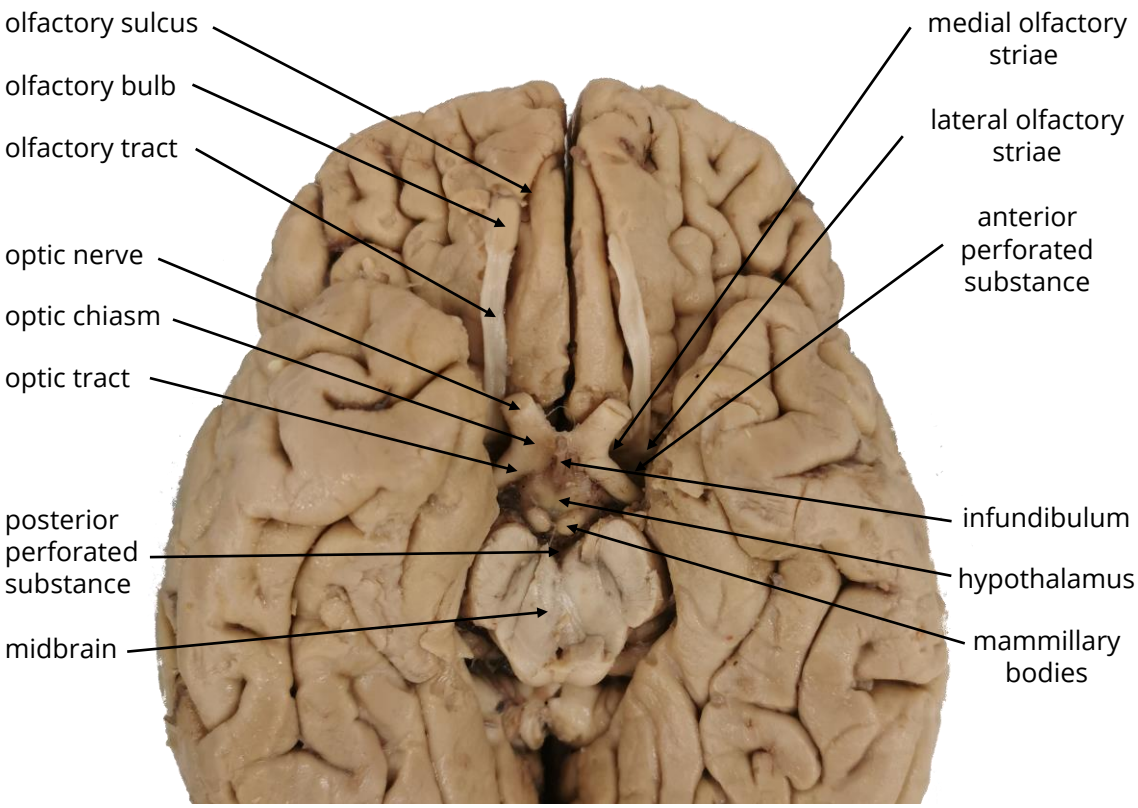


Inferior surface of the hemisphere

Subcortical structures

Aligned with the olfactory sulcus, find the olfactory bulb and the white matter coming out of it, the olfactory tract. At its posterior part, it splits into the medial olfactory striae and the lateral olfactory striae. Between them, find the anterior perforated substance.

Next, find the optic nerve, optic chiasm and optic tract. Gently move aside the parahippocampal gyrus and follow the optic tract posteriorly, notice how it reaches the lateral geniculate nucleus of the thalamus. Inferior to the optic chiasm, identify the infundibulum (funnel), it connects the hypophysis (pituitary gland) and the hypothalamus. Notice two protruding round nuclei of the hypothalamus, the mammillary bodies. Between them and the midbrain (that was cut in order to remove the brainstem and cerebellum), find the posterior perforated substance.



Cerebral white matter and basal nuclei

The white matter of the hemispheres is located deep to the cortex and consists mostly of neuronal axons. These fibers are coated with a lipid-rich (fatty) substance called myelin that gives them the light color. The white matter fibers are organized in fasciculi (bundles) that connect the various areas of the nervous system.

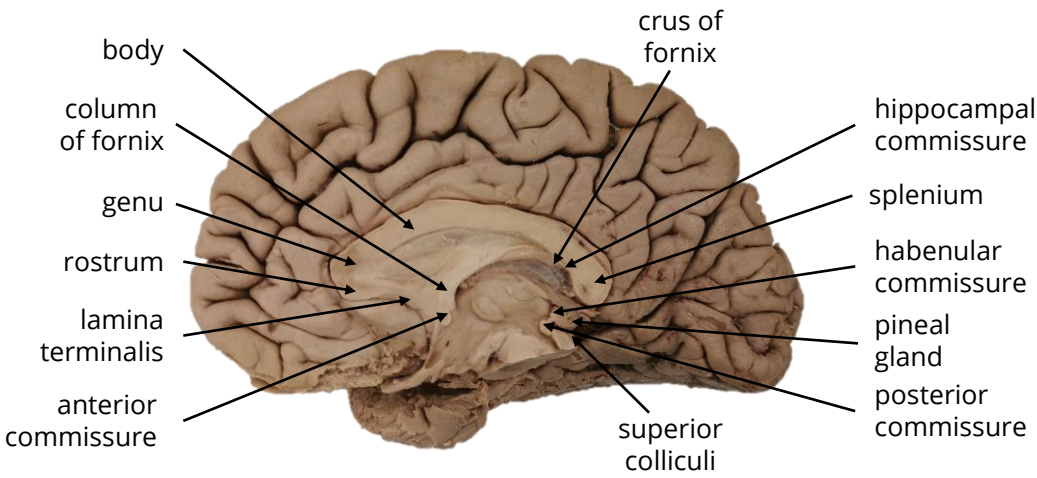
There are three main types of fibers depending on the type of areas they connect:

- Commissural fibers connect different areas between the two cerebral hemispheres.
- Association fibers connect the different cortical areas within the same cerebral hemisphere.
- Projection fibers connect the different cortical areas with subcortical structures.

Commissural fibers

We will start by examining the commissural fibers in a medial view of a midsagittal section of the hemisphere. Identify the different parts of the corpus callosum: the rostrum, genu, body and splenium. Find the remaining commissural systems: the anterior commissure is located between the lamina terminalis and the column of fornix, it connects the temporal lobes.

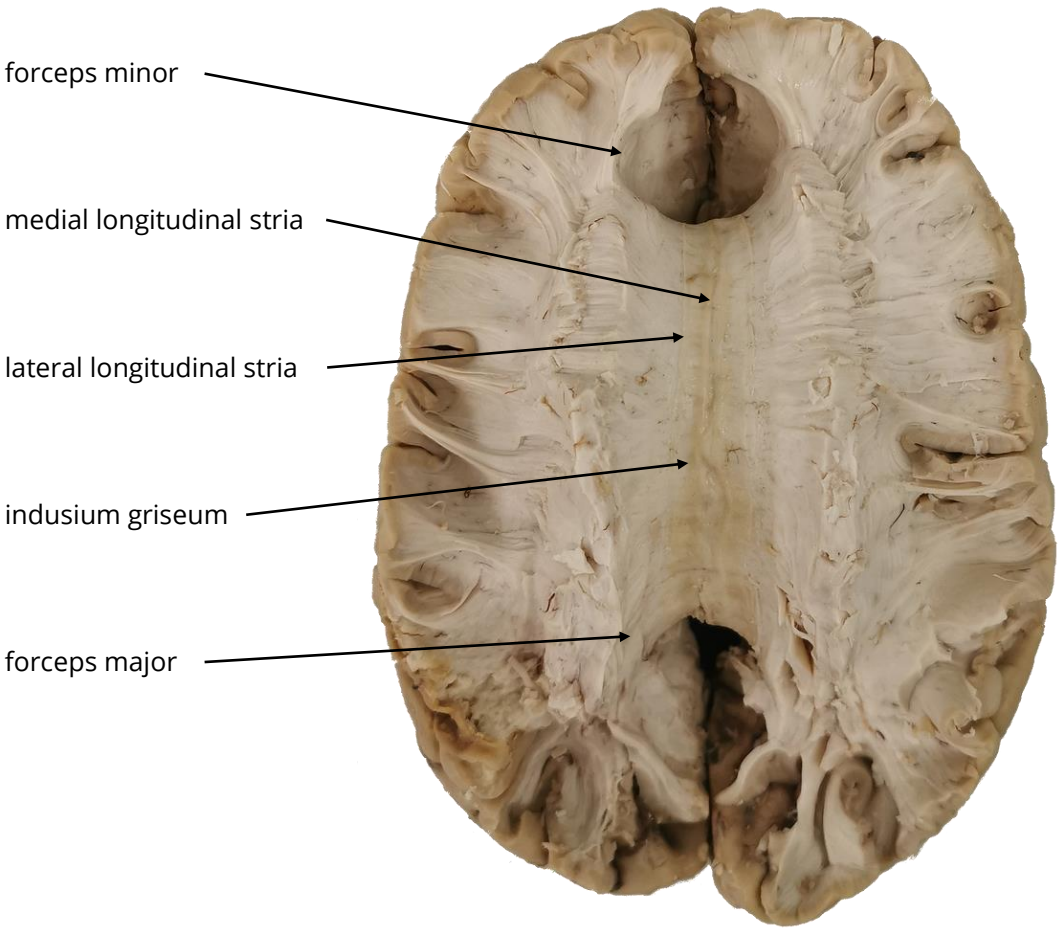
The hippocampal commissure is located between the crus of fornix of each side and it connects the two hippocampi. Since it is very thin, it is harder to see it in a midsagittal section. The habenular commissure is located anterior to the pineal gland and it connects the two habenulae. The posterior commissure is located inferior and anterior to the pineal gland and it connects the superior colliculi.



Superior view of corpus callosum

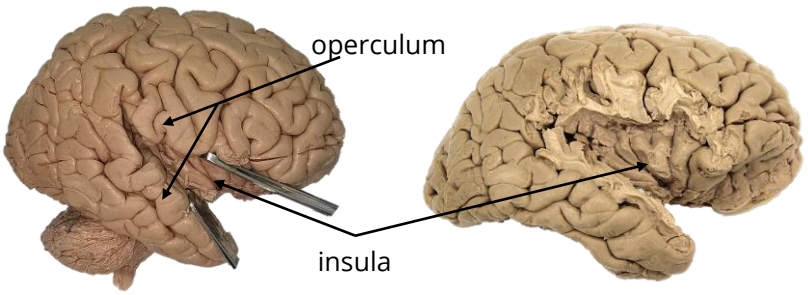
The largest commissural structure is the corpus callosum. Notice that its medial part is shorter than the length of the hemisphere. The fibers that connect the anterior parts of the frontal lobes form the forceps minor and the fibers that connect the occipital lobes form the forceps major.

The medial part of the corpus callosum is covered by a thin layer of gray matter, the indusium griseum. It is continuous with the dentate gyrus of the hippocampus. Its white matter is concentrated in two thin strips on each side, the medial longitudinal stria and the lateral longitudinal stria.

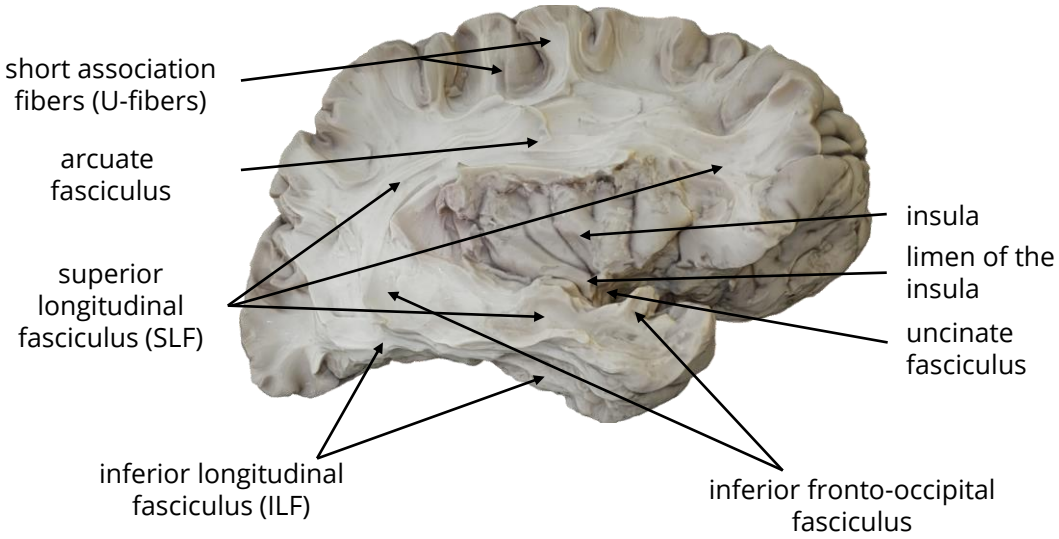


Association fibers

We will start the dissection by exposing the more superficial fibers first and then, we will continue to the deeper fibers and subcortical nuclei. We will begin by removing the cortex that covers the insula (island), the operculum (lid). Notice the thickness of the cortex (~2 mm) and the difference between it and the white matter.



Continue to remove the cortex around the insula. Notice the fibers that connect adjacent gyri, these are short association fibers (U-fibers). The other associative fibers we will study are long-association fibers. Find a long bundle of fibers that bends around the insula and connects all of the lobes, the superior longitudinal fasciculus (SLF). The fronto-temporal part of the SLF is also called arcuate fasciculus. Now, move to the limen of the insula and expose the uncinate fasciculus (hook) below it. It connects the anterior part of the frontal lobe with the anterior part of the temporal lobe. Find the inferior fronto-occipital fasciculus located above and behind the uncinate fasciculus, it connects the anterior inferior part of the frontal lobe and the occipital lobe. The inferior longitudinal fasciculus (ILF) connects the temporal lobe and the occipital lobe. It can be exposed by removing the gray matter from the lower surface of these lobes.



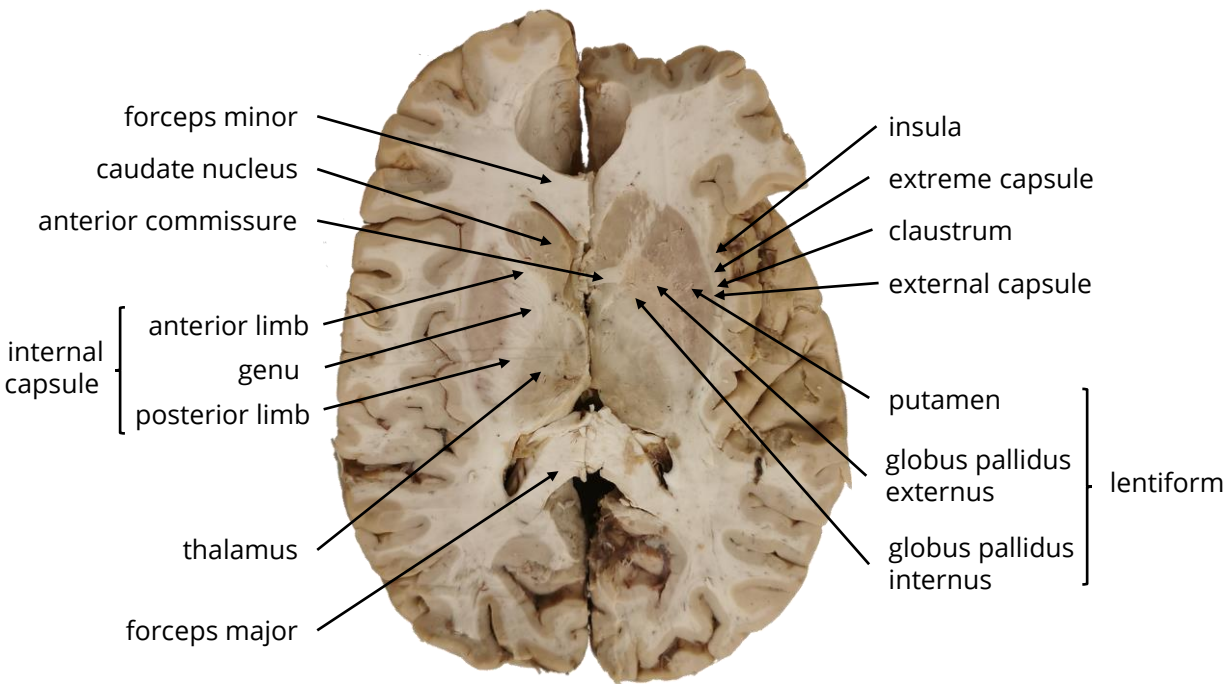
Next, proceed to the medial surface. By removing the cortex of the cingulate gyrus, expose a large structure of association fibers that connects all the lobes, the cingulum. Follow its fibers posteriorly where it passes through the isthmus (neck) and bends behind the splenium of corpus callosum. From there, it continues into the parahippocampal gyrus.

Association fibers in the medial aspect of the hemisphere

Horizontal section of the brain

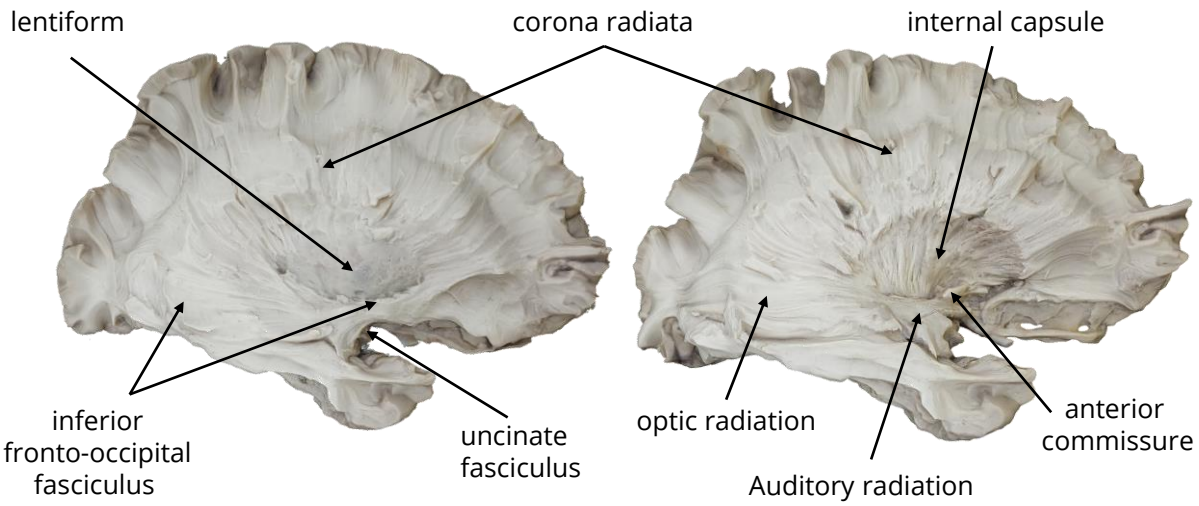
For the next part of the dissection, we will use a horizontal section of the brain as a guide to the different structures we will discover as we remove the different layers from lateral to medial (note that the right hemisphere is cut lower than the left). The most lateral is the cortex of the insula and its white matter. Medial to it, find the thin layer of white matter, the extreme capsule. Medial to it, identify the thin layer of gray matter, the claustrum (enclosed) followed by another thin layer of white matter, the external capsule. Continuing medially, find the lentiform. On the right, its three parts can be easily distinguished (from lateral to medial): the putamen (nutshell), globus pallidus externus and globus pallidus internus.

Anterior and medial to the lentiform, find the caudate nucleus (tail) and posterior and medial to the lentiform, the thalamus. between these three structures, notice the concave shape of the internal capsule and its different parts: The anterior limb is located between the lentiform and caudate and it contains cortico-pontine fibers and anterior thalamic radiation fibers that connect the thalamus and frontal lobe. The bent central part, genu, is located medially to the globus pallidus internus and it contains cortico-nuclear fibers. The posterior limb is located between the lentiform and thalamus and it contains cortico-spinal fibers and fibers that connect between the thalamus and somatosensory and association cortex. Also identify the anterior commissure and the forceps minor and forceps major of the corpus callosum.



Projection fibers

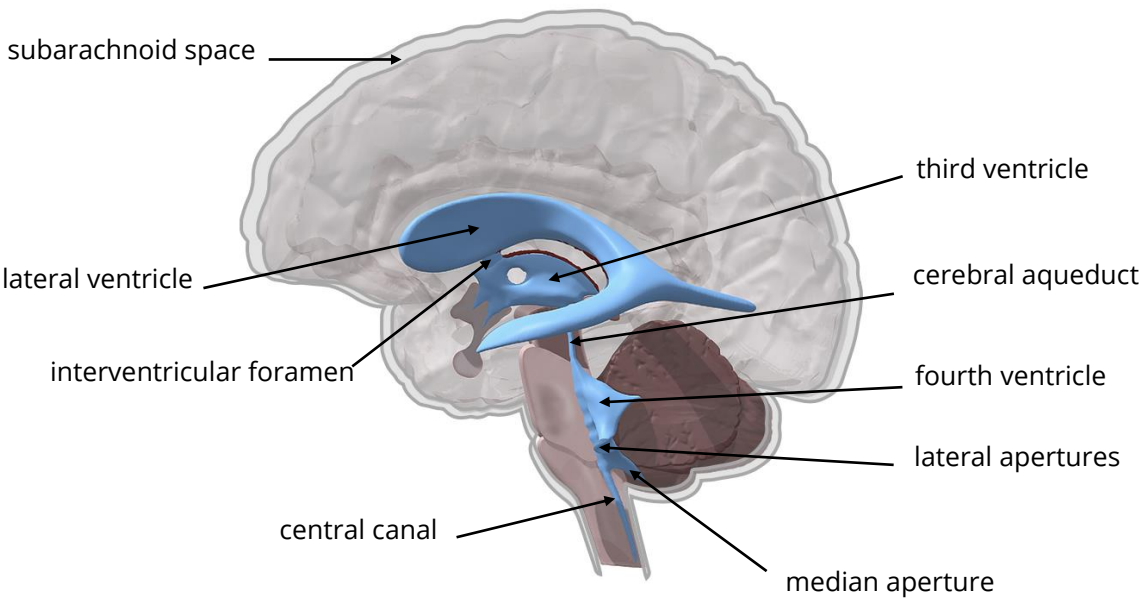
Return to the hemisphere you have started dissecting. Remove the gray matter of the insula and the thin layers of the extreme capsule, claustrum and external capsule. Continue removing the white matter until you reach a large lens-shaped nucleus, the lentiform. Finish exposing and defining the boundaries of the lentiform and remove the remaining association fibers above it. Notice the fibers of the corona radiata that surround the lentiform, they connect between the cortex of the hemisphere and subcortical structure. Now that the insula is removed, the uncinate fasciculus and the inferior fronto-occipital fasciculus can be easily seen. Gently separate the lentiform from the fibers that pass medially to it while keeping it intact. Once the lentiform is removed, you can see the internal capsule which is continues with the corona radiata. The fibers posterior to the lentiform (retro-lentiform), constitute the optic radiation, they relay visual information between the lateral geniculate nucleus of the thalamus and the primary visual area that is located in the calcarine sulcus. The fibers that pass under the lentiform (sub-lentiform), are fibers of the auditory radiation, they relay auditory information between the medial geniculate nucleus of the thalamus and the primary auditory area that is located in the anterior transverse gyrus. Notice a bundle of fibers that passes under the lentiform and continues perpendicular to the orientation of the corona radiata, this is the anterior commissure. Next, Make a coronal section in the center of the lentiform and try to distinguish between the putamen and the globus pallidus.



Lateral ventricles and third ventricle

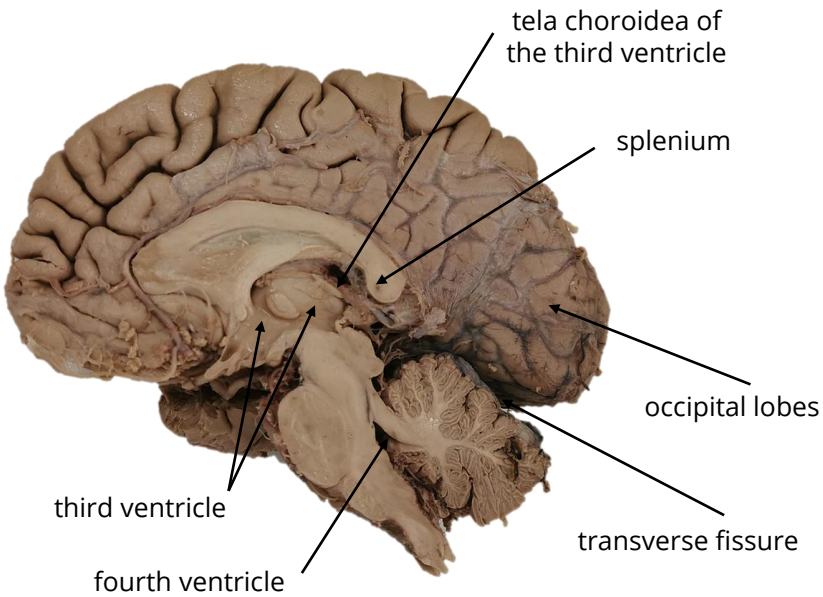
Ventricular system of the brain

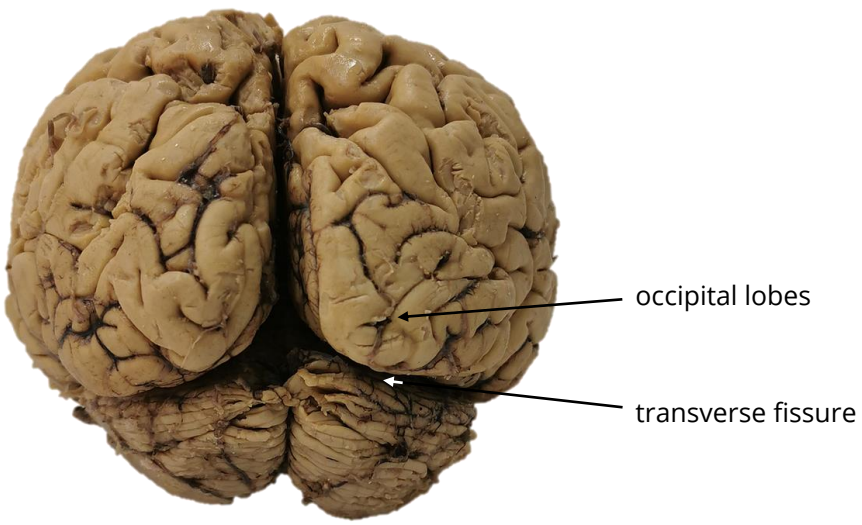
The ventricular system is located deep in the brain and it contains cerebrospinal fluid (CSF). Its main parts are the two lateral ventricles, the third ventricle and the fourth ventricle. Each lateral ventricle is connected to the third ventricle through an interventricular foramen (of Monro). The third and fourth ventricles are connected by the cerebral aqueduct (of Sylvius). Three openings in the fourth ventricle connect the CSF of the ventricular system to the CSF of the subarachnoid space, one median aperture (of Magendie) and two lateral apertures (of Luschka). The fourth ventricle is also continuous with the central canal of the spinal cord.



Transverse fissure and tela choroidea

The transverse fissure separates between the inferior surface of the occipital lobes and the superior surface of the cerebellum. Through the transverse fissure, pia mater and arteries enter underneath the splenium to the roof of the third ventricle, where they form the tela choroidea of the third ventricle. The tela choroidea is continues with the choroid plexus of the lateral ventricles and they both produce the CSF. Similar structures exist in the fourth ventricle which we will study in another lab.



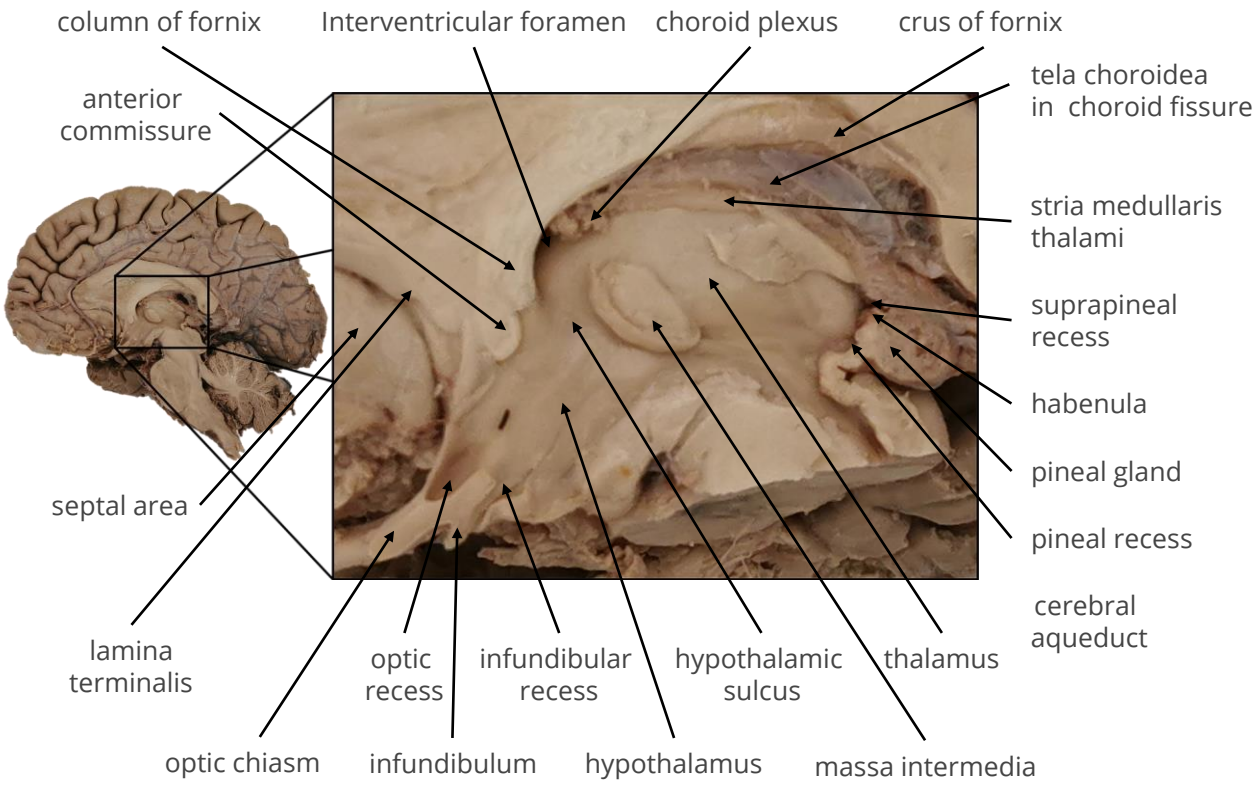


Third ventricle

Locate the oval shaped thalamus, its inferior boundary is the hypothalamic sulcus and inferior and anterior to it, is the hypothalamus. The third ventricle is the narrow space between the thalamus and hypothalamus of the two hemispheres.

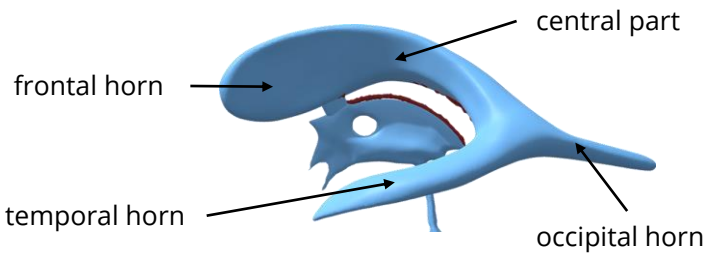
Along the border of the medial and dorsal surfaces of the thalamus, find a strip of white matter, the stria medullaris thalami. It contains fibers from the septal area to the habenula. In the center of the thalamus, find the massa intermedia (interthalamic adhesion). At the roof of the third ventricle, find the tela choroidea and above it, the fornix. Between the column of fornix and the thalamus, find the interventricular foramen that connects the third ventricle with the lateral ventricle. The tela choroidea is continuous with the choroid plexus of the lateral ventricle through the interventricular foramen and the choroid fissure (between the thalamus and fornix). The anterior boundary of the third ventricle is the lamina terminalis, between it and the column of fornix find the anterior commissure. Notice that of the third ventricle has four extensions (recesses). At the anterior part, the optic recess above the optic chiasm and the infundibular recess above the infundibulum.

At the posterior part, the suprapineal recess above the pineal gland and the pineal recess below it. At the bottom, the third ventricle is continuous with the cerebral aqueduct (of Sylvius) that connects it with the fourth ventricle.



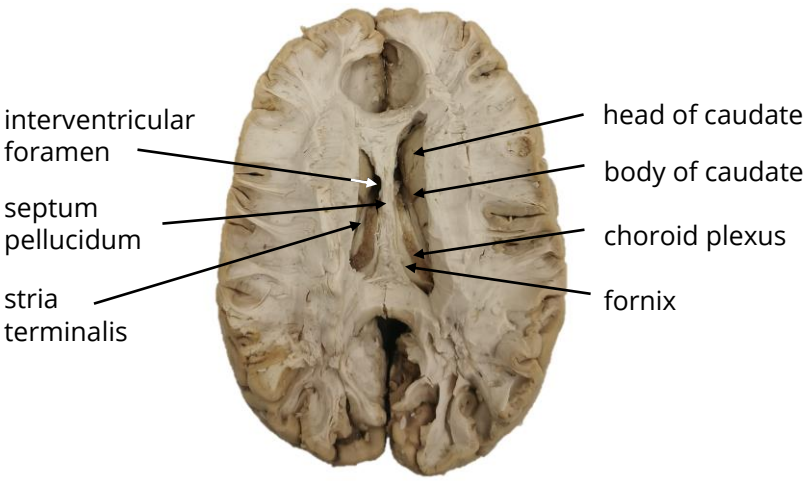
Lateral ventricles

Each lateral ventricle consists of four parts: frontal horn, central part, occipital horn and temporal horn. For each part, we will learn the different structures that define the boundaries of the lateral ventricle.



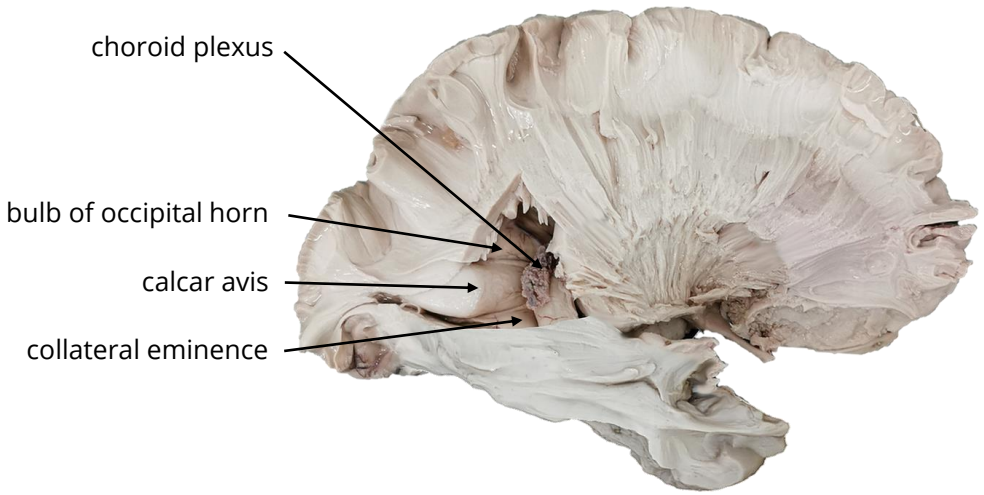
Boundaries of the lateral ventricles

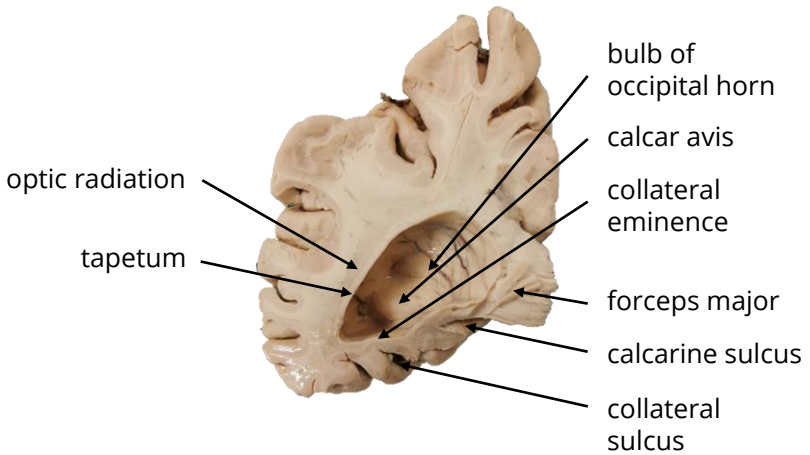
Make a cut in central part of the corpus callosum and remove it. This will expose the frontal horn and central part of the lateral ventricles. The corpus callosum forms the roof and the septum pellucidum forms the medial wall that separates the two lateral ventricles. The frontal horn is anterior to the interventricular foramen and its floor is the head of caudate. In the central part, the floor consists of the body of caudate and the thalamus (here it is covered by other structures). Between them, find the stria terminalis that contains fibers from the amygdala to the septal area and below it, the thalamostriate vein. In the central part of the lateral ventricle, notice how the choroid plexus starts at the interventricular foramen and continues posteriorly on top of the fornix.



Occipital horn of the lateral ventricle

Make a cut in the posterior part of the corona radiata and reveal the occipital horn. Notice that the choroid plexus continues into the temporal horn and does not reach the occipital horn. Also use a coronal section of the occipital horn and identify three bulges within it. The superior bulge is the bulb of occipital horn that is formed by the forceps major of the corpus callosum. The middle and largest bulge is the calcar avis, it is formed by the calcarine sulcus. The Inferior bulge is the collateral eminence, it is formed by the collateral sulcus. The lateral wall is composed of fibers of the corpus callosum that continue downwards, the tapetum. Lateral to it, find the fibers of the optic radiation, that appears slightly darker because the cut was made perpendicular to the orientation of the fibers.

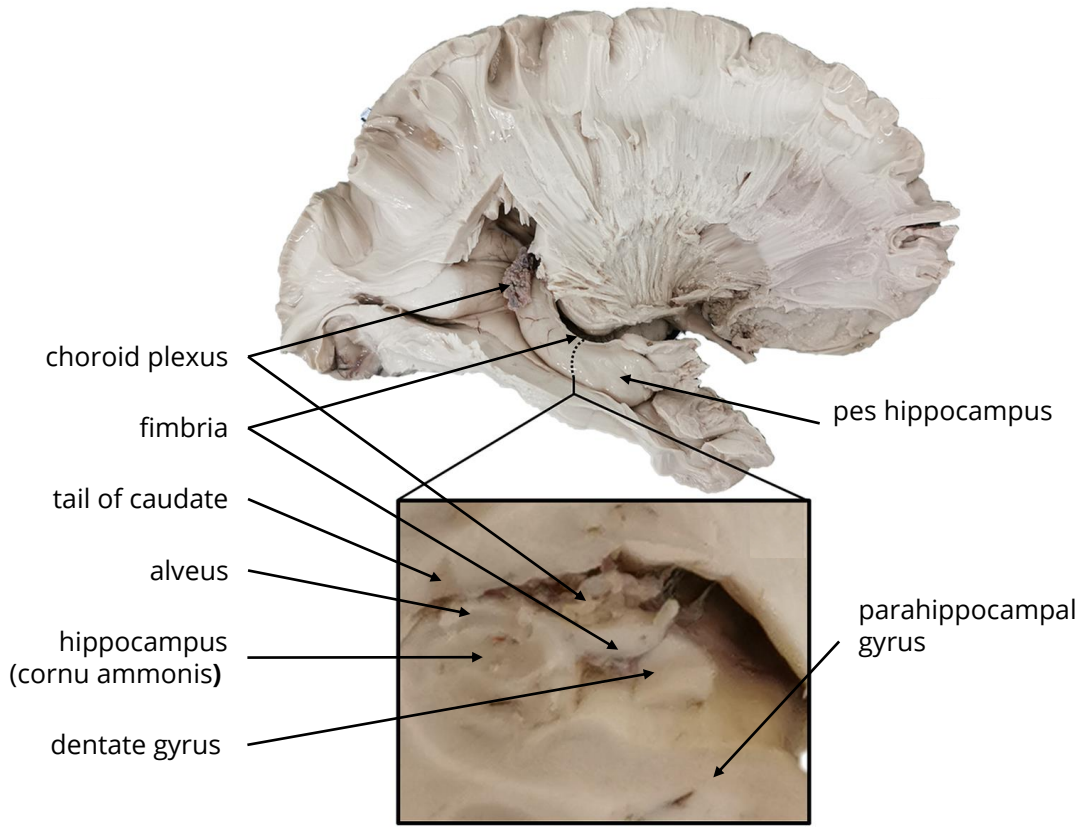




Temporal horn of the lateral ventricle

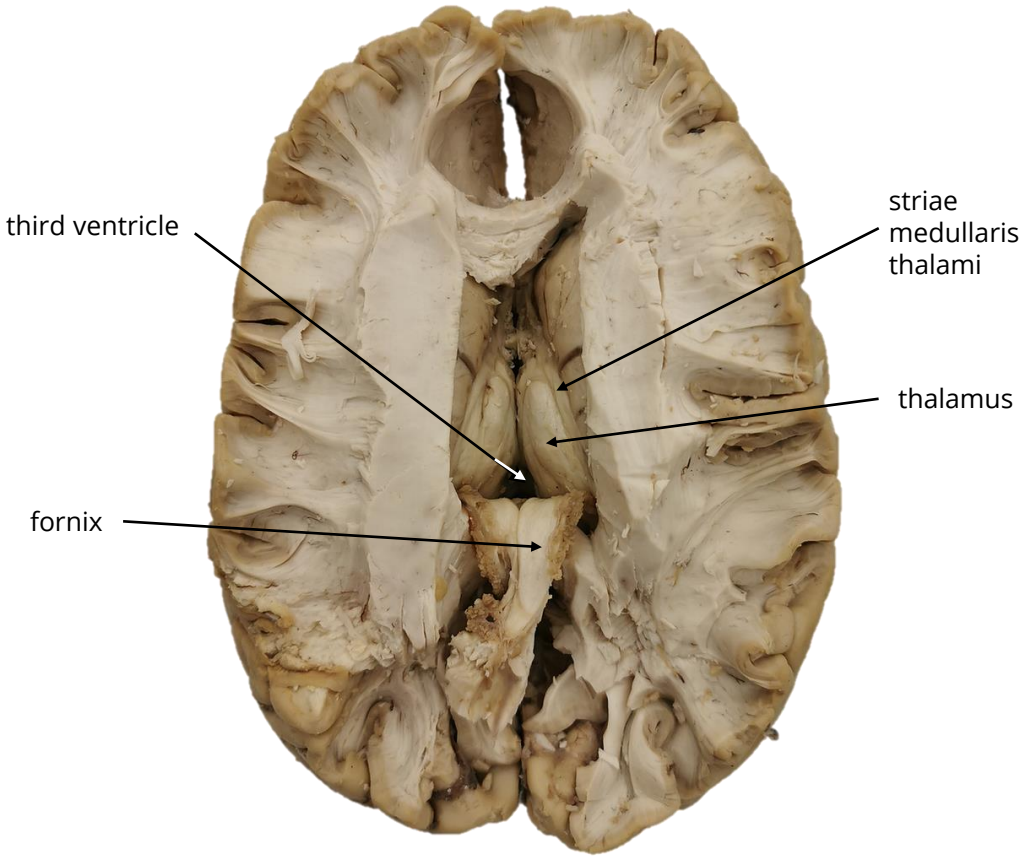
Make a cut in the white matter of the temporal lobe. This will reveal the temporal horn. At the floor, find a large structure, the hippocampus (sea horse). It is a three-layer archicortex that is continuous with the six-layered neocortex of the parahippocampal gyrus. Its anterior part is the pes hippocampus (paw). The white matter that covers the hippocampus is the alveus, along its medial line notice a separated fold of white matter, the fimbria (fringe) which is continuous with the fornix.

Make a coronal cut in the hippocampus and notice that its cortex folds on itself, the cornu ammonis (horns of Ammon). Along the medial line, below the fimbria, find a row of bulges, the dentate gyrus (teeth), it is continuous with the indusium griseum.
At the roof of the temporal horn, find the tail of caudate. Also notice the choroid plexus.



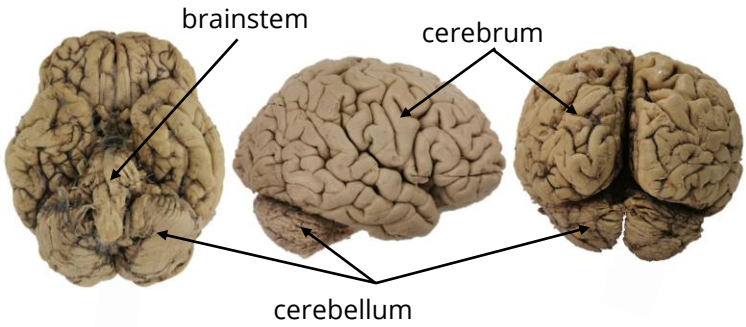
Superior view of the third ventricle

Now that we have finished examining the parts of the lateral ventricles, return to the superior view of the ventricles. Make an incision in the columns of fornix and retract the two fornices backwards to reveal the third ventricle, the narrow space between the two thalami. Along their medial line, find the striae medullaris thalami. Gently separate the thalami and peer into the anterior part of the third ventricle. Find the two columns of fornix with the anterior commissure forming an "A" shape between them.



Cerebellum

The cerebellum is located inferior to the cerebrum and dorsal to the brainstem. It consists of cortex, white matter and nuclei.

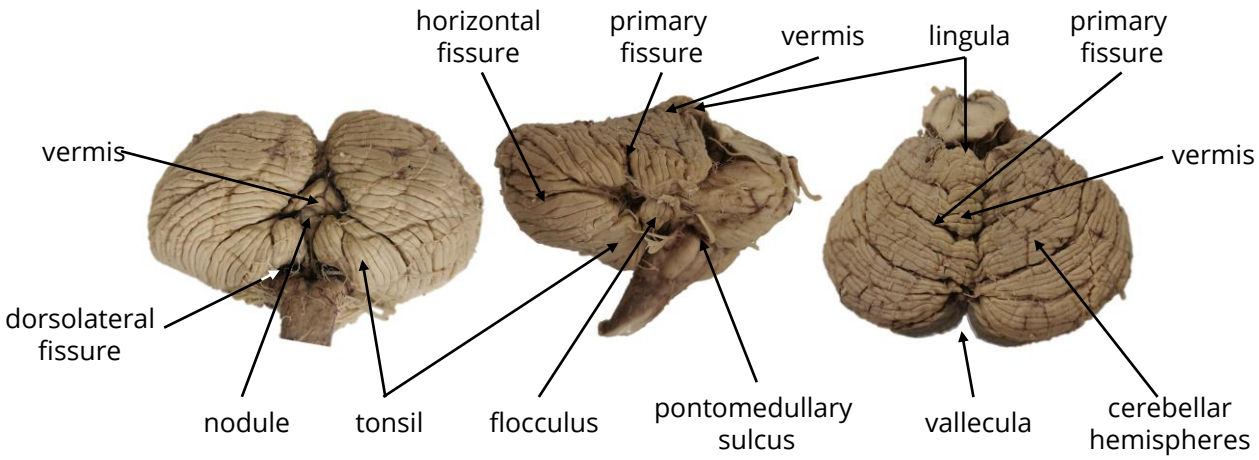


Surfaces of the cerebellum

The cortex of the cerebellum is made of folds called folia and between them deep fissures. The cerebellum is divided into two cerebellar hemispheres and between them the vermis (worm). The superior part of the vermis protrudes beyond the hemispheres and its inferior part is imbedded between them. The most anterior part of the vermis is the lingula (small tongue) and the most posterior part is the nodule (small knot). The space between the hemispheres is the vallecula (valley). In the inferior surface, adjacent to the posterior part of the medulla, find the tonsil. Between each hemisphere and the pontomedullary sulcus find the flocculus (tuft of wool).

There are 3 main fissures that divide the cerebellum:

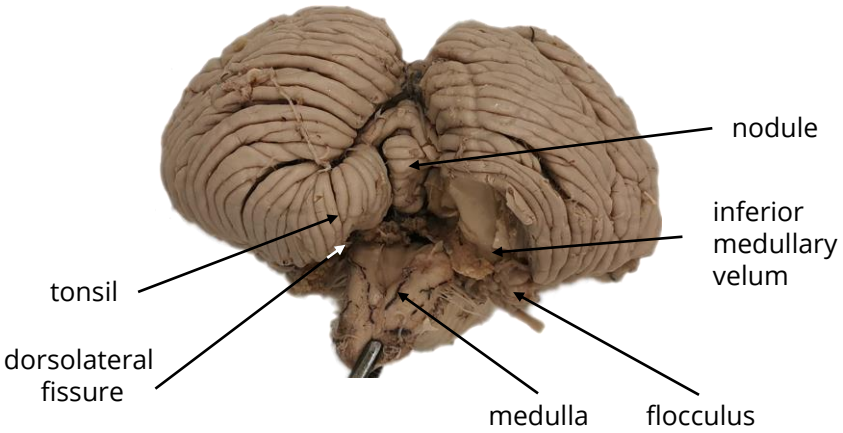
- The primary fissure separates the anterior lobe from the posterior lobe.
- The horizontal fissure separates the superior surface from the inferior surface.
- The dorsolateral fissure separates the posterior lobe from the flocculonodular lobe



The dorsolateral fissure and the flocculonodular lobe

Remove the tonsil and expose the dorsolateral fissure. Retract the medulla and find the inferior medullary velum. It consists of neuroglia and white matter that connects the flocculus and the nodule.

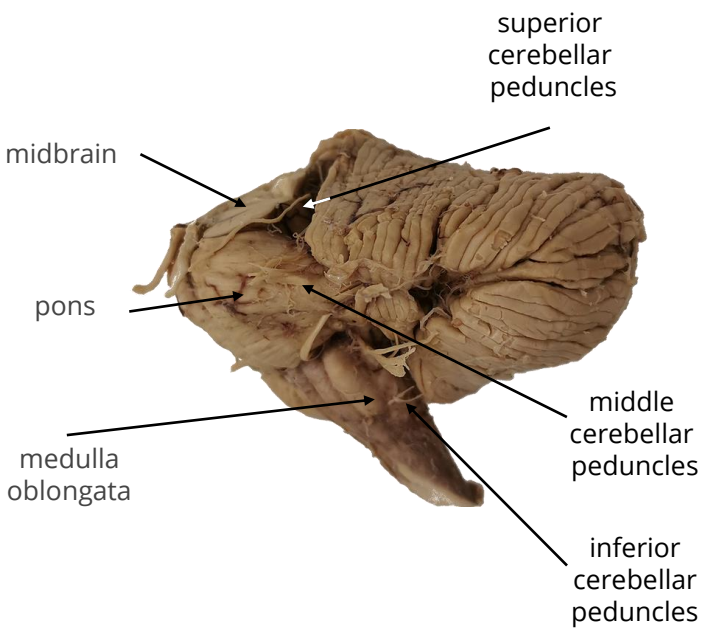
Together, the flocculus, inferior medullary velum and nodule make up the flocculonodular lobe.



The cerebellar peduncles

The cerebellum is connected to the brainstem by three pairs of cerebellar peduncles:

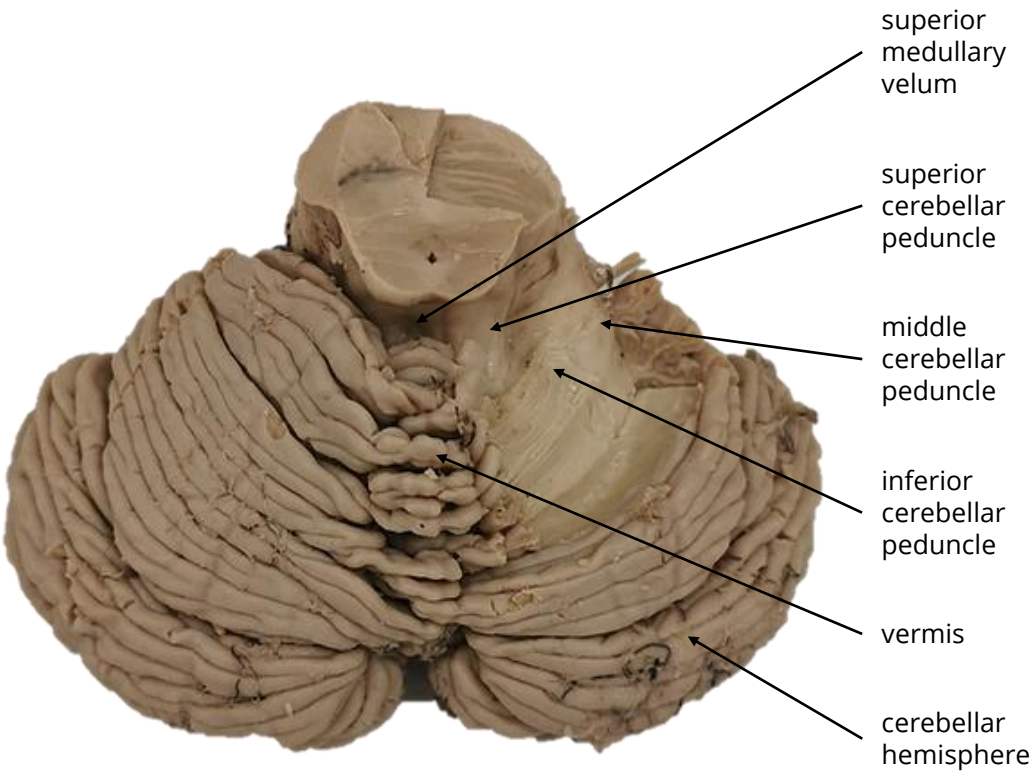
- To the midbrain by the superior cerebellar peduncles.
- To the pons by the middle cerebellar peduncles.
- To the medulla oblongata by the inferior cerebellar peduncles.



Dissection of the cerebellum

The middle cerebellar peduncle is the most lateral of the cerebellar peduncles. It contains fibers that originate from nuclei in the pons and terminate in the cortex of the cerebellar hemisphere. Remove the cortex from over the middle cerebellar peduncle to reveal the course of the fibers. The superior cerebellar peduncle is the most medial. It contains fibers that originate from subcortical nuclei of the cerebellum and terminate in the thalamus. Between the two superior cerebellar peduncles, find the superior medullary velum. The fibers of the inferior cerebellar peduncle pass between the superior and middle cerebellar peduncles. They originate from nuclei in the medulla and terminate in the vermis and the adjacent cortex, paravermis.

Continue by removing the fibers of the inferior cerebellar peduncle.
At the center of the hemisphere find the dentate nucleus. It receives fibers from the cortex of the hemisphere and the fibers that leave it form the superior cerebellar peduncle. There are other nuclei in the cerebellum, but they are smaller and difficult to see in this dissection.



The fourth ventricle

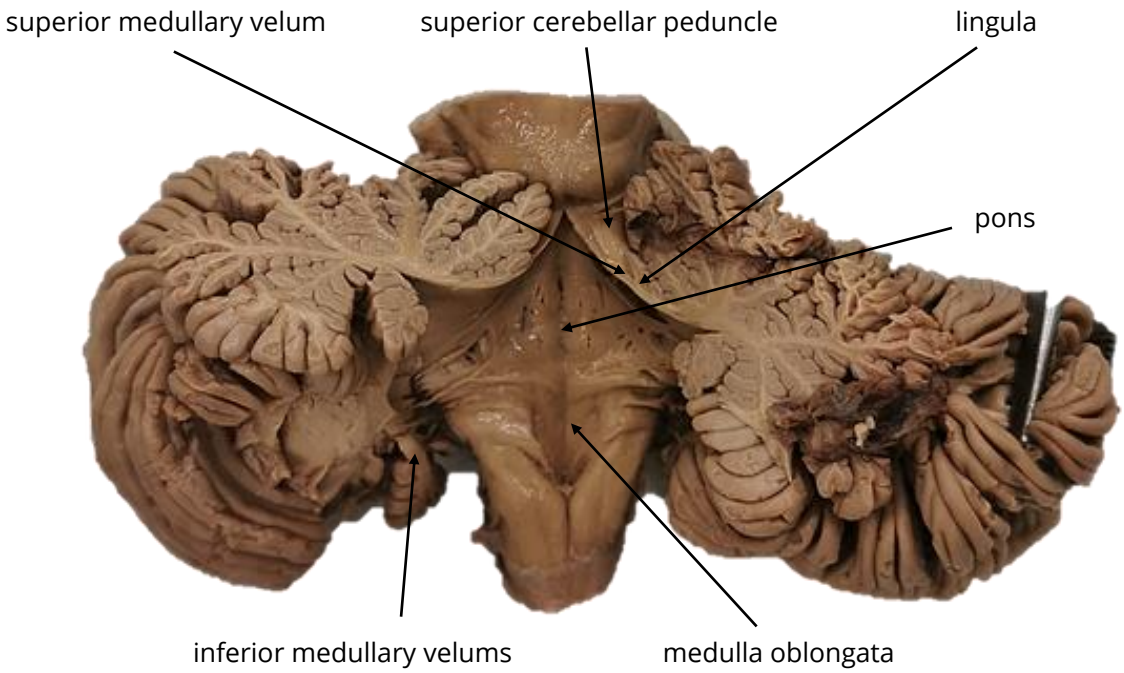
Boundaries of the fourth ventricle

Make a midsagittal cut in the vermis, notice its branching treelike pattern (arbor vitae cerebelli). Spread apart the two parts of the cerebellum and examine the structure of the fourth ventricle. The diamond-shaped floor of the fourth ventricle, also called the rhomboid fossa, is made of the dorsal aspects of the pons and medulla oblongata. The rostral part of the roof is made of the superior cerebellar peduncles with the superior medullary velum stretched between them in the middle. Notice the lingula next to it. The caudal part of the roof is made of the inferior medullary velums with the tela choroidea of the fourth ventricle in the middle.

Openings of the fourth ventricle

Rostrally, the fourth ventricle is continuous with the cerebral aqueduct and caudally, with the central canal of the spinal cord. Three apertures (openings) in the fourth ventricle connect the CSF of the ventricular system and the subarachnoid space.

The median aperture is located at the caudal end between the cerebellum and the medulla and it opens into the cerebellomedullary cistern. Two lateral recesses of the fourth ventricle surround the inferior cerebellar peduncle on each side. Their openings, the lateral apertures are located between each flocculus and the pontomedullary sulcus and they open into the pontine cistern.

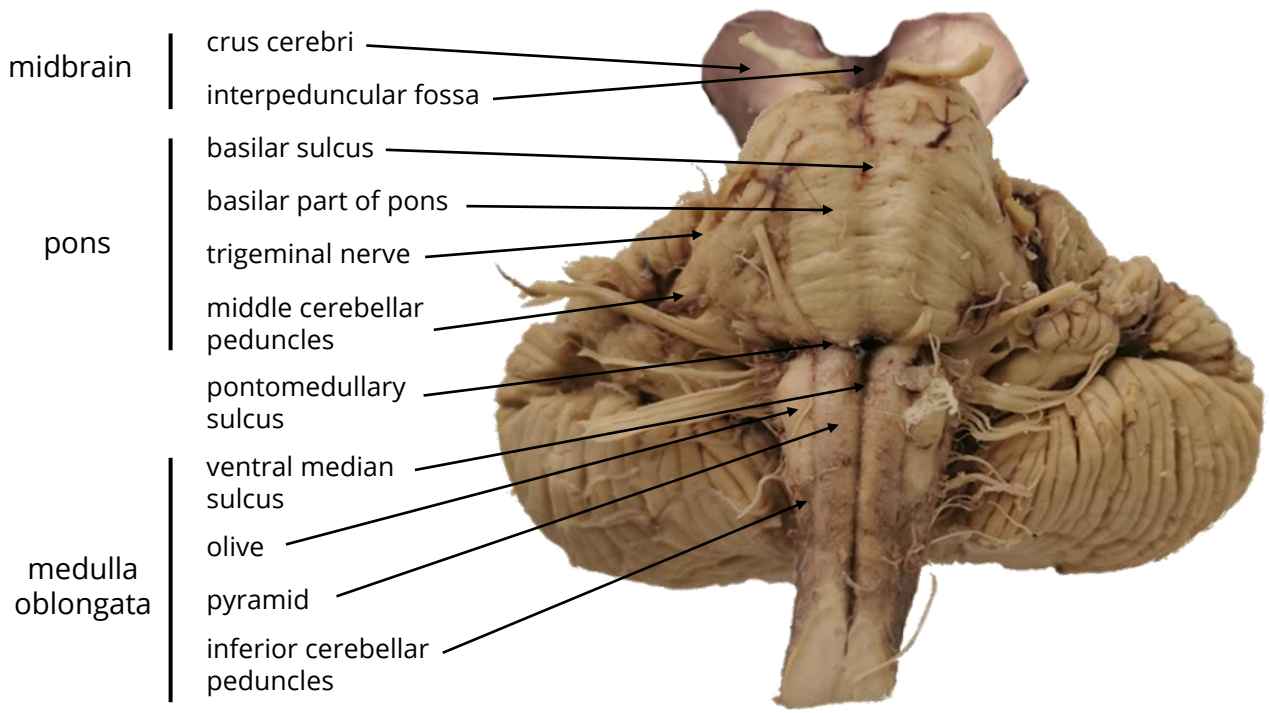


Brainstem

The brainstem is located inferior to the cerebrum and ventral to the cerebellum. It contains nuclei and white matter. The three main parts of the brainstem are the midbrain, pons and medulla oblongata. Surfaces of the brainstem

Ventral surface of the brainstem

In the ventral surface of the midbrain, notice two broad columns of white matter, crus cerebri (legs of the brain). They are composed of ascending and descending fibers that connect the spinal cord and the brainstem with the cerebrum. The deep depression between them is the interpeduncular fossa. The ventral surface of the pons is divided by the trigeminal nerve (CN V) into two parts. The medial part is the basilar part of pons, along its midline find the basilar sulcus where the basilar artery sits. The lateral parts are the middle cerebellar peduncles. The pontomedullary sulcus separates between the pons and the medulla oblongata. Along the midline of the ventral surface of the medulla oblongata, find the ventral median sulcus. On either side of it there is an elongated bulge that contains motor fibers from the cortex to the spinal cord, the pyramid. These fibers cross sides at the border between the medulla oblongata and the spinal cord in the pyramidal decussation. Lateral to each pyramid, find an oval bulge, the olive, that contains nuclei involved in the processing of auditory and motor information. At the lateral aspect of the medulla oblongata, find the inferior cerebellar peduncles.



Dorsal surface of the midbrain

Remove the cerebellum to expose the dorsal surface of the brainstem. In the midbrain, notice four round bulges, the corpora quadrigemina. The two superior bulges, superior colliculi, are each connected by the superior brachium to the lateral geniculate nucleus (LGN) of the thalamus and are part of the visual system. The two inferior bulges, inferior colliculi, are each connected by the inferior brachium to the medial geniculate nucleus (MGN) of the thalamus and are part of the auditory system. Inferior to the corpora quadrigemina, find the superior cerebellar peduncles that connect the midbrain and the cerebellum.

Dorsal surface of the pons and medulla oblongata: floor of the fourth ventricle

The dorsal surface of the pons and the open superior part of the medulla oblongata form the floor of the fourth ventricle, the rhomboid fossa. Along its midline, find the median sulcus. Across it, the bundles of white matter of the medullary striae divide the rhomboid fossa to a superior triangle that belongs to the pons and an inferior triangle that belongs to the medulla oblongata. In the superior triangle, on each side of the median sulcus notice an elongated bulge, the medial eminence. It is defined laterally by the sulcus limitans. In the lower part of the medial eminence find the facial colliculi. They each contain the nucleus of the abducens nerve that is surrounded by the fibers of the facial nerve.The inferior triangle is divided into three sub-triangles that contain the nuclei of cranial nerves. The most medial is the hypoglossal trigone. Next to it is the vagal trigone and the most lateral is the vestibular area. In its inferior part, the fourth ventricle becomes narrower until it ends at the obex (barrier). Its small opening is continuous with the central canal of the spinal cord. The margins of the obex are the location of the area postrema that is involved in the vomiting reflex.

Dorsal surface of the inferior medulla oblongata

The inferior part of the medulla oblongata is closed.

The dorsal median sulcus runs along its midline. On each of its sides, find two round bulges, the gracile tubercle and cuneate tubercle. They contain the gracile nucleus and cuneate nucleus. Inferior to them, find their white matter, the fasciculus gracilis and fasciculus cuneatus. They all belong to the sensory system.

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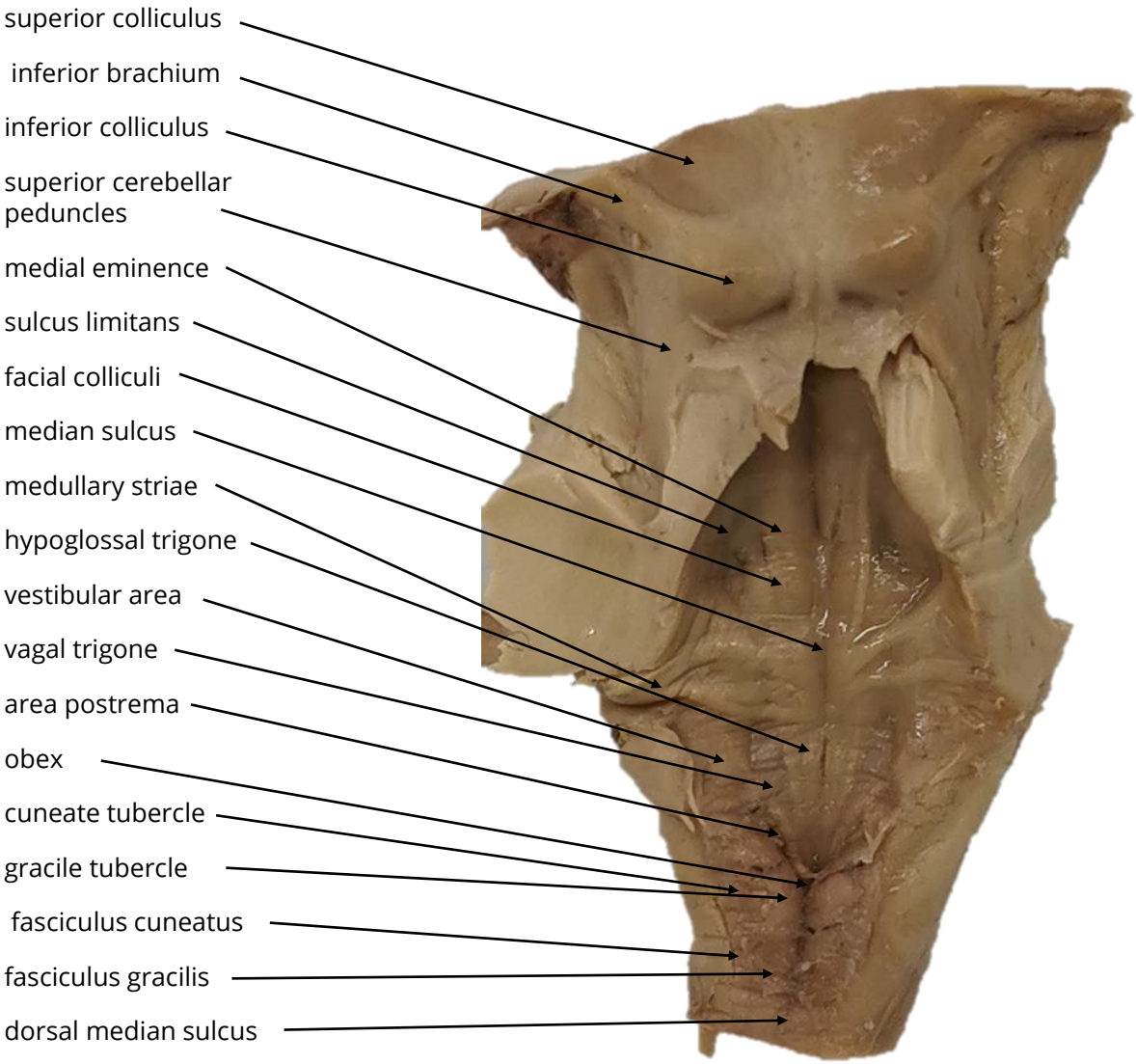
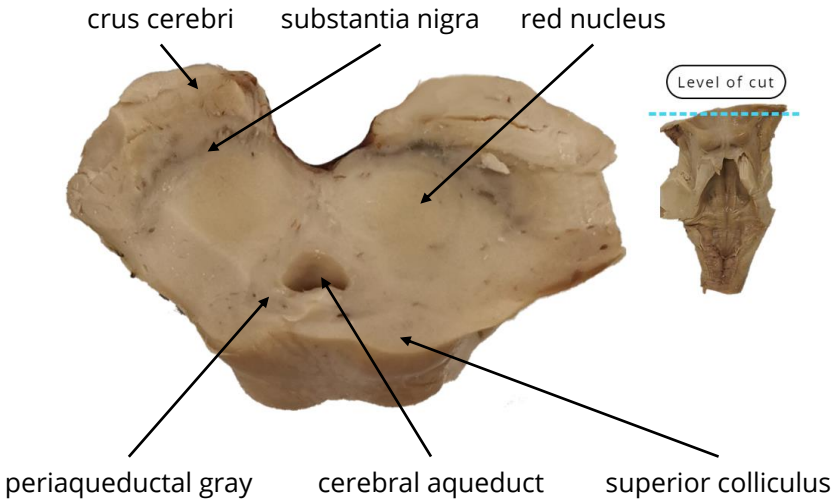
Dorsal surface of the brainstem



Horizontal sections of the brainstem

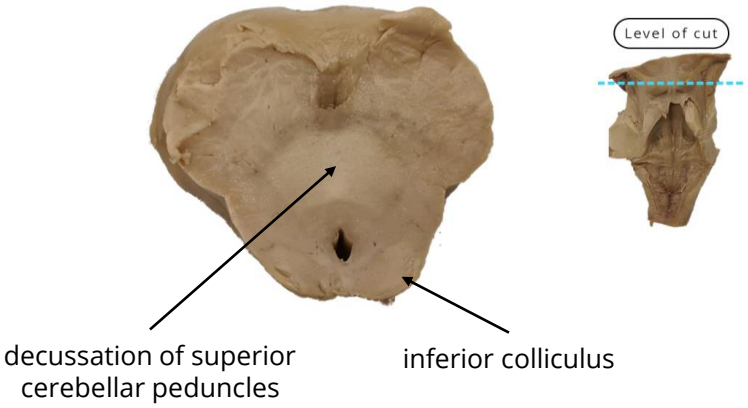
Midbrain: section through the superior colliculi

In order to separate the brain stem from the rest of the brain we made a cut in the midbrain at the level of the superior colliculi. Notice the hole of the cerebral aqueduct at the center and the periaqueductal gray that surrounds it. It divides the midbrain into the dorsal tectum and the ventral tegmentum. The tectum contains the superior colliculi and the tegmentum contains the red nucleus and substantia nigra. Anterior to the substantia nigra find the crus cerebri. Together, the crus cerebri and the tegmentum make up the cerebral peduncle.



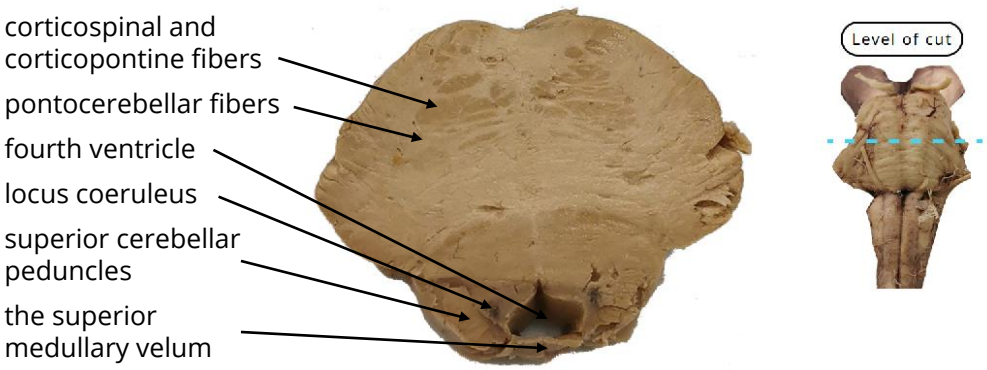
Midbrain: section through the inferior colliculi

Make cut in the midbrain at the level of the inferior colliculi. In the center, find the decussation of superior cerebellar peduncles.



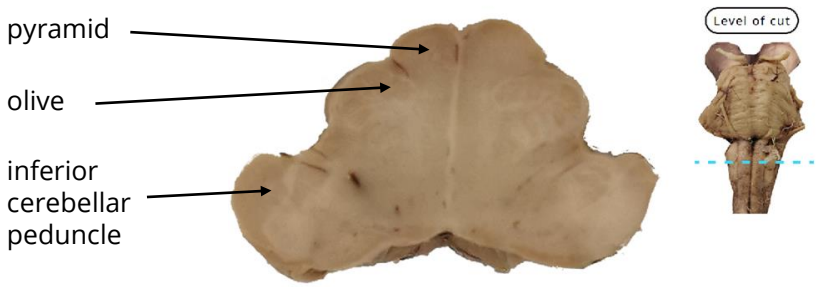
Pons: section through the trigeminal nerve

Make a cut in the pons at the level of the trigeminal nerve. In the basilar part, the light colored lateral fibers of the pontocerebellar fibers can be seen. Their cell bodies are located in the nuclei of the pons and they pass through the middle cerebellar peduncle to the cerebellum. The vertical corticospinal and corticopontine fibers that are continuous with fibers of the midbrain and medulla are cut perpendicularly to their orientation and therefore appear darker. In the tegmentum, find the superior cerebellar peduncles and the superior medullary velum between them. Near the wall of the fourth ventricle locate a bluish spot, the locus coeruleus.



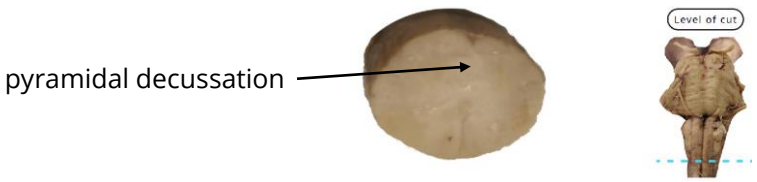
Medulla oblongata: section through the olive nucleus

Make a cut in the medulla oblongata at the level of the olive nucleus. In the ventral part, find the pyramid. Dorsal to it, identify the convoluted shape of the olive nucleus. Most lateral, find the inferior cerebellar peduncles.



Cross section of the medulla oblongata - pyramidal decussation

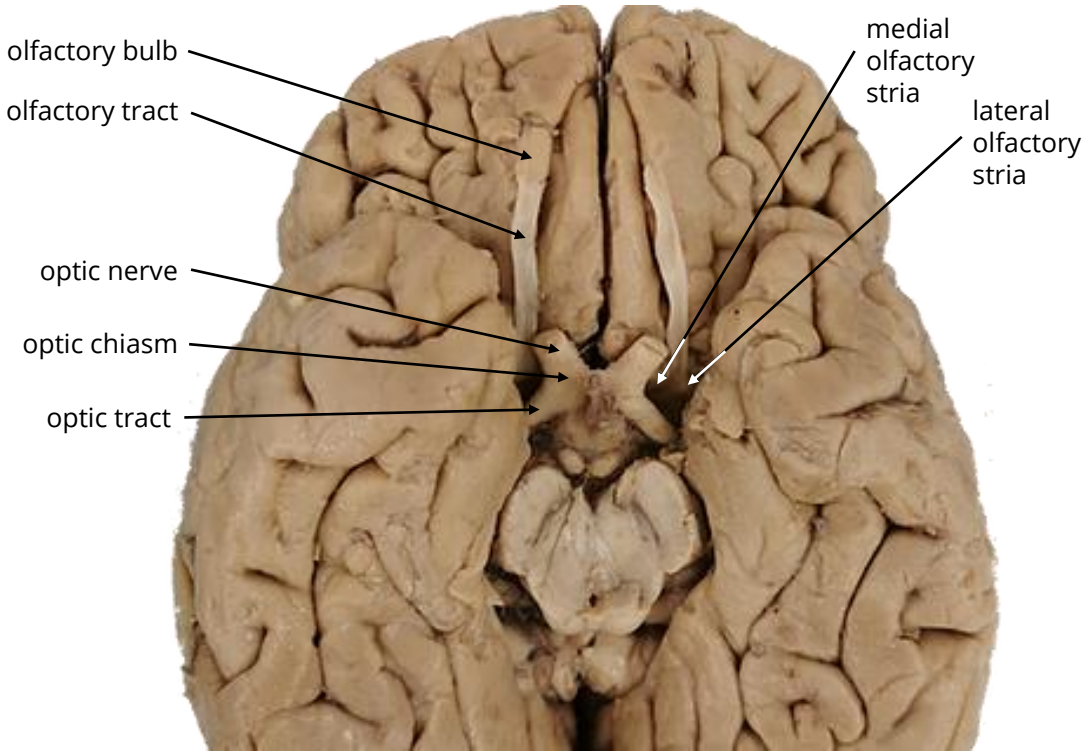
Make a cut in the medulla oblongata below the olive. Notice the crossing of the pyramid fibers, the pyramidal decussation.



Cranial nerves

There are twelve pairs of nerves that connect the central and peripheral nervous systems and pass through openings in the skull.

1. The olfactory nerves (CN I) are located at the roof of the nasal cavities and their fibers reach the olfactory bulb. The fibers coming out of the olfactory bulb form the olfactory tract that splits into a lateral olfactory stria and a medial olfactory stria.
2. The optic nerve (CN II) consists of the fibers from the retina of the eye. Some of the fibers of each optic nerve cross to the opposite side in the optic chiasm. From there, the fibers of the optic tract contain visual information from both eyes and reach the lateral geniculate nucleus (LGN) of the thalamus.

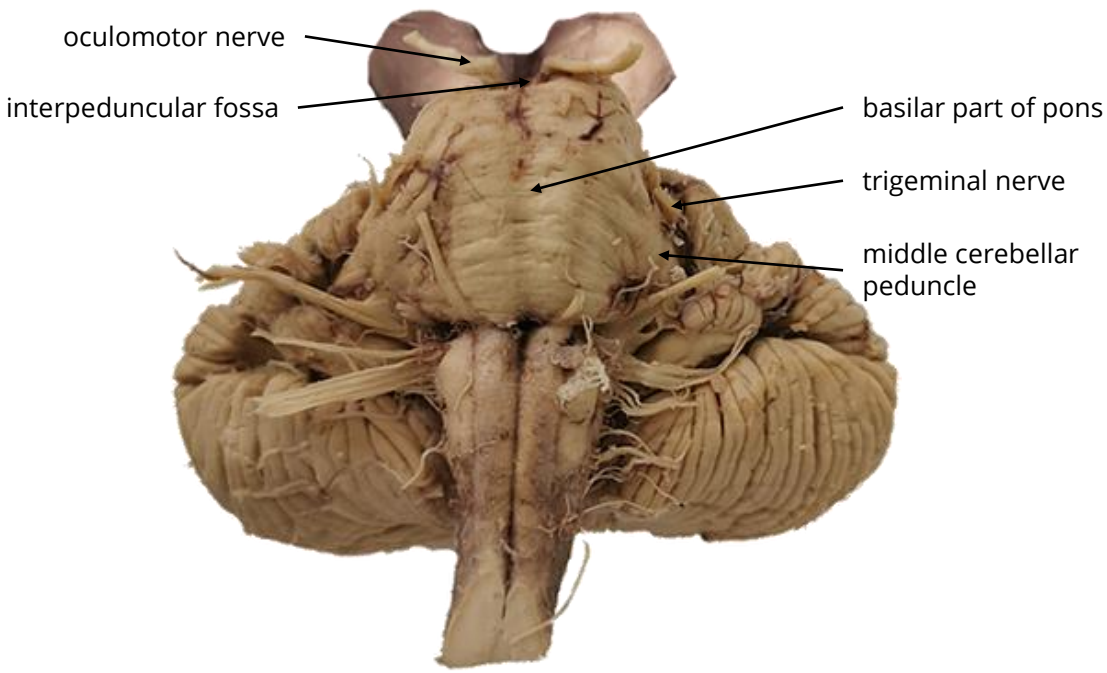


The nuclei of cranial nerves III - XII are all located in the brainstem.

3. The oculomotor nerve (CN III) exits at the interpeduncular fossa and innervates four of the ocular muscles (superior rectus, medial rectus, inferior rectus & inferior oblique), the levator palpebrae superioris (upper eyelid) and the sphincter pupillae (iris).

4. The trochlear nerve (CN IV) is the only cranial nerve that exits from the dorsal aspect of the brainstem, below the inferior colliculi. It innervates one of the ocular muscles (superior oblique).

5. The trigeminal nerve (CN V) exits from the pons and defines the boundary between the basilar part of pons and the middle cerebellar peduncle. It has three branches that bring sensory information from the face and innervate some of the jaw muscles.



Cranial nerves VI-VIII are located in the pontomedullary sulcus.

6. The abducens nerve (CN VI) is the most medial, it innervates one of the ocular muscles (lateral rectus).

7. The facial nerve (CN VII) innervates the facial muscles and brings taste information from the anterior two thirds of the tongue.

8. The vestibulocochlear nerve (CN VIII) is the most lateral, it has two branches that bring sensory information from the ear: auditory information from the cochlea and vestibular information from the vestibular system.

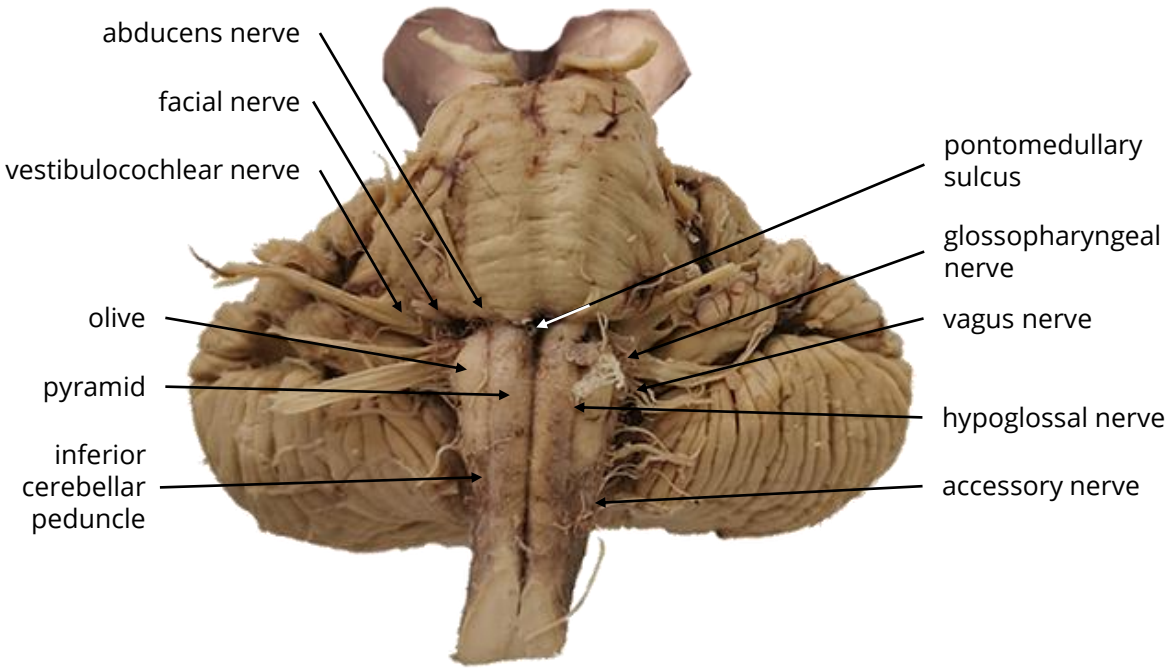
Cranial nerves IX-XI are located between the olive and the inferior cerebellar peduncle.

9. The glossopharyngeal nerve (CN IX) is the most superior, it brings taste information from the posterior one third of the tongue and innervate muscles in the pharynx.

10. The vagus nerve (CN X), parasympathetically innervates the heart, lungs and digestive system.

11. The accessory nerve (CN XI) is the most inferior, it innervates the neck and trapezius muscles.

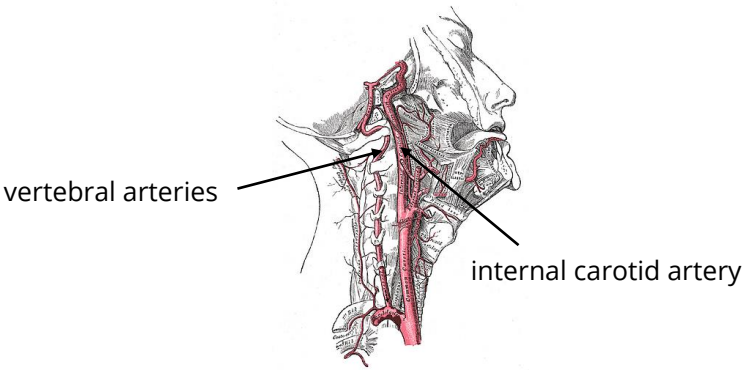
12. The hypoglossal nerve (CN XII) exits between the olive and the pyramid and it innervates the muscles of the tongue.



Blood vessels of the brain

Blood supply to the brain

The blood supply to the brain consists of an anterior portion originating from the internal carotid artery (ICA) and a posterior portion originating from the vertebral arteries.



Blood supply to the cerebrum

There are three main arteries that supply the cerebrum: anterior, middle and posterior cerebral arteries. The anterior and middle cerebral arteries are part of the anterior blood supply, and the posterior cerebral artery is part of the posterior blood supply. The anterior cerebral artery (ACA) branches sharply forward from the internal carotid artery (ICA). It ascends over the corpus callosum and its branches provide the anterior 2/3 of the medial surface of the cerebrum. The middle cerebral artery (MCA) branches from the ICA while keeping its general course. It enters into the lateral fissure and its branches run above the insula and supply the anterior 2/3 of the inferior and lateral surfaces of the cerebrum. Try to identify some of the small branches of the MCA. The most medial is the anterior choroidal artery that supply the choroid plexus. Lateral to it, the thin striate arteries penetrate the anterior perforated substance and supply the striatum and internal capsule. The posterior cerebral artery (PCA) is a part of the posterior blood supply. In their superior part, the two vertebral arteries merge to form the basilar artery. At the most superior part, the basilar artery splits into the two posterior cerebral arteries. The PCA provides the posterior 1/3 of the cerebrum surfaces. The posterior choroidal arteries branch from the PCA and supply the choroid plexus of the lateral ventricles and the tela choroidea of the third ventricle.

Cerebral arterial circle

The main arteries that supply the cerebrum are connected in an arterial circle (circle of Willis). This circle consists of the two anterior cerebral arteries that are connected by the anterior communicating artery and the two internal carotid arteries each connected to the posterior cerebral artery by the two posterior communicating arteries.

Blood supply of the cerebellum

Three arteries supply the cerebellum, they are all part of the posterior blood supply of the brain. The superior cerebellar artery branches from the rostral part of the basilar artery, below the posterior cerebral artery. Notice the oculomotor nerve that originates between them. Follow the basilar artery caudally, identify small branches that supply the pons, the pontine arteries. The anterior inferior cerebellar artery (AICA) branches from the lower part of the basilar artery near the merging point of the vertebral arteries. Try to find the thin labyrinthine artery that supply the inner ear and the abducens nerve that are located above it. The posterior inferior cerebellar artery (PICA) branches from the vertebral artery.

Blood supply of the spinal cord

There are three main arteries that supply the spinal cord, they are part of the posterior blood supply of the brain.

In the superior part of the vertebral arteries, two small medial branches merge into the anterior spinal artery that supplies the anterior part of the spinal cord. Two posterior spinal arteries branch from the lateral part of each vertebral artery and supply the posterior part of the spinal cord.

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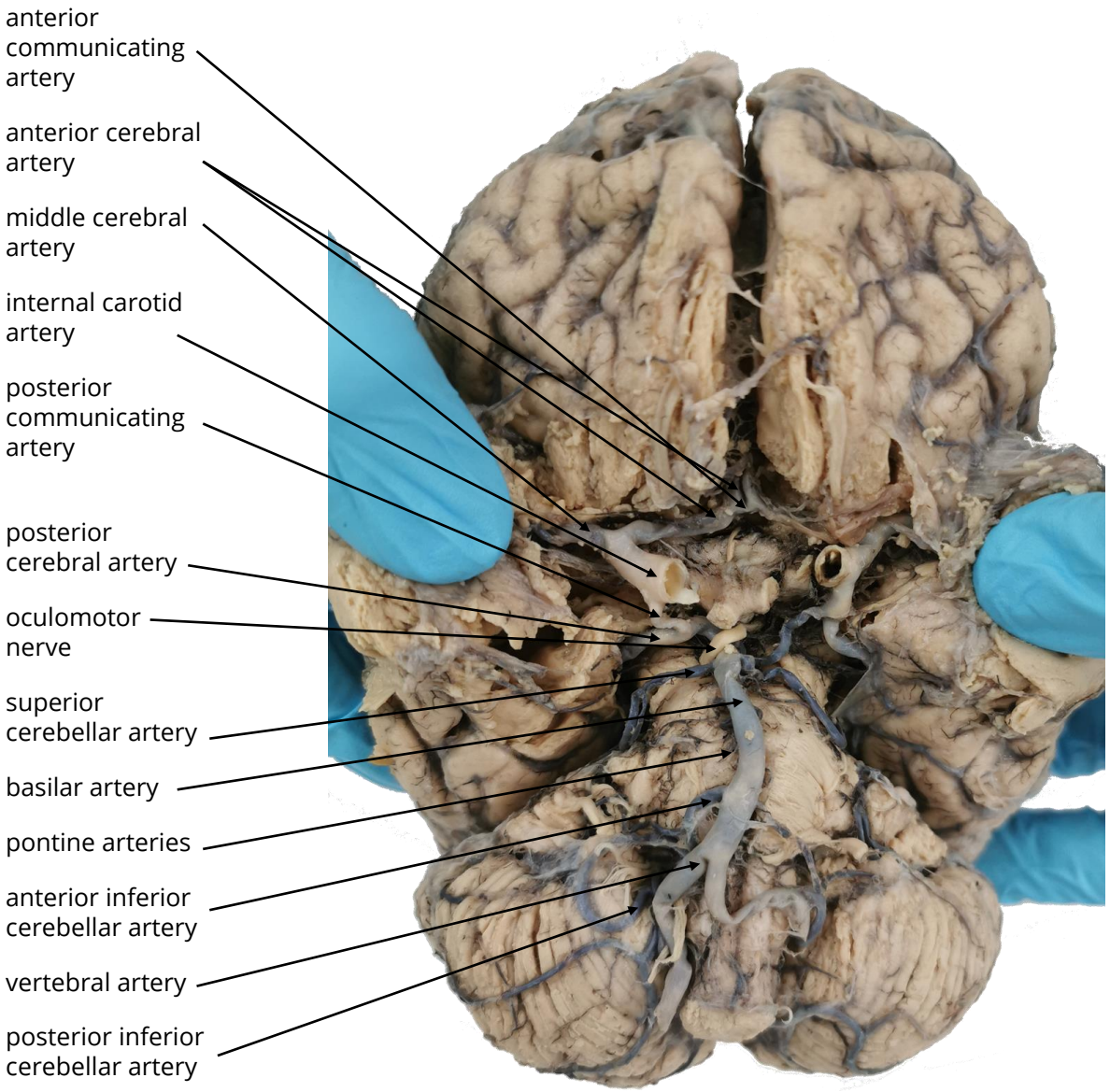
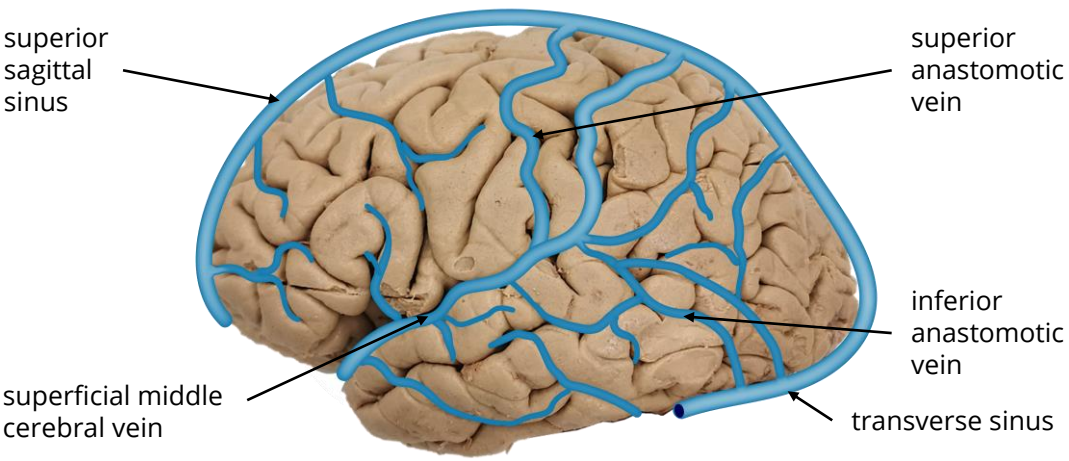
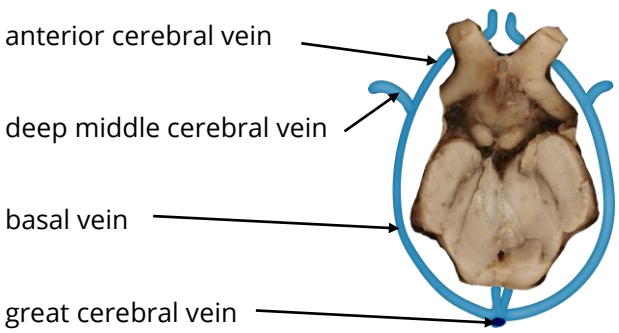
Blood supply to the brain



External venous system

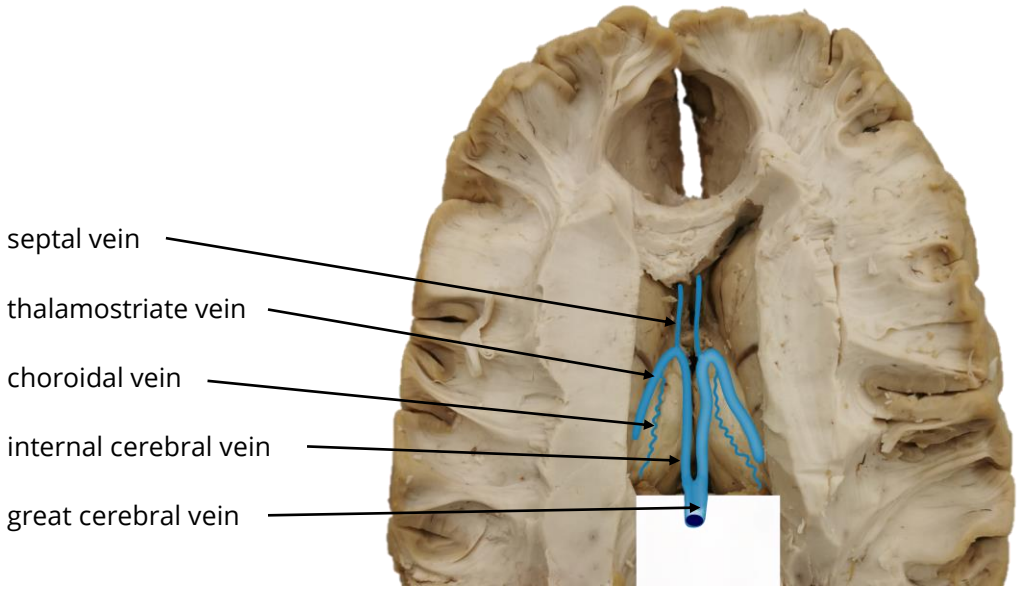
On the lateral surface of the hemisphere, find the superior cerebral veins that drain into the superior sagittal sinus. Superficial to the lateral fissure, find the superficial middle cerebral vein that drains into the cavernous sinus. Two anastomotic veins branch from the superficial middle cerebral vein: the superior anastomotic vein (of Trolard) that drains into the superior sagittal sinus and the inferior anastomotic vein (of Labbe) that drains into the transverse sinus. It is difficult to differentiate between these veins and other veins in the preserved brain. In the depth of the lateral sulcus lies the deep middle cerebral vein. It is easier to identify it at its posterior part where the anterior cerebral vein drains into it and both form the basal vein (of Rosenthal). This vein encircles the midbrain and drains into the great cerebral vein (of Galen).

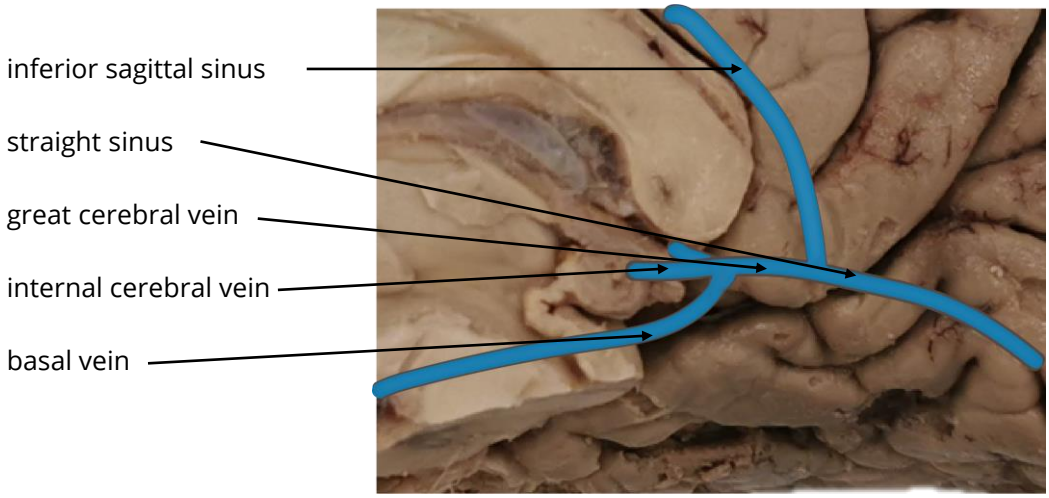




Internal venous system

The internal venous system consists of two internal cerebral veins that lie within the tela choroidea of the third ventricle. Each such vein is formed from the drainage of the thalamostriate vein, septal vein and choroidal vein. Posteriorly, the two internal cerebral veins merge to form the great cerebral vein (of Galen) that also drains the basal vein. The great cerebral vein drains into the straight sinus.



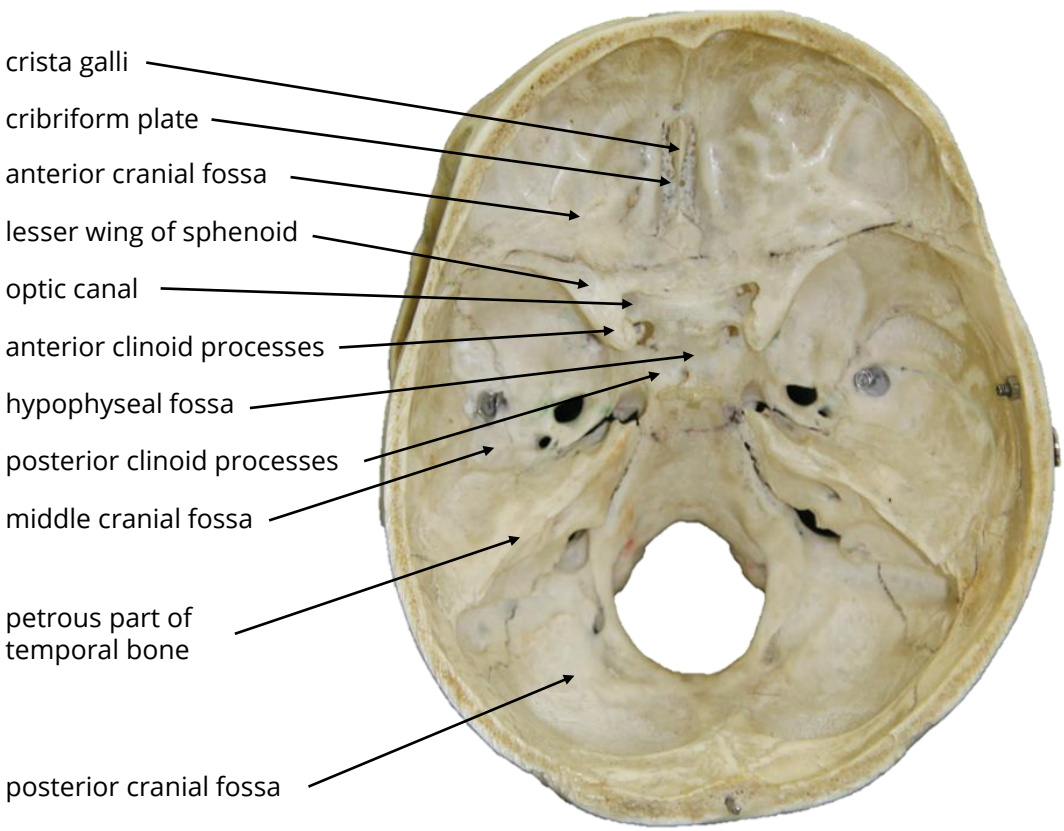


Endocranium and dural sinuses

The dry skull

Remove the calvarium of the skull and examine the interior of the cranium. The base of the endocranium is divided into three cranial fossae: anterior, middle and posterior. The anterior cranial fossa is separated from the middle cranial fossa by a bone ridge, the lesser wing of sphenoid bone. Identify it and follow it towards the midline, notice how it ends in two projections, the anterior clinoid processes. The middle cranial fossa is separated from the posterior cranial fossa by an elongated pyramid shape bone protrusion, the petrous part of the temporal bone.

Look at the center of the floor of the cranial cavity. Notice a saddle shaped raised structure, the sella turcica (Turkish saddle). It is defined by four processes: the anterior clinoid processes and the posterior clinoid processes. Between the two posterior clinoid processes identify the hypophyseal fossa, the site of the hypophysis (pituitary) gland. Anterior and medial to each anterior clinoid process find a circular opening leading to the orbital cavity, the optic canal.

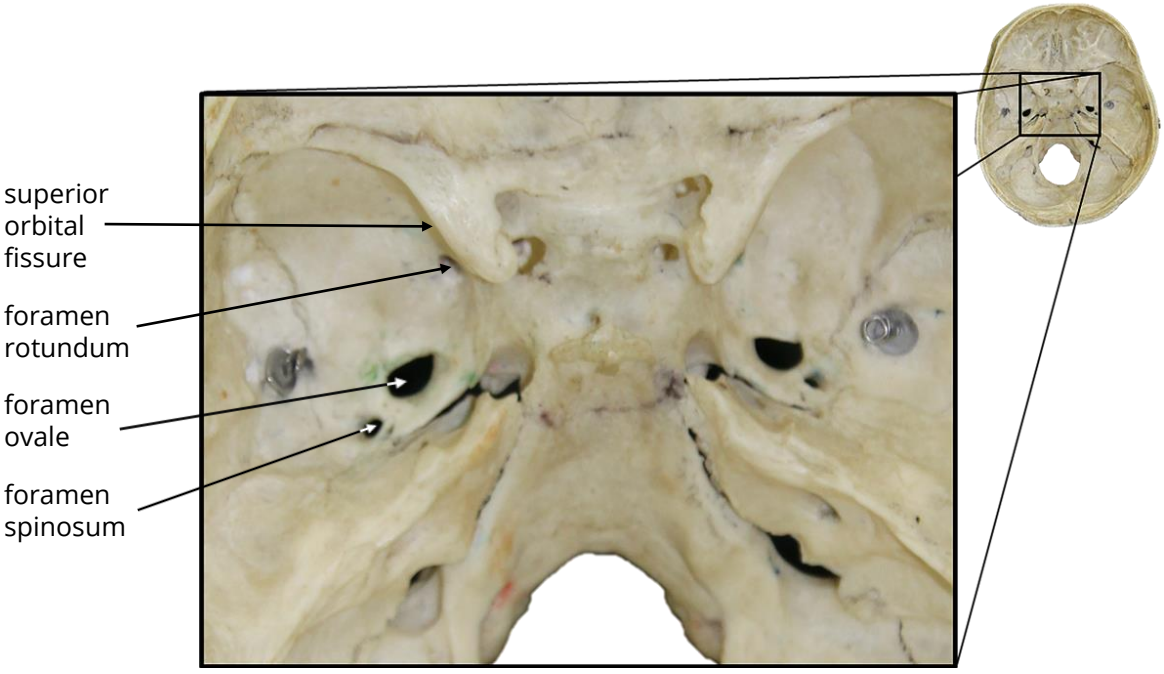


The dry skull

The anterior cranial fossa contains the frontal lobe, in its medial part notice a perforated part of the bone, the cribriform plate through which the olfactory nerve fibres pass. Perpendicular to the cribriform plate, locate a comb shaped plate, the crista galli. The middle cranial fossa contains the temporal lobe. In its medial part, on either side of the sella turcica there is a series of foramina arranged in the shape of a crescent, the crescent of foramina.

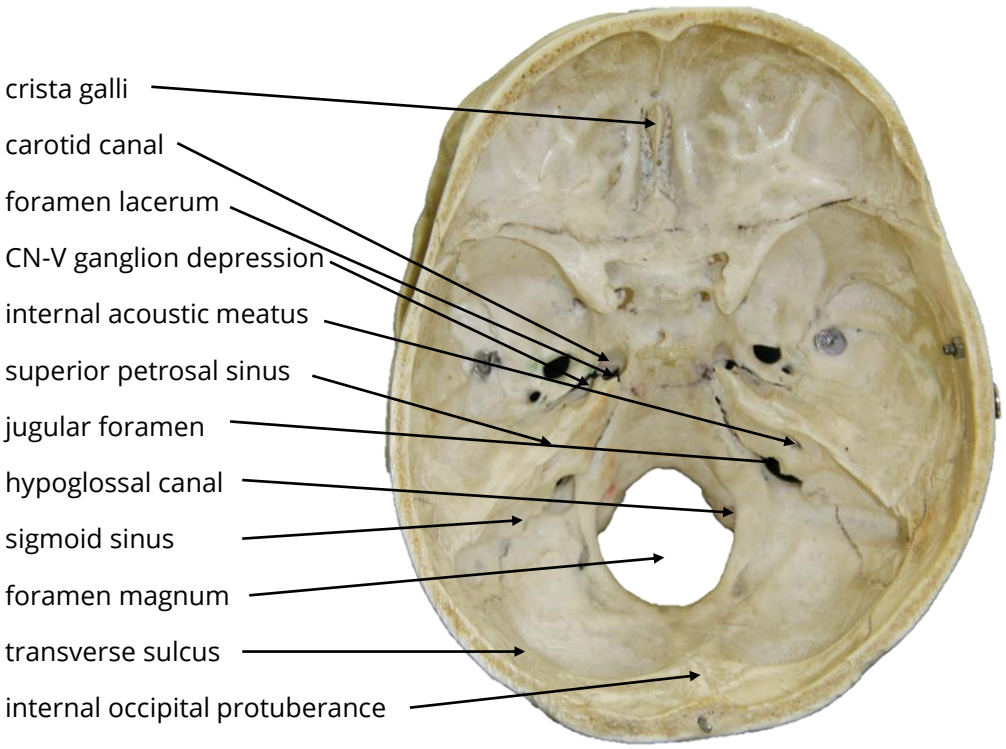
Crescent of foramina

In the crescent of foramina identify the different openings from anterior to posterior. The superior orbital fissure through which cranial nerves: III, IV, V1 (ophthalmic branch) & VI pass. Next, is the foramen rotundum through which the nerve V2 (maxillary branch) passes. The next opening is the foramen ovale through which the nerve V3 (mandibular branch) passes. The most posterior small opening is the foramen spinosum through which the middle meningeal artery passes.



The dry skull

Near the anterior medial edge of the petrous, find the foramen lacerum. Next to it, lateral to the posterior clinoid process, identify the carotid canal that contains the internal carotid artery. Posterior to it, find the depression for trigeminal ganglion. From this region the trigeminal nerve (CN-V) splits into its three sensory branches: ophthalmic, maxillary and mandibular. Along the ridge of the petrous find a thin canal, the superior petrosal sinus. The posterior cranial fossa contains the cerebellum. At its anterior part, in the posterior slope of the body of the petrous, find the internal acoustic meatus, through which cranial nerves VII and VIII pass. Posterior to it, there is a large hole that is formed in the space between the body of the petrous and the floor of the posterior cranial fossa, the jugular foramen. Through it, the internal jugular vein and the cranial nerves: IX, X & XI pass. At the bottom of the center of the posterior fossa find the foramen magnum. In the lateral part of it's edges find the hypoglossal canal (anterior condylar) through which the cranial nerve XII passes. At the midline of the posterior cranial fossa, find a thickening in the bone, the internal occipital protuberance. From this point try to identify the impression of the transverse sulcus, where the transverse sinus lies. Follow the canal laterally and notice how it winds down posterior to the petrous and ends in the jugular foramen. This tortuous section is the sigmoid sinus. Return to the internal occipital protuberance, notice a ridge that extends upward and continue sagittally along the entire length of the skull and reach the crista galli in the frontal bone, this is the superior sagittal sinus.

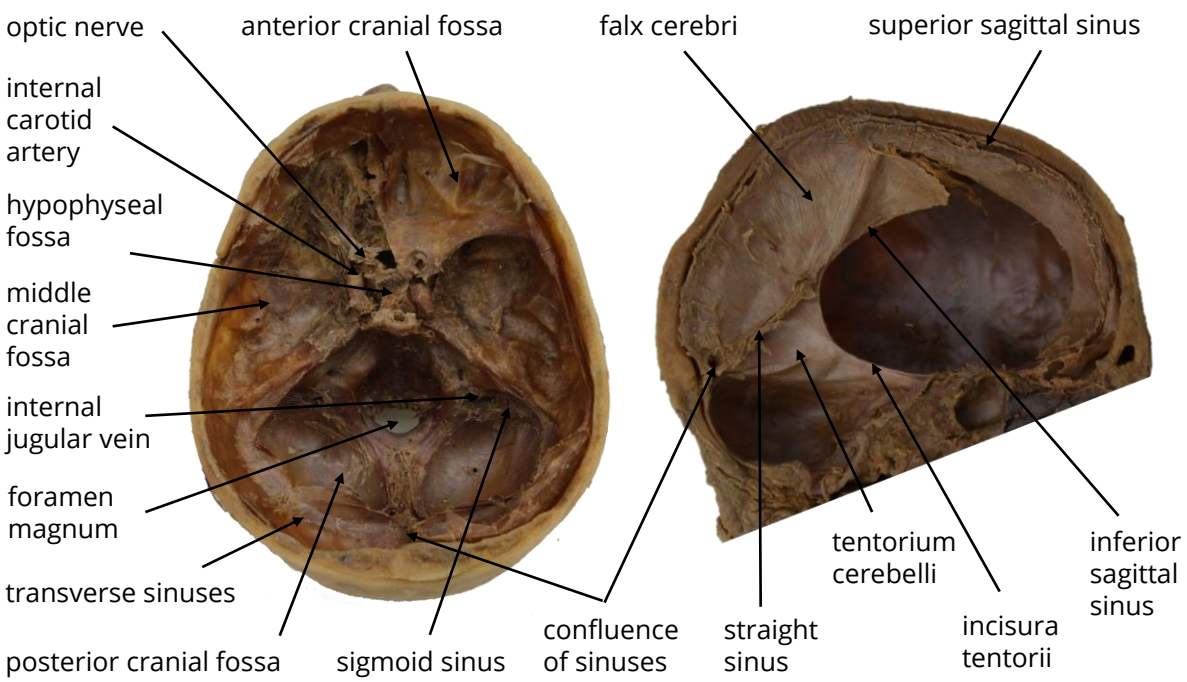


The endocranium in the cadaver

In the center of the endocranium, at the meeting point of the anterior cranial fossa and the middle cranial fossa, find the entry point of the optic nerve and posterior to it, the entry point of the internal carotid artery (the bone is removed on the left side). Notice the elevated structure of the sella turcica (Turkish saddle) and in its center the hypophyseal fossa, the seat of the hypophysis. In the posterior cranial fossa, find the foramen magnum through which the spinal cord continues.

The dural sinuses

Examine the dura mater in the endocranium. In the midline, identify a deep fold, the falx cerebri. It enters the longitudinal fissure between the two hemispheres. At its posterior margins, the falx cerebri splits sideways and forms the tentorium cerebelli that separates the occipital lobe from the cerebellum. Notice the anterior margins of the tentorium that surround the midbrain, the incisura tentorii. Idetify two sinuses that run along the falx cerebri and drain venous blood and the cerebrospinal fluid (CSF). The superior sagittal sinus is located continues backward and drains into the confluence of sinuses located at the posterior junction of the falx and tentorium. The lower inferior sagittal sinus continues backwards and drains into the straight sinus located in the center of the meeting point of the falx and the tentorium. At the posterior margins of the tentorium, two lateral sinuses leave the confluence of sinuses, the transverse sinuses. Follow the canal in the lateral direction and notice how it winds down the sigmoid sinus to the internal jugular vein that drain all the blood and CSF from the brain.

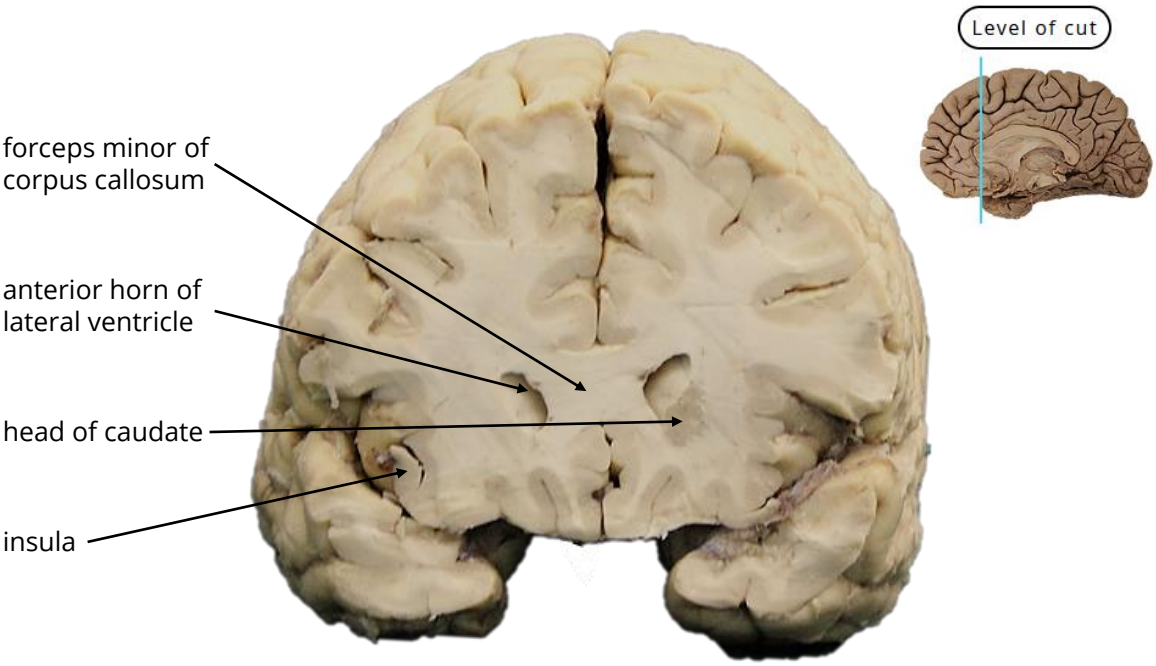


Coronal sections of the brain

Now that we have finished learning about the different structures of the cerebrum, we will examine them in the coronal sections. Using the hemisphere that has remained intact, make coronal sections according to the following instructions. After each cut identify the different structures in the anterior and posterior aspects of each section and compare them with the figures.

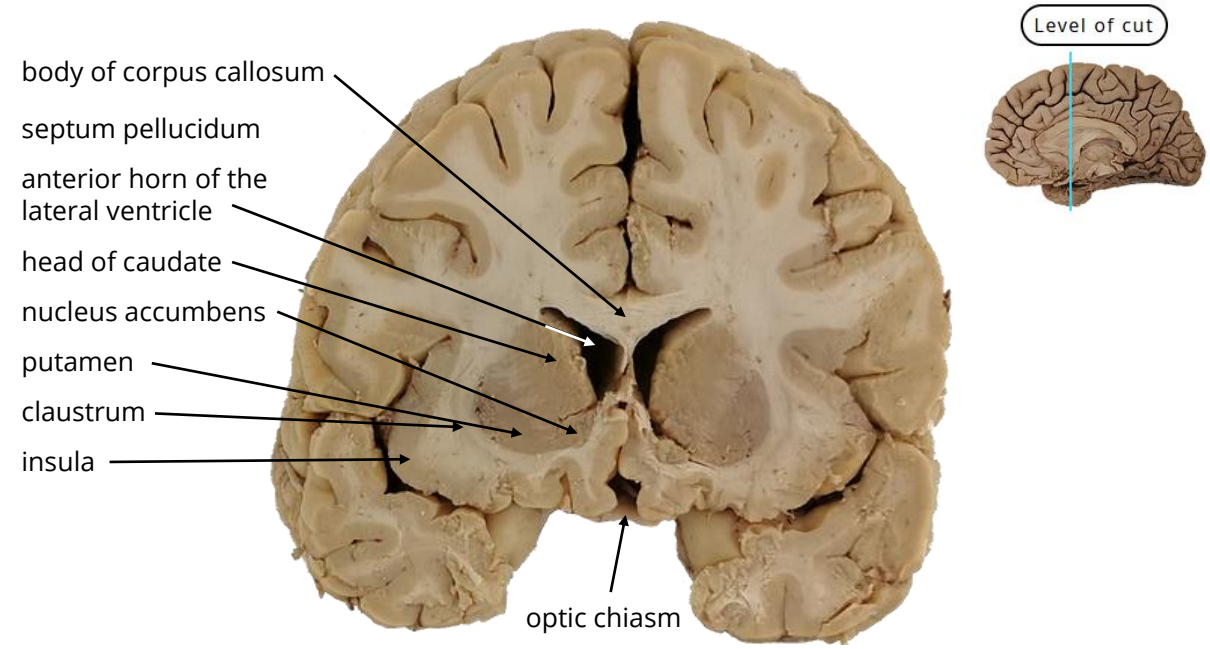
Cut through the genu of the corpus callosum

In this section, you can see the anterior horn of the lateral ventricle. The roof and medial wall are made of the white matter of the forceps minor of corpus callosum and the floor is the head of caudate nucleus. Notice the insula as well.



Cut through the optic chiasm

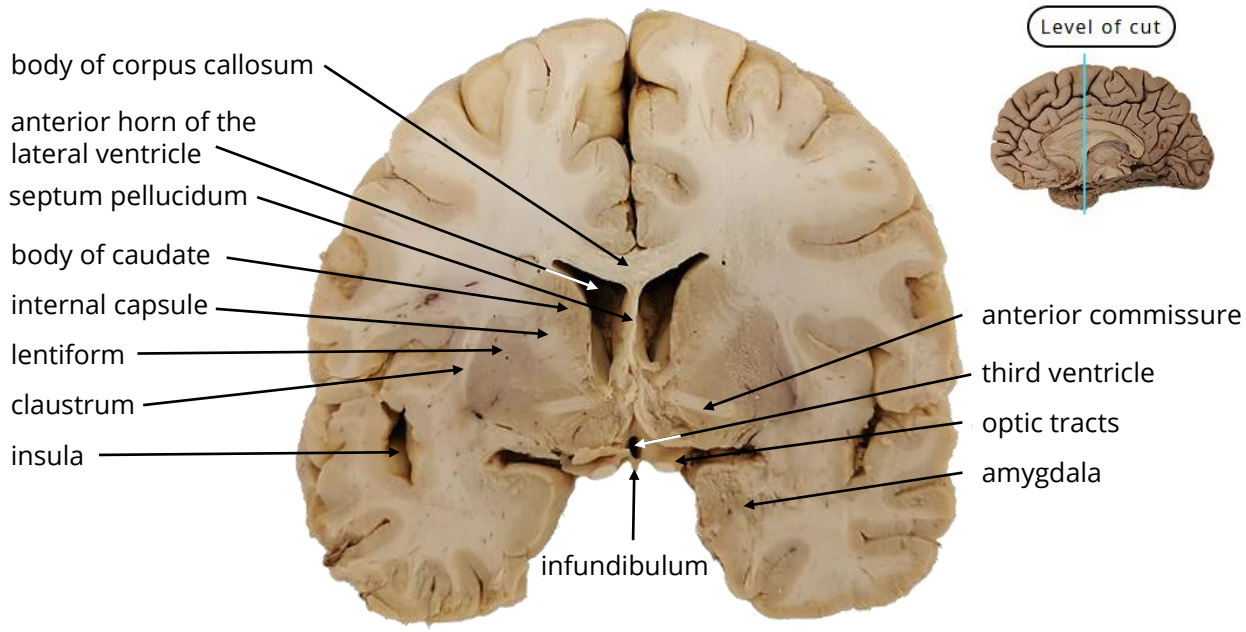
In this section through the optic chiasm, continue to follow the anterior horn of the lateral ventricle. The floor is made of the head of caudate nucleus, the roof is made of the body of corpus callosum and the medial wall is the septum pellucidum. In this section, you can also see the putamen, nucleus accumbens, claustrum and insula.



Cut through the anterior commissure

In this section through the anterior commissure, identify the optic tracts on both sides of the infundibulum. In this section, you can also see the anterior part of the third ventricle. In the temporal lobe, notice a gray matter nucleus, the amygdala (almond). In this section, the floor of the anterior horn of the lateral ventricle is made of the body of caudate nucleus, the roof is made of the body of corpus callosum and the medial wall is made of the septum pellucidum.

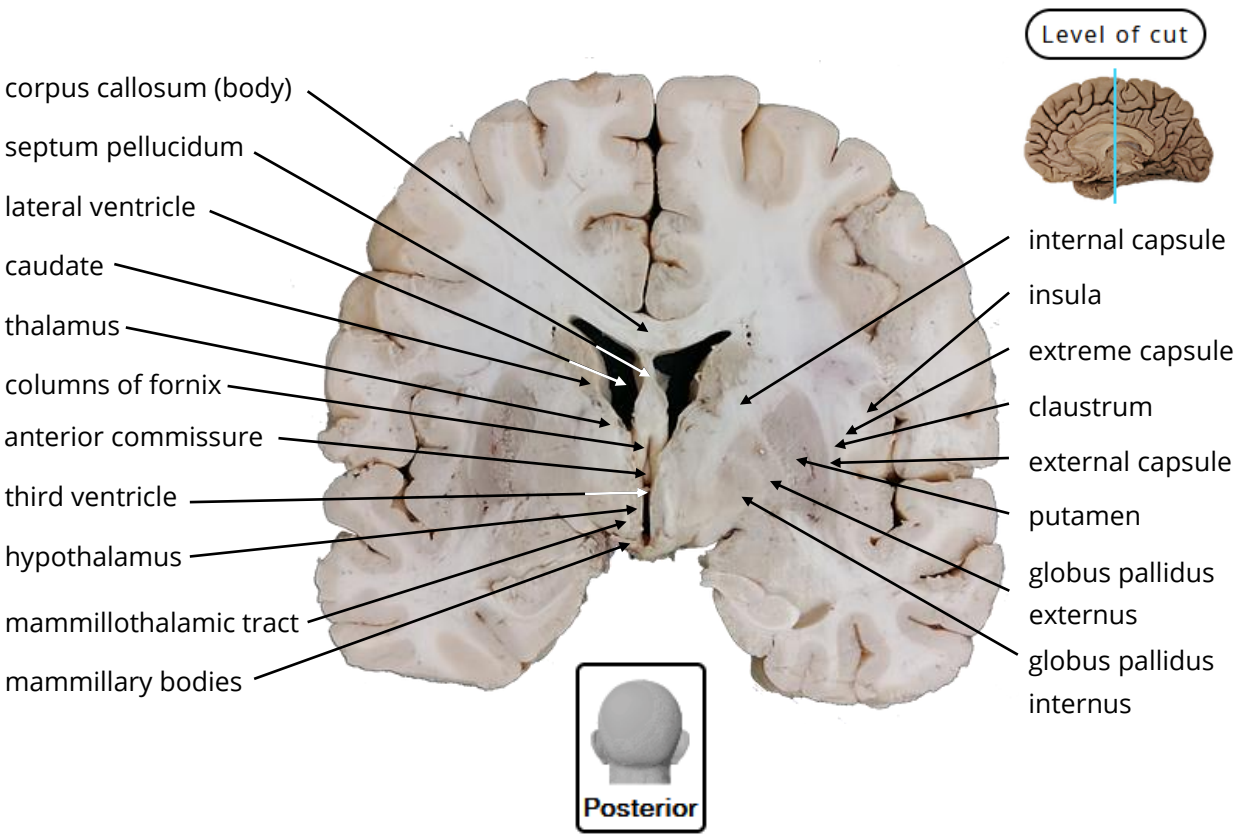
Also find the internal capsule, lentiform (putamen and globus pallidus), claustrum and insula.

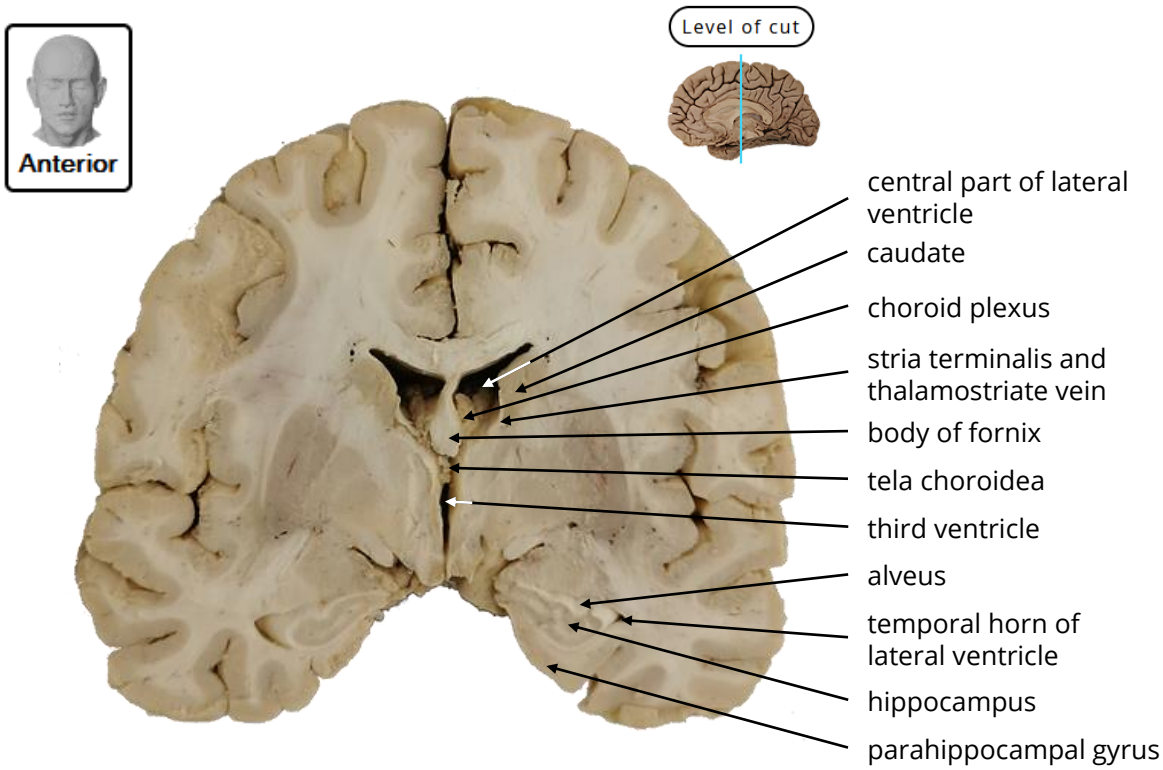


Cut through the mamillary bodies

In this section, we see a posterior view of the anterior part of the brain and an anterior view of the posterior part of the brain. In the anterior part of the brain, notice the columns of fornix and anterior to them, the anterior commissure. In both parts of the brain, find the mammillothalamic tract. It is composed of the fibers that connect the mammillary bodies to the anterior nucleus of thalamus. In this section, you can see the third ventricle between the two hypothalami and the interventricular foramens that connect it with the lateral ventricles. In the posterior part of the brain, find the tela choroidea at the roof of the third ventricle below the body of fornix and the choroid plexus in the central part of the lateral ventricle. The floor of the central part of the lateral ventricle is the body of caudate and the thalamus. Between them, find the thalamostriate vein and stria terminalis. The roof is made of the body of corpus callosum and the medial wall is made of the septum pellucidum. In the temporal lobe, notice that we can now see the temporal horn of the lateral ventricle. At its floor, find the anterior part of the hippocampus (pes) covered with its white matter, the alveus. Notice how its cortex folds on itself and is continuous with parahippocampal gyrus. Identify the optic tracts and notice how they move laterally as we continue to more posterior sections. In this cut, you can identify the different nuclei of the lentiform: putamen, globus pallidus externus and globus pallidus internus.

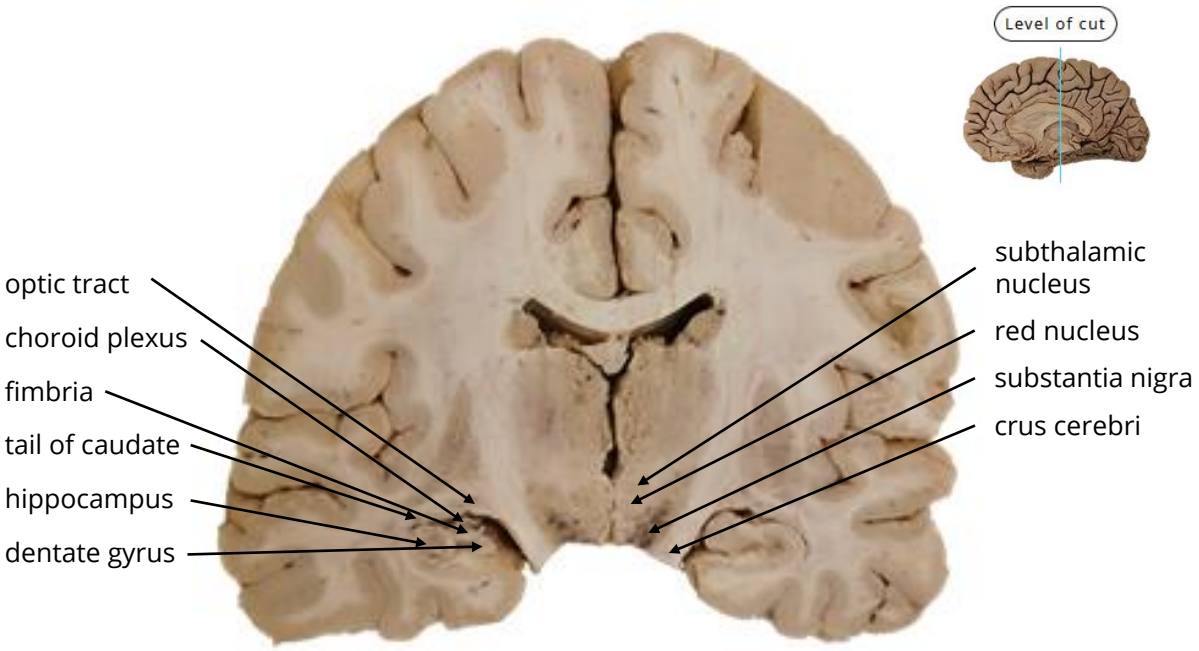
Here, you can clearly see the distinction between the internal capsule, external capsule, claustrum, extreme capsule and insula.





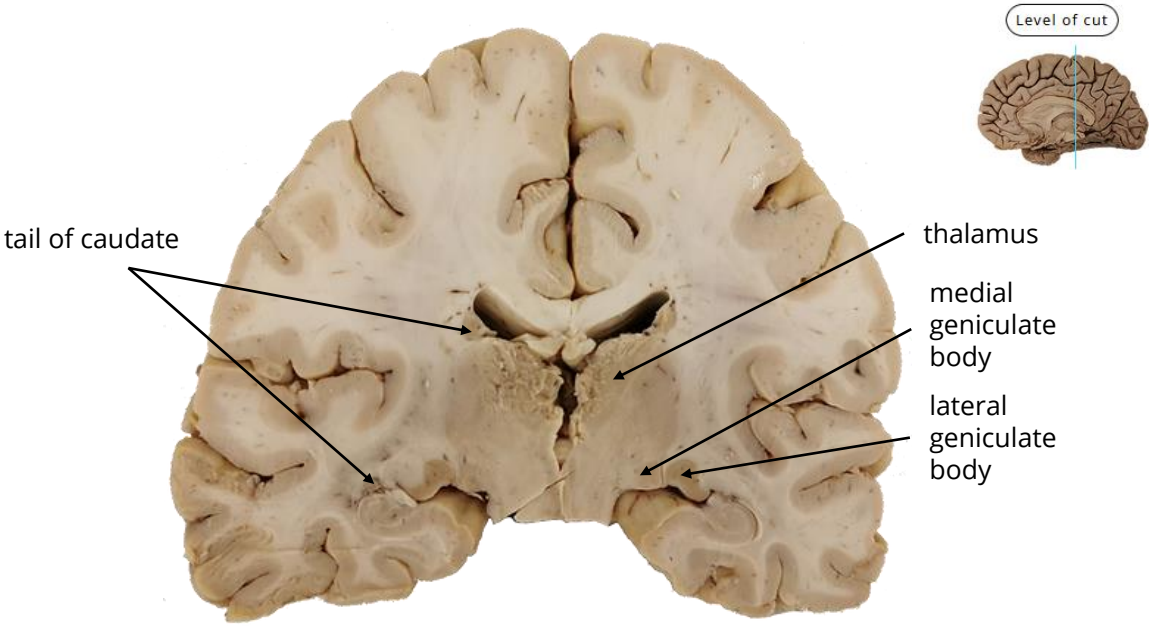
Cut through the tegmentum of the midbrain

In this section, you can see some of the structures of the midbrain such as the red nucleus, substantia nigra, subthalamic nucleus and the crus cerebri. Lateral to the crus cerebri of each side, find the optic tract. In the temporal horn of the lateral ventricle, you can see the central part of the hippocampus and the alveus. Notice a separate fold of white matter, the fimbria. Above it, find the choroid plexus and below it the dentate gyrus. At the roof of the temporal horn of the lateral ventricle, find the tail of caudate nucleus. Note that it is also present at the floor of the central part of the lateral ventricle. Identify the structures you have seen in the previous section that are also present here: corpus callosum, septum pellucidum, body of fornix, choroid plexus, thalamus, third ventricle, internal capsule, lentiform, external capsule, claustrum, extreme capsule, insula and parahippocampal gyrus.



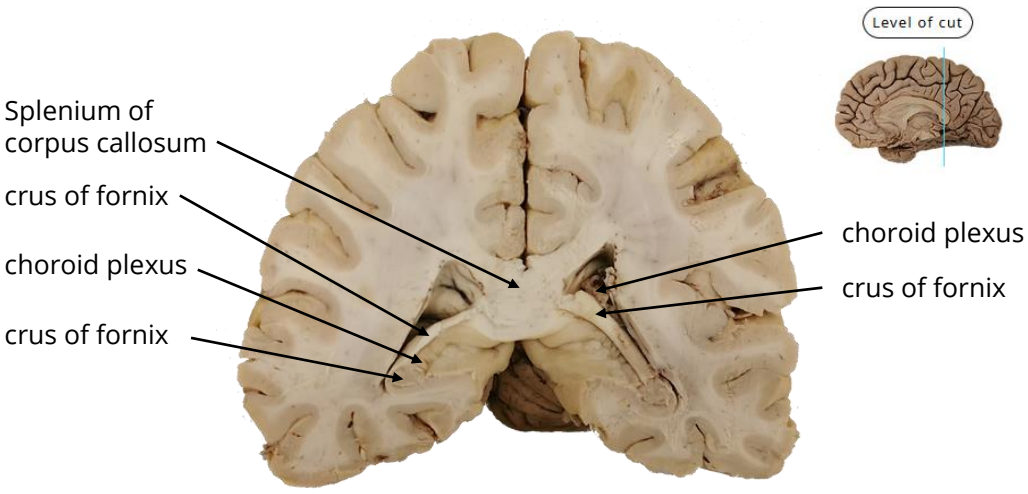
Cut through the lateral geniculate nucleus

In this section, you can see the lateral geniculate body and medial geniculate body of the thalamus. Identify the structures you have seen in the previous section that are also present here: central part of the lateral ventricle, corpus callosum, fornix, tail of caudate nucleus, third ventricle, temporal horn of the lateral ventricle, hippocampus, alveus, fimbria and dentate gyrus.



Cut through the splenium of corpus callosum

In this section through the splenium of corpus callosum, you can see the crus of fornix and how it is continuous with the fimbria. Identify the structures you have seen in the previous section that are also present here: hippocampus, dentate gyrus and choroid plexus.



Cut through the occipital horn of the lateral ventricle **(right hemisphere)**

In this section, you can see the occipital horn of the lateral ventricle, notice that it does not contain the choroid plexus. Find three bulges within it. The superior bulge is the bulb of the occipital horn that is formed by the forceps major of the corpus callosum. The middle and largest bulge is the calcar avis that is formed by the calcarine sulcus. The Inferior bulge is the collateral eminence that is formed by the collateral sulcus. The lateral wall is composed of fibers of the corpus callosum that continue downwards, the tapetum. Laterally to it, find the fibers of the optic radiation of the internal capsule. It appears slightly darker because the cut was made perpendicular to the orientation of the fibers.