BRAIN ANATOMY

Adapted from Human Anatomy & Physiology by Marieb and Hoehn (9th ed.)

The anatomy of the brain is often discussed in terms of either the embryonic scheme or the medical scheme. The embryonic scheme focuses on developmental pathways and names regions based on embryonic origins. The medical scheme focuses on the layout of the adult brain and names regions based on location and functionality. For this laboratory, we will consider the brain in terms of the medical scheme (Figure 1):

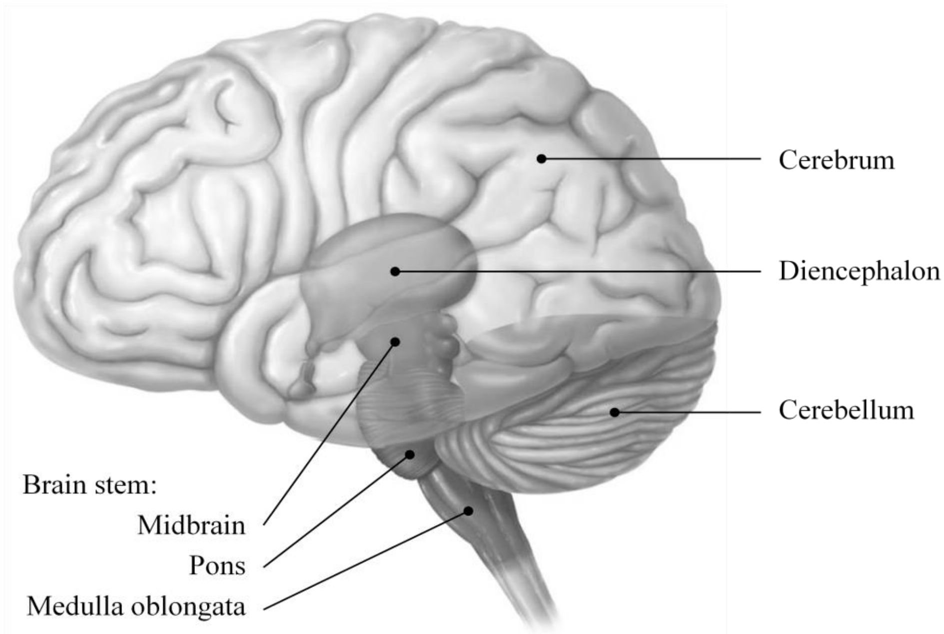


Figure 1: General anatomy of the human brain

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 12.2

CEREBRUM:

Divided into two hemispheres, the cerebrum is the largest region of the human brain – the two hemispheres together account for ~ 85% of total brain mass. The cerebrum forms the superior part of the brain, covering and obscuring the diencephalon and brain stem similar to the way a mushroom cap covers the top of its stalk. Elevated ridges of tissue, called **gyri** (singular: gyrus), separated by shallow groves called **sulci** (singular: sulcus) mark nearly the entire surface of the cerebral hemispheres. Deeper groves, called **fissures**, separate large regions of the brain.

Much of the cerebrum is involved in the processing of somatic sensory and motor information as well as all conscious thoughts and intellectual functions. The outer cortex of the cerebrum is composed of **gray matter** – billions of neuron cell bodies and unmyelinated axons arranged in six discrete layers. Although only 2 – 4 mm thick, this region accounts for ~ 40% of total brain mass. The inner region is composed of **white matter** – tracts of myelinated axons. Deep within the cerebral white matter is a third basic region of the cerebrum, a group of sub-cortical gray matter called **basal nuclei**. These nuclei, the caudate nucleus, putamen, and globus pallidus, are important regulators of skeletal muscle movement.

Below are listed the major anatomical regions / landmarks of the cerebrum with their corresponding functions (Figures 2 & 3):

REGION / LANDMARK	FUNCTION
Longitudinal fissure	Deep fissure that separates the two hemispheres (right and left) of the cerebrum.
Frontal lobe	Region of the cerebrum located under the frontal bone; contains the primary motor cortex (**precentral gyrus**) and is involved in complex learning.
Parietal lobe	Region of the cerebrum located under parietal bone; contains the primary sensory cortex (**postcentral gyrus**) and is involved in language acquisition.
Central sulcus	Deep groove that separates the frontal lobe from the parietal lobe of the cerebrum.
Occipital lobe	Region of the cerebrum located under occipital bone; processes visual information and is related to our understanding of the written word.
Parieto-occipital sulcus	Groove on medial surface of hemisphere that separates the parietal lobe from the occipital lobe of the cerebrum.
Temporal lobe	Region of the cerebrum located under temporal bone; processes information associated with hearing and equilibrium.
Lateral sulcus	Deep groove that separates the frontal and parietal lobes from the temporal lobe of the cerebrum.
Insula	Region of the cerebrum deep within the lateral sulcus; processes information associated with hearing and equilibrium.
Transverse fissure	Deep fissure that separates the cerebrum from the cerebellum.
Corpus callosum	The major bridge of white fibers that connects the two hemispheres of the cerebrum.
Fornix	Bridge of white matter inferior to the corpus callosum; links regions of the limbic system ('emotional' brain) together.
Anterior commissure	Bridge of white fibers found near the anterior tip of the corpus callosum; connects the two hemispheres of the cerebrum.
Caudate nucleus	Basal nucleus; initiates voluntary movements and coordinates slow skeletal muscle contractions (e.g., posture and balance)
Putamen	Basal nucleus; initiates voluntary movements and coordinates slow skeletal muscle contractions (e.g., posture and balance)
Globus pallidus	Basal nucleus; initiates voluntary movements and coordinates slow skeletal muscle contractions (e.g., posture and balance)

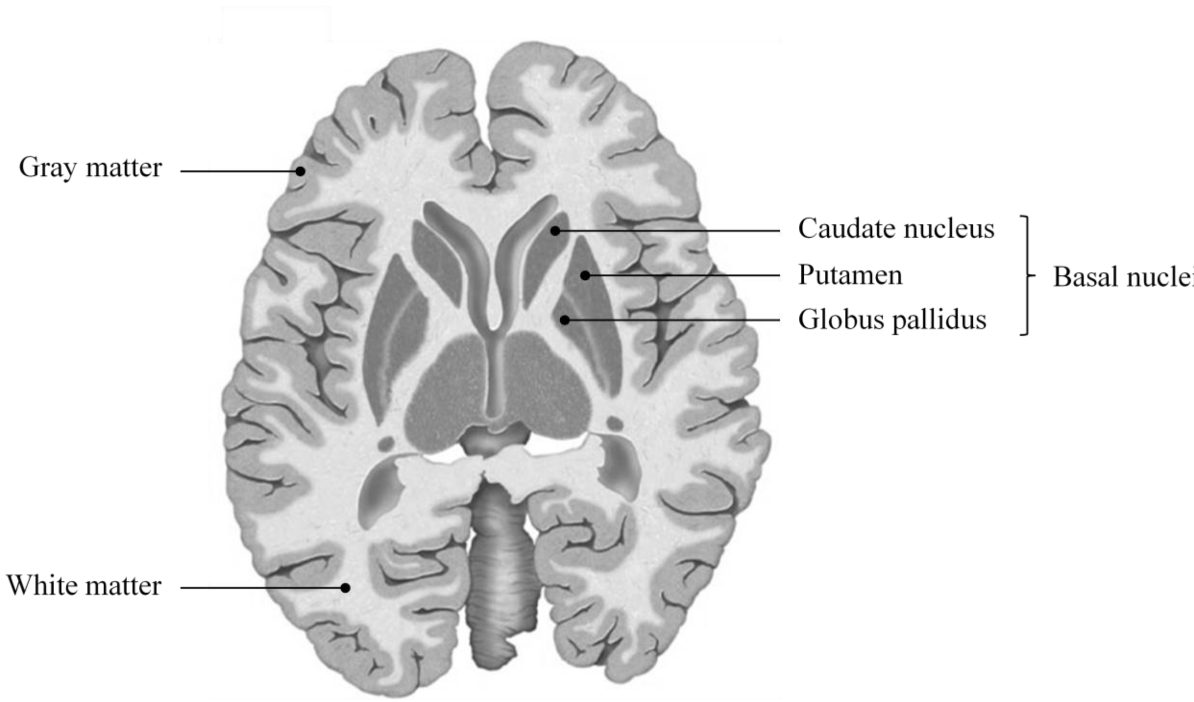


Figure 2: Transverse section of cerebrum showing major regions of cerebral hemispheres

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 12.9

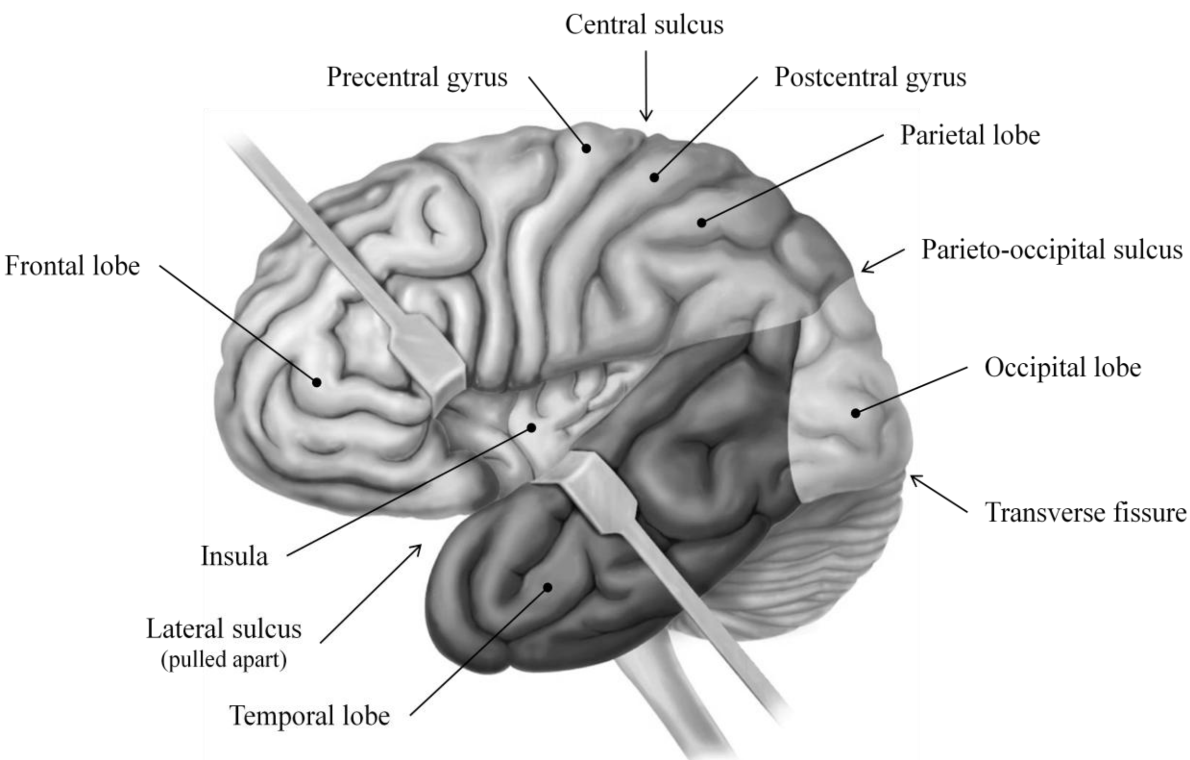


Figure 3: Lobes, sulci, and fissures of the cerebral hemispheres (longitudinal fissure not pictured)

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 12.4

Exercise 1:

Utilize the model of the human brain to locate the following structures / landmarks for the cerebrum:

- Longitudinal fissure
- Frontal lobe
- Parietal lobe
- Central sulcus
- Precentral gyrus
- Postcentral gyrus
- Occipital lobe
- Parieto-occipital sulcus
- Temporal lobe
- Lateral sulcus
- Transverse fissure
- Corpus callosum
- Fornix
- Anterior commissure

DIENCEPHALON:

Surrounded by the cerebral hemispheres, the diencephalon forms the central core of the brain. Consisting of largely of three paired structures, the thalamus, hypothalamus, and epithalamus, the diencephalon plays a vital role in integrating conscious and unconscious sensory information and motor commands.

Below are listed the major anatomical regions / landmarks of the diencephalon with their corresponding functions (Figure 4):

REGION / LANDMARK	FUNCTION
Thalamus	Composes 80% of diencephalon; major relay point and processing center for all sensory impulses (excluding olfaction).
Intermediate mass	A flattened gray band of tissue connecting the two halves of the thalamus.
Hypothalamus	Region inferior to thalamus; main regulatory center involved in visceral control of the body and maintenance of overall homeostasis.
Mammillary body	Pea-like structure posterior to hypothalamus; function as relay station in olfactory pathway.
Infundibulum	Neural stalk originating near mammillary bodies; connects pituitary gland to hypothalamus.
Pituitary gland	Glandular tissue handing under hypothalamus; important producer and releaser of endocrine hormones.
Pineal gland	Glandular tissue posterior to the thalamus; important producer and releaser of endocrine hormones.
Posterior commissure	Bridge of white fibers found inferior to the pineal gland; connects the two hemispheres of the cerebrum.

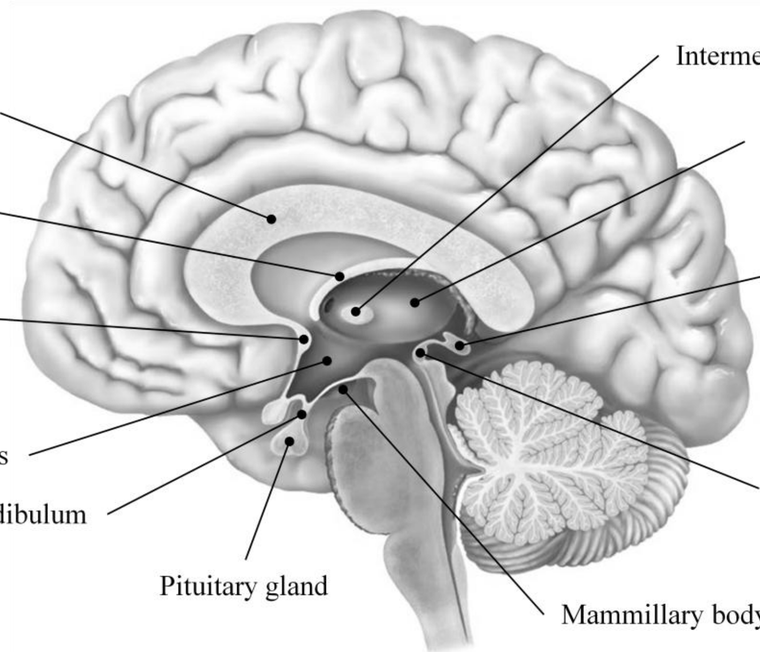


Figure 4: Mid-sagittal section of brain showing diencephalon (includes corpus callosum, fornix, and anterior commissure)

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 12.10

Exercise 2:

Utilize the model of the human brain to locate the following structures / landmarks for the diencephalon:

- Thalamus
- Intermediate mass
- Hypothalamus
- Mammillary body
- Infundibulum
- Pituitary gland
- Pineal gland
- Posterior commissure

BRAIN STEM:

The brain stem begins inferior to the thalamus and runs approximately 7 cm before merging into the spinal cord. The brain stem centers produce the rigidly programmed, automatic behaviors necessary for survival. Positioned between the cerebrum and the spinal cord, the brain stem also provides a pathway for fiber tracts running between higher and lower brain centers.

Below are listed the major anatomical regions / landmarks of the brain stem with their corresponding functions (Figure 7):

REGION / LANDMARK	**FUNCTION**
Midbrain	Region of brain stem between the diencephalon and pons; contains multiple fiber tracts running between higher and lower neural centers.
Cerebral peduncle	Bulge located on the ventral aspect of the midbrain; contains fiber tracts running between the cerebrum and spinal cord.

Superior colliculus	Part of midbrain (**corpora quadrigemina**); contains nerve reflex centers involved in coordinated eye movements, focusing, and papillary responses.
Inferior colliculus	Part of the midbrain (**corpora quadrigemina**); contains nerve reflex centers involved in auditory reflexes.
Pons	Region of brain stem between the midbrain and medulla oblongata; serves as the bridge (connection) between the two regions, and the cerebellum.
Medulla oblongata	The most inferior portion of the brain stem; contains the cardiac, vasomotor, and respiratory centers.
Pyramid	Longitudinal ridge flanking mid-line of the medulla oblongata; contains fiber tracts running between the cerebrum and spinal cord.
Olive	Located lateral to the pyramid of the medulla oblongata; regulates impulse propagation from the cerebrum and midbrain to the cerebellum.

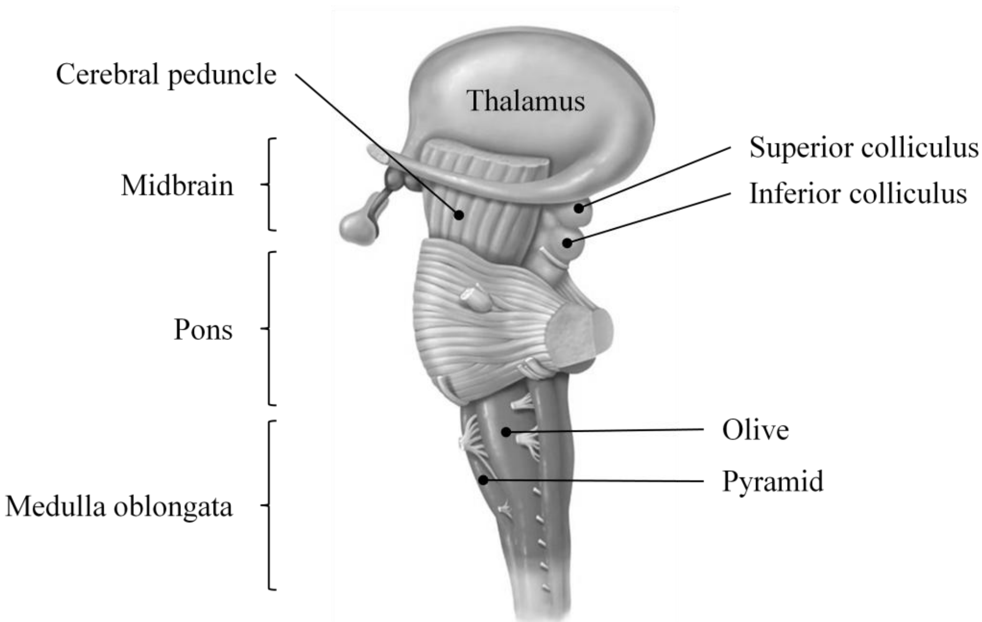


Figure 7: Lateral view of the brain stem

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 12.13

Exercise 3:

Utilize the model of the human brain to locate the following structures / landmarks for the brain stem:

- Midbrain
- Cerebral peduncles
- Superior colliculus
- Inferior colliculus
- Pons
- Medulla oblongata
- Pyramid
- Olive

CEREBELLUM:

Located on the lower dorsal aspect of the brain, the cerebellum accounts for ~ 11% of the total brain mass. Like the cerebrum, the cerebellum has two major hemispheres with an outer cortex made up of gray matter with an inner region of white matter. The cerebellum is located dorsal to the pons and medulla and it protrudes under the occipital lobes of the cerebral hemispheres, from which it is separated by the transverse fissure.

By processing inputs received from the cerebral motor cortex, various brain stem nuclei, and sensory receptors, the cerebellum provides the precise timing and appropriate patterns of skeletal muscle contraction for smooth, coordinated movements and agility needing for our daily lives (e.g., driving). Cerebellar activity occurs subconsciously, we have no awareness of it.

Below are listed the major anatomical regions / landmarks of the cerebellum with their corresponding functions (Figure 8):

REGION / LANDMARK	FUNCTION
Vermis	Mid-line ridge of tissue ('worm-like) that connects the two cerebellar hemispheres together.
Folia	Fine, transversely-oriented pleat-like gyri on the surface of the cerebellum; increase surface area.
Arbor vitae	Distinctive pattern of white matter deep within the cerebellum; resembles a branching tree
Cerebellar peduncles	Connection points between the cerebellum and brain stem; contains fiber tracts running between the cerebellum and midbrain, pons, and medulla.

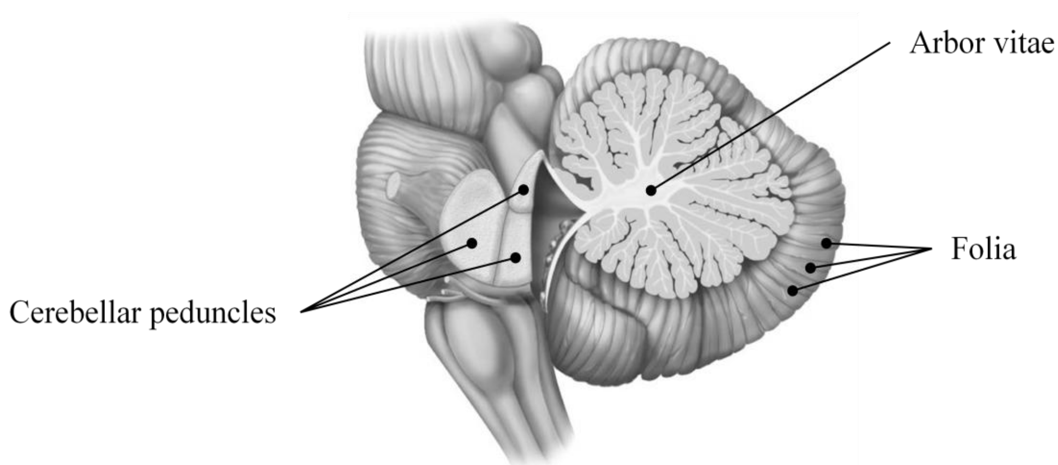


Figure 8: Mid-sagittal section of the cerebellum (vermis not pictured)
Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 12.15

Exercise 4:

Utilize the model of the human brain to locate the following structures / landmarks for the cerebellum:

- Vermis
- Folia
- Arbor vitae
- Cerebral peduncles

VENTRICLES

Situated within the brain are central hollow civilities called ventricles. These ventricles are continuous with one another and with the central canal of the spinal cord. The hollow ventricular chambers are filled with cerebrospinal fluid, a fluid that forms a liquid cushion for the brain. In addition, the cerebrospinal fluid helps nourish the brain and there is some evidence that hormones circulate in the brain via this pathway.

Below are listed the major ventricular chambers and associated openings / passageways found in the brain (Figure 7):

CHAMBER / STRUCTURE	FUNCTION
Lateral ventricles	C-shaped chambers buried deep within each cerebral hemisphere; house choroid plexi that produces cerebrospinal fluid.
Septum pellucidum	Thin vertical partition that separates lateral ventricles.
Third ventricle	Chamber surrounding the thalamus; houses a choroid plexus that produces cerebrospinal fluid.
Interventricular foramen	Small opening between each lateral ventricle and the third ventricle; drains cerebrospinal fluid.
Fourth ventricle	Chamber that occupies the space between the dorsum of the pons / medulla and the overlying cerebellum; houses cerebrospinal fluid.
Cerebral aqueduct	Narrow passageway between the third ventricle and the fourth ventricle; contains cerebrospinal fluid.
Central canal	Central opening that runs through the medulla oblongata and is continuous with the spinal cord; contains cerebrospinal fluid.

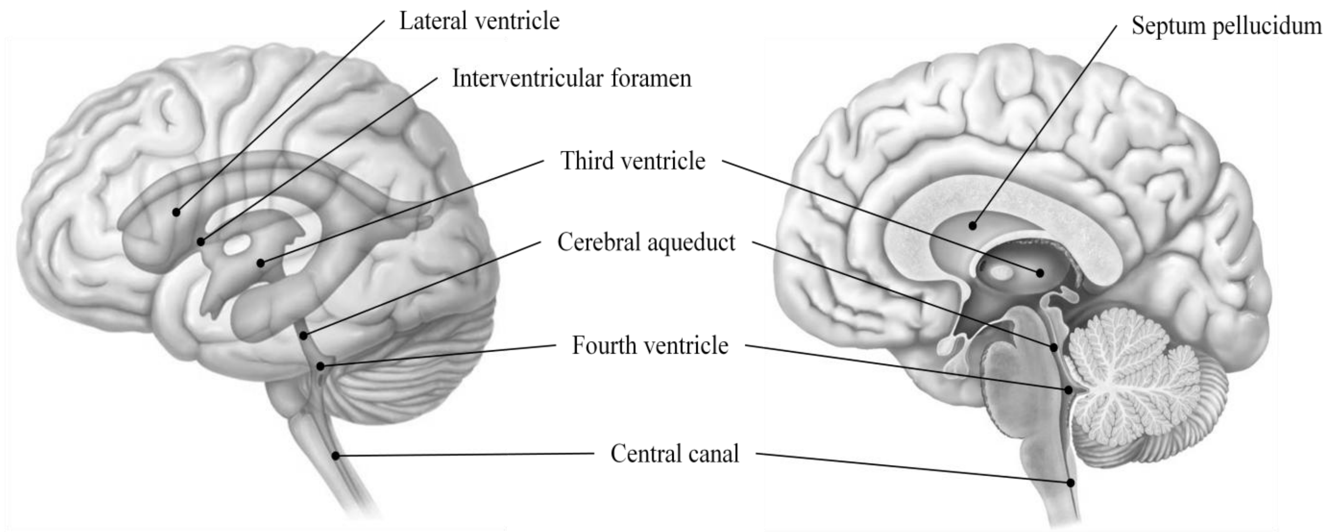


Figure 7: Lateral and mid-sagittal views of the brain showing the ventricular chambers
Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figures 12.3 & 12.10

Exercise 5:

Utilize the models of the ventricular system and the human brain to locate the following ventricular chambers / passageways:

- Lateral ventricle
- Septum pellucidum
- Third ventricle
- Intraventricular foramen
- Fourth ventricle
- Cerebral aqueduct
- Central canal

MENINGES

The meninges are three connective tissue membranes that lie just external to the brain. The function of theses layers are to: 1) cover and protect the brain, 2) protect blood vessels and enclose venous sinuses, 3) contain cerebral spinal fluid, and 4) form partitions within the skull.

Below are listed the major connective tissue layers forming the meninges and the general function of each (Figure 8):

TISSUE LAYER	FUNCTION
Dura mater	External leathery tissue layer ('tough mother'); protects brain, encloses venous sinuses, and forms partitions within the skull.
Arachnoid mater	Middle tissue layer forming loose brain covering ('spider mother'); houses cerebrospinal fluid.
Pia mater	Innermost delicate tissue layer ('gentle mother') adhered tightly to brain; contains many blood vessels.

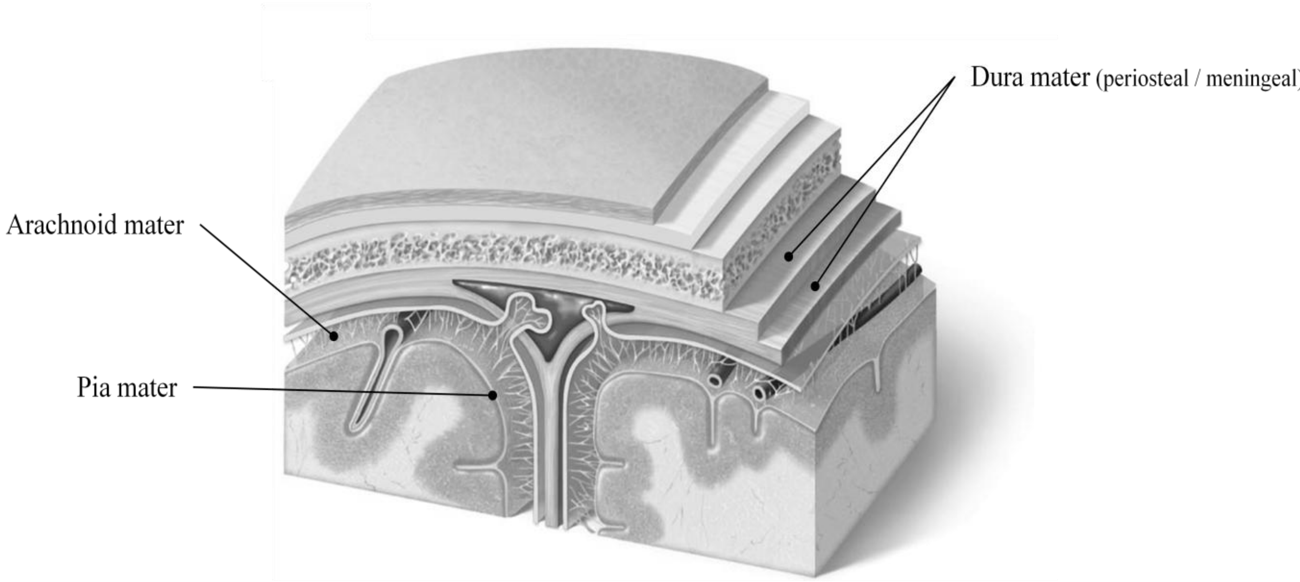
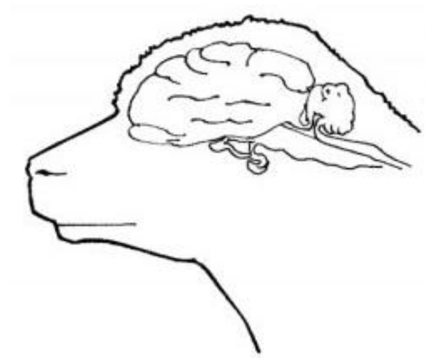


Figure 8: Section of brain and skull showing meningeal layers

Marieb & Hoehn (Human Anatomy and Physiology, 9th ed.) – Figure 12.22

SHEEP BRAIN DISSECTION:

Utilizing preserved sheep brains, we will continue our examination of the brain. In general, a sheep brain is easy to work with because of 1) its size, 2) its availability, and 3) its relevance in comparative dissection – there are many anatomical similarities between the sheep brain and the human brain. Of course, general differences do exist:



- The human brain is rounded, whereas the sheep's brain is elongated in shape
- The sheep's brain has a more developed olfactory bulb, giving them a sharper sense of smell
- The human brain has a larger frontal lobe than the sheep's brain ('seat of consciousness')

As we dissect the sheep brain, please be aware of the following:

- ➢ The sheep brains are stored in a substance that is toxic if ingested. You should wear gloves for this dissection and absolutely, positively have no food or drinks near the specimen.
- ➢ Because of the chemicals used to preserve the sheep brains, please do not place brain tissue in the garbage or down the sink. There is a plastic bag at the front of the room to place all unwanted neural tissue.
- ➢ Please be sure to scrub dissecting pans out completely and rinse tools after dissection is complete. Most of the brains will be saved after use, so be sure to handle them carefully and place them where instructed after their use.

Step 1: Set up dissection arena

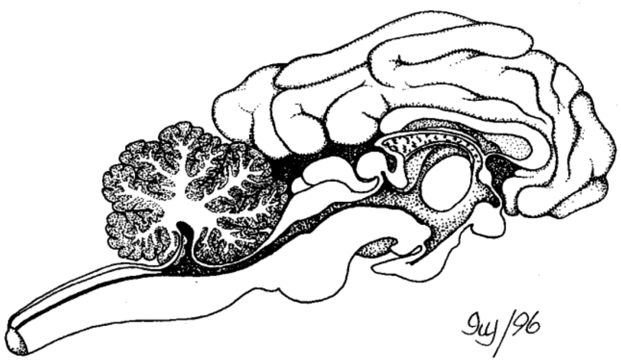
1) Before beginning inspection and dissection of the brain, you should have the following materials on hand:

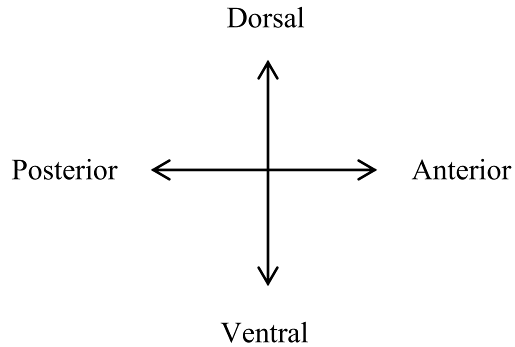
- dissection pan
- large knife
- scissors
- forceps
- metal probe
- gloves

2) After putting on your gloves take your dissection pan up to the front of the room and retrieve a brain from the container.

Step 2: External examination

1) Examine the sheep brain carefully and determine which side is dorsal and which side is ventral. In addition, determine which area is toward the anterior (rostral) and which toward the posterior (caudal).





2) To get your bearings, identify the **cerebral hemispheres**, **cerebellum**, and **brain stem**. Note that there may be some additional tissue on the underside of the brain that does not appear to be associated with the brain. This tissue was left on to protect the olfactory bulbs and the **pituitary gland**, all of which can be easily damaged or lost otherwise.

3) The brain you receive is still be encased in the **dura mater** – note how tough the dura mater is. The dura mater can be removed from the dorsal surface of the brain by carefully cutting down between the hemispheres and along the lateral edges of the cerebral hemispheres. At this point, do not remove the dura mater from the ventral region of the brain or the brain stem.

4) Once the dura mater is removed, examine the dorsal surface of the brain – notice how its surface is thrown into convolutions (raised ridges = **gyri**; grooves = **sulci**). Locate the **arachnoid mater**, which appears on the brain surface as a delicate "cottony" material spanning the sulci. In contrast, the innermost layer, the **pia mater**, closely follows the cerebral contours and is what is responsible for giving the 'shiny' look to the tissue.

5) Notice the deeper grooves that you observe on the brain. The **longitudinal fissure** separates the two cerebral hemispheres and the **transverse fissure** is what separates the cerebrum from the cerebellum. Utilizing your knowledge of the brain model, identify the **frontal**, **parietal**, **temporal**, and **occipital** lobes of the cerebrum.

6) Now move on to externally observe the cerebellum. Find the **cerebellar hemispheres** and note that they are separated by an additional cerebellar lobe, the **vermis**, rather than by a fissure as in the cerebrum. Note the **folia** forming the ridges on the surface of the cerebellum.

7) Using a blunt probe, return to the dorsal surface of the brain and gently pull apart the two cerebral hemispheres. When you look down into the longitudinal fissure, you will see light-colored tissue holding the hemispheres together (DO NOT pull the hemispheres completely apart at this time…). The tissue holding the hemispheres together is the **corpus callosum**.

8) Next, move to the transverse fissure and carefully spread the cerebellum back from the cerebrum. When you pull the cerebellum back, you should see the **corpora quadrigemina** region of the midbrain. Locate the **superior** and **inferior colliculi** that compose this region. While still spreading the cerebellum back from the cerebrum, gently part the cerebral hemispheres slightly to see the **pineal gland**.

Step 3: Ventral examination (Plate 1)

1) Turn the sheep brain so that you are now looking at the ventral surface. Very carefully, remove the remaining dura mater from the ventral area. Looking at the ventral side, you should be able to find structures of the diencephalon, including the **infundibulum** (if still present), **pituitary gland** (if still present), and **mammillary bodies**. In addition, examine the structures associated with the brainstem, including the **cerebral peduncles** of the **midbrain**, the **pons**, and the **pyramids** and **olives** of the **medulla oblongata**.

1. Olfactory bulb
2. Optic chiasma
3. Infundibulum (not visible)
4. Mammillary bodies
5. Cerebral peduncle
6. Pons
7. Pyramid
8. Olive

Step 4: Sagittal section examination (Plate 2)

1) You are now ready to make a sagittal section through the midline of the brain. For this cut, you will use the large knife – it is important to make a single cut through the whole brain (do not 'saw' back and forth through the tissue) and to cut directly down the longitudinal fissure, dividing the brain into two equal halves.

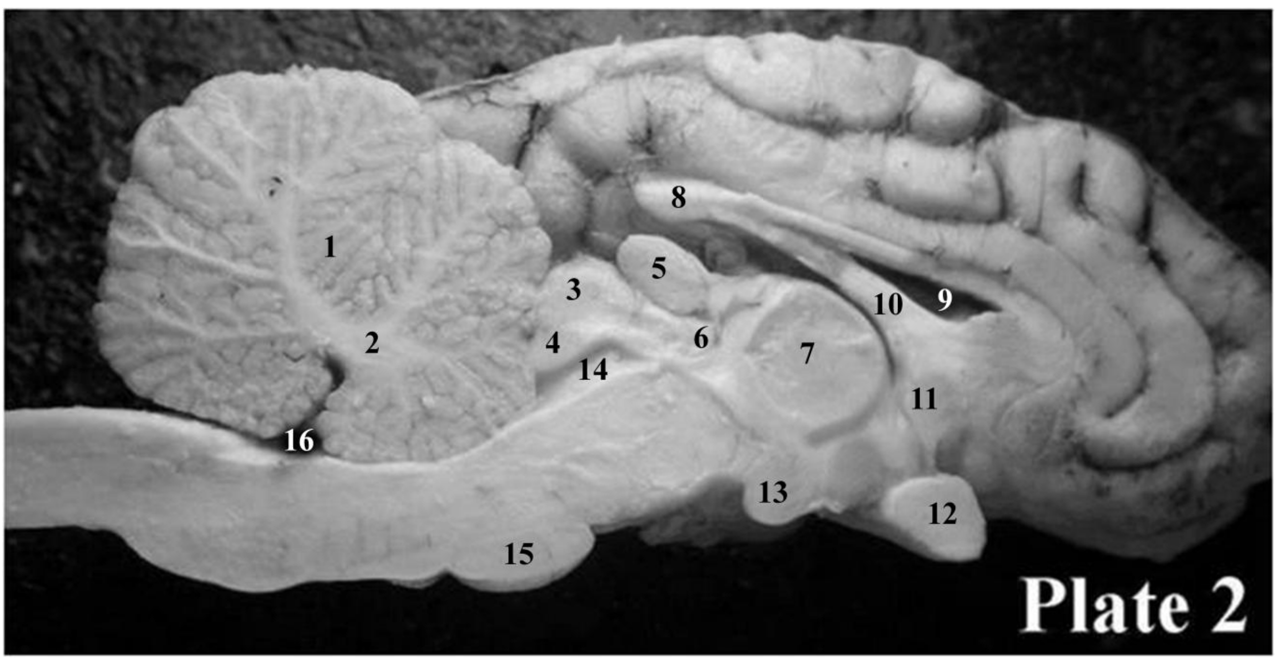
2) Turn your attention to the longitudinal section through the cerebellum. You now should be able to identify the **arbor vitae** ('tree of life'), the branching structure forming the cerebellum. The 'branches' of this tree are formed by cerebellar white matter, while the 'leaves' are formed by cerebellar gray matter.

3) The sagittal section also allows you to find the **intermediate mass** of the **thalamus**. This is the circular structure which has a slightly different texture than the areas surrounding it and represents the point at which the two halves of the thalamus join across the midline. The **hypothalamus** is located in the region below the thalamus, toward the optic chiasma (where the optic nerves cross). Just posterior to the thalamus it is possible to see the **pineal gland**.

4) The hypothalamus forms the walls of the **third ventricle**. The **lateral ventricles** are visible just ventral from the **corpus callosum** within each hemisphere of the cerebrum (you may have to remove the **septum pellucidum** to see into the lateral ventricles). The lateral ventricles are connected to the third ventricle by the **interventricular foramen** – carefully push the probe into the third ventricle, and you should be able to make the end of it come out into the lateral ventricle. The **cerebral aqueduct** connects the third ventricle and **fourth ventricle**. The fourth ventricle is then contiguous with the **central canal** of the spinal cord.

5) The sagittal section gives a good opportunity to see the bridges of white matter connecting the two hemipheres of the brain. As noted above, dorsal to the septum pellucidum is the corpus callosum. The **fornix** lies ventral to the septum pellucidum. The **anterior commissure** lies anterior to the thalamus / hypothalamus whereas the **posterior commissure** is posterior to the thalamus and ventral to the pineal gland.

6) In addition to the new structures presented in the sagittal view, be sure to take a look at the structures presented earlier in the dorsal and ventral views to see how they may appear in the sagittal view (e.g., mammillary bodies, pons).



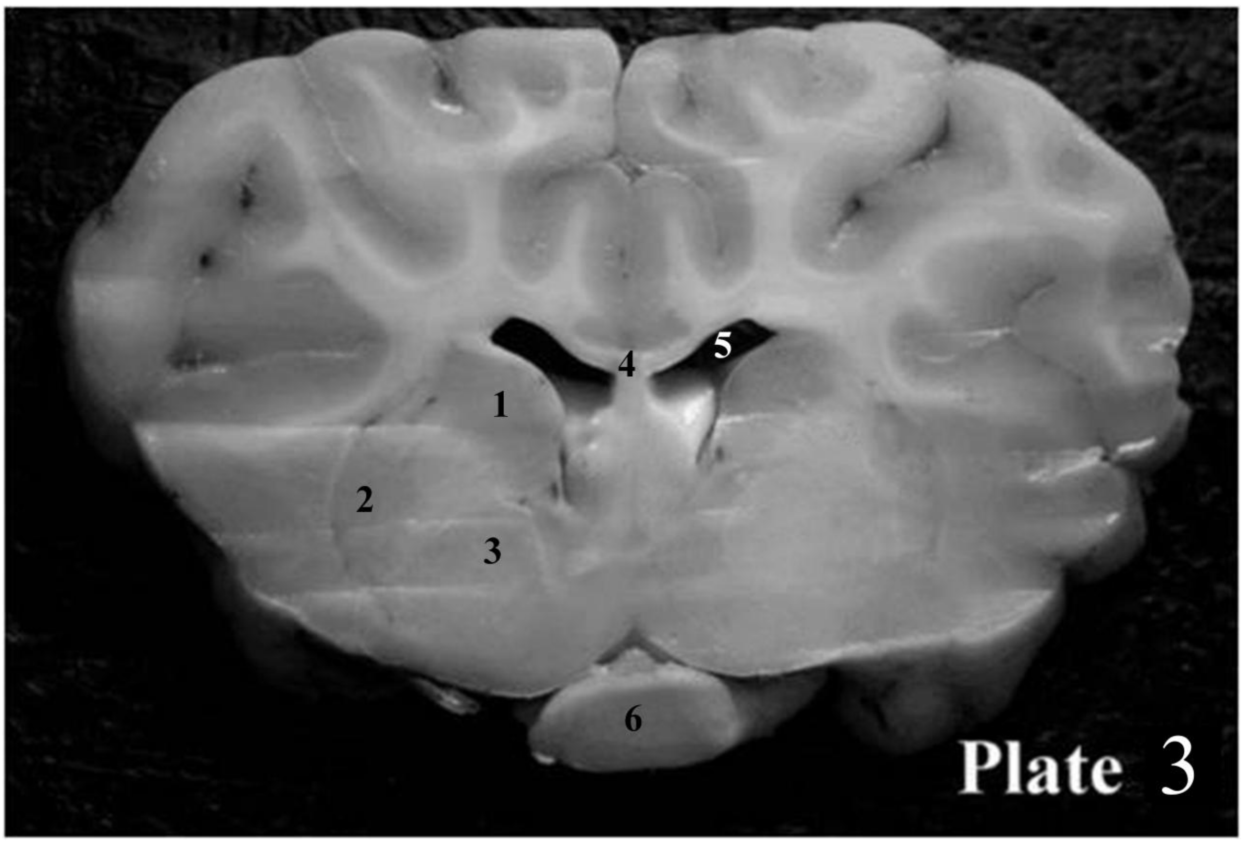
1. Cerebellum
2. Arbor vitae
3. Superior colliculus
4. Inferior colliculus
5. Pineal gland
6. Posterior commissure
7. Thalamus (intermediate mass)
8. Corpus callosum
9. Lateral ventricle
10. Fornix
11. Anterior commissure
12. Optic chiasma
13. Mammillary bodies
14. Cerebral aqueduct
15. Pons
16. Fourth ventricle

Step 5: Coronal section examination (Plate 3)

1) It is now time to make a coronal section through the brain. For this cut, you are going to want to use the long knife again. Put the two halves of the brain together and make a transverse cut through the brain at the level of the optic chiasma.

2) Turn your attention to the posterior sections of the brain. You now should be able to get a clear look at the relationship of gray matter to white matter in the brain. The superficial gray matter represents the **cerebral cortex**; see how the convolutions of the brain allow for an increase in surface area and thus an increase in cortical grey matter.

3) You can also see the three major basal ganglia in this section, the **caudate nucleus**, the **putamen**, and the **globus pallidus**, tucked deep down within the white matter. The caudate nucleus lies next to the lateral ventricle on each side whereas the putamen and globus pallidus are tucked deeper with the putamen lateral to the globus pallidus.



1. Caudate nucleus
2. Putamen
3. Globus pallidus
4. Corpus callosum
5. Lateral ventricle
6. Optic chiasma

CHECKLIST:

CEREBRUM:

- Frontal lobe*
- Parietal lobe*
- Temporal lobe*
- Occipital lobe*
- Longitudinal fissure*
- Transverse fissure*
- Precentral gyrus
- Postcentral gyrus
- Central sulcus
- Lateral sulcus
- Parieto-occipital sulcus
- Corpus callosum*
- Fornix*
- Anterior commissure*

DIENCEPHALON:

- Thalamus*
  - Intermediate mass*
- Hypothalamus*
- Mammillary bodies*
- Pituitary gland*
- Infundibulum*
- Pineal gland*
- Posterior commissure*

BRAIN STEM:

Midbrain*

- Cerebral peduncles*
- Superior colliculi* } Corpora quadrigemina*
- Inferior colliculi* } Corpora quadrigemina*

Pons*

Medulla oblongata*

- Olives*
- Pyramids*

CEREBELLUM:

- Vermis*
- Folia*
- Arbor vitae*
- Cerebellar peduncles

BASAL NUCLEI:

- Caudate nucleus*
- Putamen*
- Globus pallidus*

VENTRICLES:

Lateral ventricles*

- Septum pellucidum*
- Interventricular foramen

Third ventricle*

- Cerebral aqueduct*

Fourth ventricle*

Central canal*

MENINGES:

- Dura mater*
- Arachnoid mater*
- Pia mater*

* Want to be familiar with location on sheep brain