

Medical Neuroscience | Tutorial Notes

Internal Capsule and Deep Gray Matter

MAP TO NEUROSCIENCE CORE CONCEPTS¹

NCC1. The brain is the body's most complex organ.

NCC3. Genetically determined circuits are the foundation of the nervous system.

LEARNING OBJECTIVES

After study of the assigned learning materials, the student will:

1. Identify major white matter and gray matter structures that are apparent in sectional views of the forebrain, including the structures listed in the chart and figures in this tutorial.
2. Describe and sketch the relations of the deep gray matter structures to the internal capsule in coronal and axial sections of the forebrain.
3. Describe the distribution of the ventricular spaces in the forebrain and brainstem.

NARRATIVE

by Leonard E. WHITE and Nell B. CANT
Duke Institute for Brain Sciences
Department of Neurobiology
Duke University School of Medicine

Overview

Now that you have acquired a framework for understanding the regional anatomy of the human brain, as viewed from the surface, and some understanding of the blood supply to both superficial and deep brain structures, you are ready to explore the internal organization of the brain. This tutorial will focus on the sectional anatomy of the forebrain (recall that the forebrain includes the derivatives of the embryonic prosencephalon). As you will discover, much of our framework for exploring the sectional anatomy of the forebrain is provided by the **internal capsule** and the deep gray matter, including the **basal ganglia** and the **thalamus**. But before beginning to study this internal anatomy, it will be helpful to familiarize yourself with some common conventions that are used to describe the deep structures of the central nervous system.

Some terminology and general principles

The next few pages contain definitions and illustrations of some commonly used neuroanatomical

¹ Visit [BrainFacts.org](https://www.brainfacts.org) for Neuroscience Core Concepts (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

terminology. They may be useful for reference as you study the material in this and the related neuroanatomical tutorials.

The simplest classification of central nervous tissue is **white matter** and **gray matter** (Figure 1). The gray matter (so-named because it looks grayish in fresh specimens) is made up of neuronal cell bodies, their dendrites, and the terminal arborizations of both local axons and those from distant sources. The dendrites and the axons that form synapses with them are sometimes referred to as “neuropil.” The white matter is made up of the axons that connect separated areas of gray matter. The myelin that ensheathes many of these axons gives the white matter its glistening white appearance. Note that an individual neuron can contribute to both gray and white matter. Axons projecting from one part of the brain to another usually group together in bundles. Likewise, neurons that serve similar functions often form clusters.

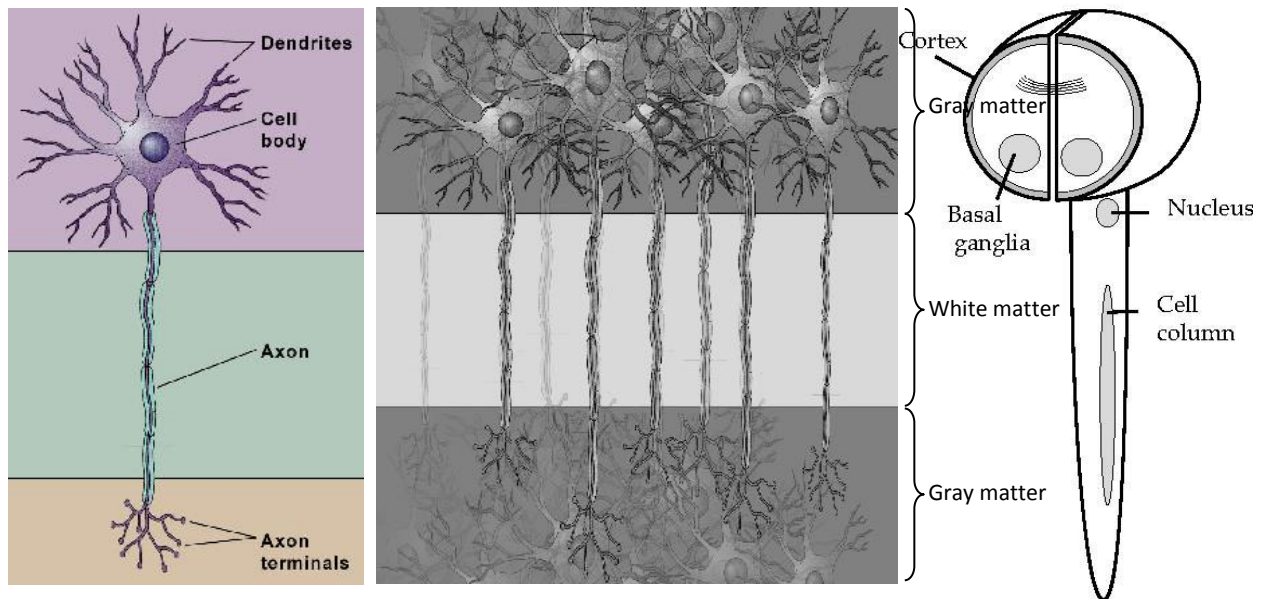


Figure 1. Gray and white matter in the central nervous system. *Left*, Drawings depicting the composition of both types of neural tissue (Illustration courtesy of Pyramis Studios, Durham NC). *Right*, Drawing of the organization of gray and white matter in the brain and spinal cord; cortex, basal ganglia, nucleus and cell column are all examples of gray matter in the central nervous system. (Illustration by N.B. Cant)

Common terms used to refer to white matter bundles and gray matter clusters:

Terms used to refer to gray matter

- Column
- Cortex (plural: cortices; L., bark)
- Ganglion (plural: ganglia; Gr., swelling)
- Layer
- Nucleus (plural: nuclei)

Terms used to refer to white matter

These five terms are used to refer to bundles of axons:

- Column
- Fasciculus (L., fascia, band or bundle)
- Funiculus (L., funis, cord)
- Lemniscus (L. from Gr., lemniskos, fillet)
- Tract

These terms also refer to bundles of axons, but they are usually used to refer to bundles that can be seen from the surface of the brain:

- Brachium (L., arm)
- Peduncle (L., pes, foot, stalk)

These terms refer to the crossing of axons from one side of the CNS to the other. A **commissure** contains axons crossing from one location to its counterpart on the other side. A **decussation** contains axons that travel to a contralateral location different from their origin.

- Commissure (L., joining together)
- Decussation (L., decussare, to cross in the form of an “X”)

Many nuclei and tracts in the central nervous system are much longer than they are wide, calling to mind a column. (Note that the word ‘column’ is used to refer to both white matter and gray matter.) Although the terms that refer to white matter structures are not used interchangeably, they all refer to essentially the same constituent—axons (often in a compact bundle) connecting one area of gray matter to another.

You will also encounter the following terms used to refer to general regions of the central nervous system:

tectum (L., roof)—used to refer to brainstem structures located dorsal to the ventricular system. In mammals, this term has become synonymous with the dorsal midbrain.

tegmentum—this term refers to structures that form the core of the brainstem ([Figure 2](#)). It can be thought of (very loosely) as the part of the brainstem that is most like the spinal cord in the sense that the cell groups in the tegmentum have functions similar to those of cell groups in the spinal cord. For the most part, the structures that lie outside the tegmentum have no counterparts in the spinal cord.

base—the ventral aspect of the brain. The term ‘basal’ is synonymous with ‘ventral.’

floor, wall—usually used with respect to structures that bound the ventricles (e.g., the floor of the fourth ventricle corresponds to the part of the pons and medulla that forms the ventral boundary of the ventricle).

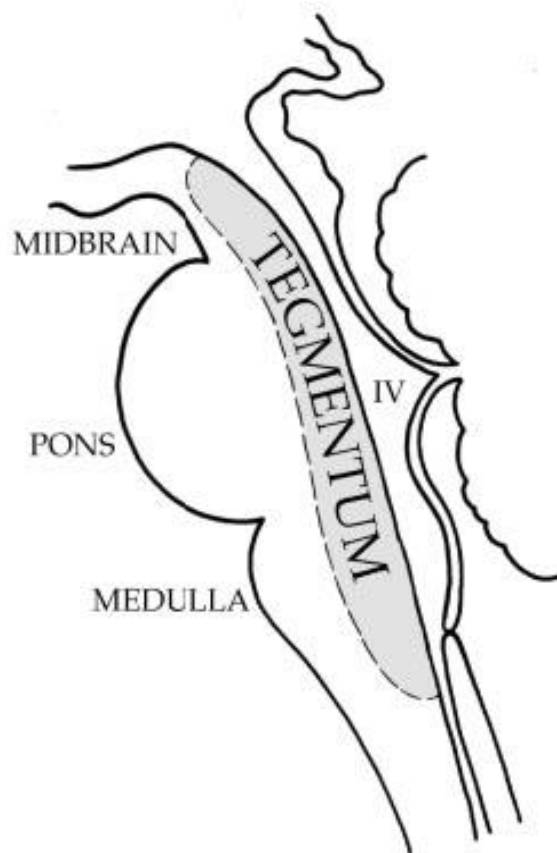


Figure 2. Structures in the core of the brainstem make up the tegmentum. It includes the cranial nerve nuclei, most long tracts, and loosely arranged groups of neurons known collectively as the reticular formation. (Illustration by N.B. Cant)

The large number of terms used to refer to similar structures may seem annoying, but it is not unlike the case in non-medical English usage. Consider, for example, the many terms that refer to roadways (street, avenue, boulevard, interstate, path, road, highway, etc.).

Internal anatomy of the forebrain

For the rest of this tutorial, we will discuss the appearance of sections through the forebrain, so that you can learn to identify the structures that are not visible on a surface view. The anatomy of the forebrain as seen in sections is relatively simple; however the geometry of some of these deep structures can be a challenge to appreciate. For an example, if you have *Neuroscience 5th Ed.*, note the locations of the **hippocampal formation** and the **lateral ventricle** in the illustration of a partially dissected hemisphere in [Figure A13²](#). You will soon learn why these structures appear where they do. In brief, the hippocampus and other deep forebrain structures follow the course of the lateral ventricle into the temporal lobe. The hippocampus (one component of the hippocampal formation) lies in the ‘floor’ of the lateral ventricle in the temporal lobe. The fornix is a bundle of axons that arises mainly in the hippocampus and essentially travels to the diencephalon along this same path (i.e., following the course of the lateral ventricle).

As you work through the remainder of this tutorial—and hopefully, as you explore the brain on your own in a digital brain atlas such as [Sylvius4 Online](#), be sure to recognize and locate the following structures on sections cut in any of the three standard anatomical planes:

	Gray Matter	White Matter	Ventricle
Telencephalon (cerebral hemispheres)	Cortical/corticoid structures: cerebral cortex; hippocampus; amygdala Basal ganglia (deep structures): caudate nucleus, putamen, nucleus accumbens, globus pallidus	Corpus callosum Anterior commissure Fornix Internal capsule	Lateral ventricle
Diencephalon	Thalamus Hypothalamus	Fornix	Third ventricle

Let’s approach our study of internal forebrain anatomy with the **cerebral cortex**. The cerebral cortex is a thin layer of gray matter that covers the entire surface of the hemispheres. Most of the cortex that is visible from the surface in humans is known as **neocortex**, cortex which is made up of six layers of neurons. Phylogenetically older cortex, which has fewer cell layers, is found on the inferior surface of the temporal lobe, separated from neocortex by the rhinal fissure ([Figure 3](#)). The cortex with the fewest layers (three) is known as the **hippocampus** (paleocortex of the parahippocampal gyrus). The hippocampus is the medial edge of temporal cortex that becomes double-folded into the medial aspect of the temporal lobe; it is visible only in dissected brains or in sections. It is worth remembering that the entire cerebral cortex is derived from the walls of the largest and most anterior swelling of the embryonic brain, the prosencephalon. Thus, despite its deep sulci and fissures and phylogenetic divisions, the entire cerebral cortex in one hemisphere is a continuous sheet of neural tissue.

² Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [\[click here\]](#)

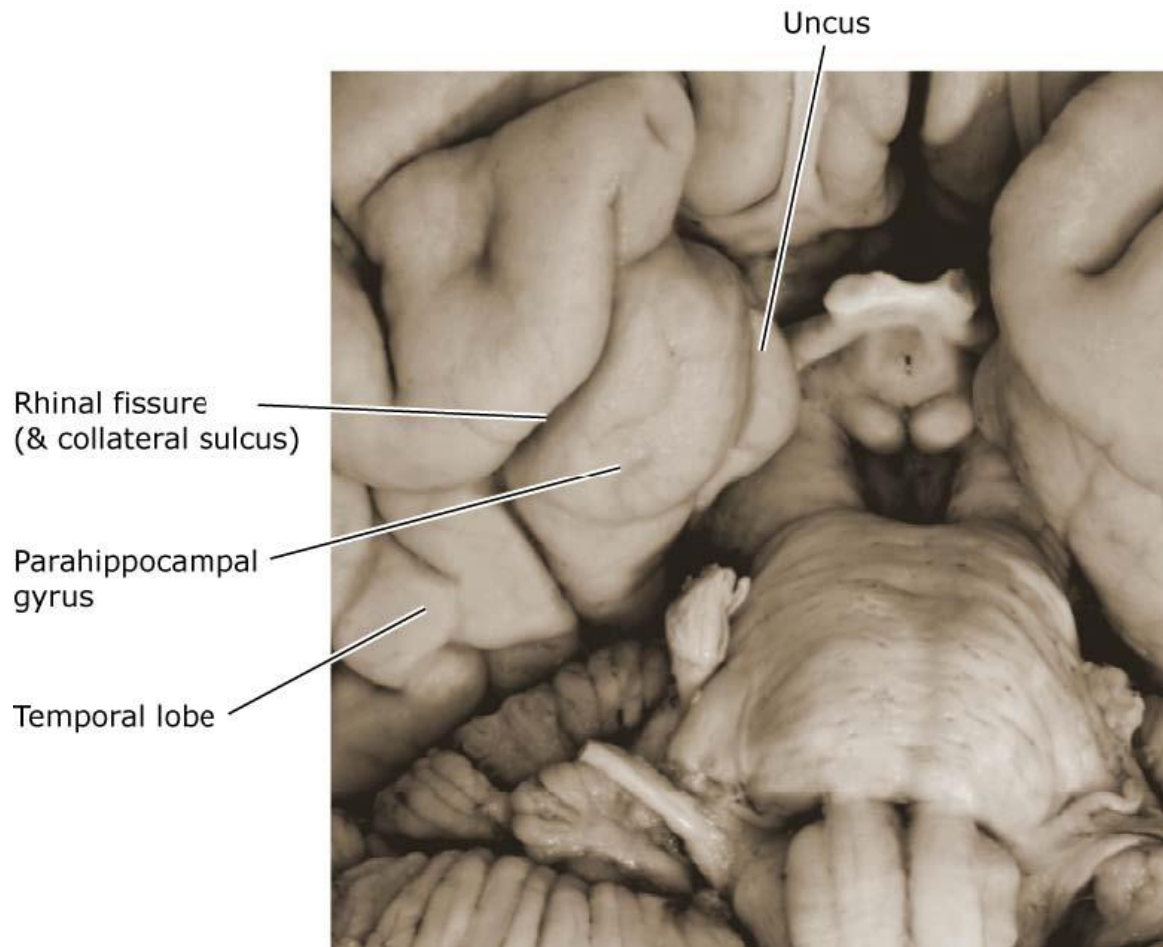


Figure 3. Close-up view of the ventral-medial surface of the temporal lobe to show the parahippocampal gyrus and related sulci. The rhinal fissure separates the lateral neocortex from the medial paleocortex. The medial protuberance in the parahippocampal gyrus is called the uncus, which is cortical division of the posterior amygdala.

The cortex is made up of neuronal cell bodies, their dendrites, and the terminal arborizations of axons coming from the thalamus and other sources, mainly from other neurons in the cerebral cortex. Indeed, many neurons in the cortex send axons that travel some considerable distance in the central nervous system to make synaptic connections with other neurons. Axons that enter and leave the cortex form the white matter that makes up a large part of the hemispheres. We often speak of axons as though they were moving, using words such as ‘entering,’ ‘leaving,’ ‘descending,’ ‘traveling,’ ‘projecting,’ etc. Of course, their place is fixed in the adult, and what we are actually referring to are the directions in which action potentials normally propagate along the axons.

Buried deep within the hemispheres are the **basal ganglia** (Figure 4), which are large gray matter structures concerned with modulating thalamic interactions with the frontal lobe. (The term ‘ganglion’ is *not* usually used for clusters of neurons inside the central nervous system; this is an exception.) The basal ganglia lie partly rostral and partly lateral to the diencephalon (refer to the chart on page 1 for their embryonic relations). They can be divided into four main structures: the **caudate**, the **putamen**, the **nucleus accumbens**, and the **globus pallidus**.

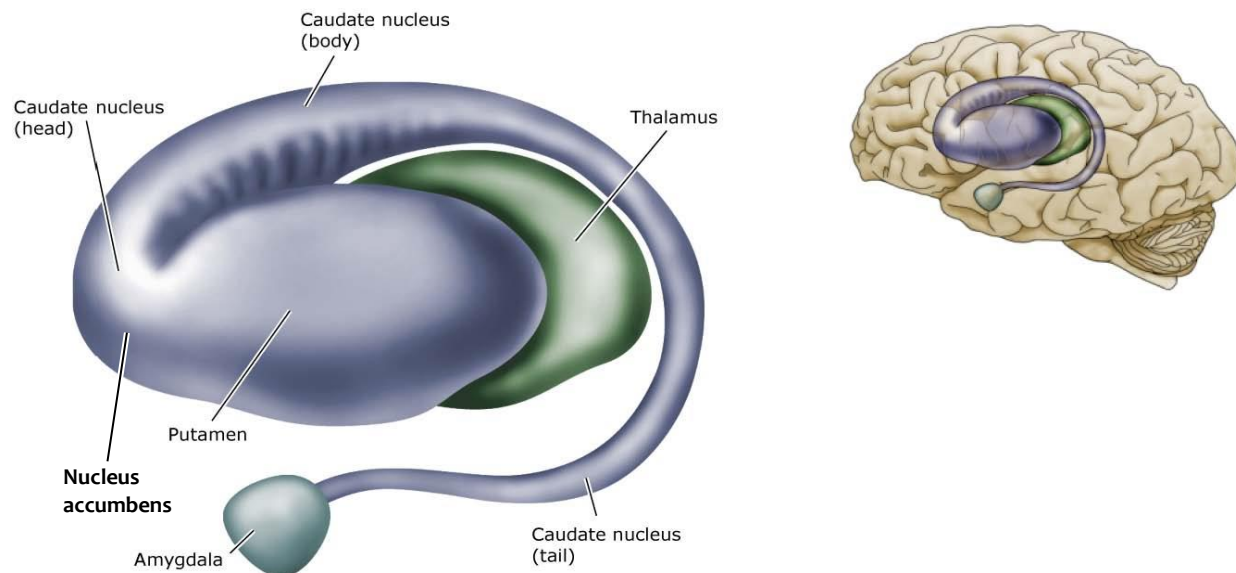


Figure 4. The basal ganglia and thalamus drawn with all of the cortex and white matter of the hemispheres stripped away; viewed from the side (refer to the inset for orientation). The head of the caudate is in the frontal lobe; its body lies just dorsal to the thalamus, and its tail descends into the temporal lobe. The amygdala is an additional structure deep in the anterior temporal lobe that is situated near the anterior tip of the caudate’s tail (but it really is not part of the caudate as this illustration might imply). The nucleus accumbens is located at the anterior, inferior junction of the caudate nucleus and putamen. The globus pallidus is hidden from view by the putamen, which is lateral to it. The groove between the putamen and the caudate—and between the putamen (and globus pallidus) and the thalamus—is occupied by a massive fan-like array of white matter, called the internal capsule (omitted from this depiction to illustrate the body of the caudate nucleus and the thalamus). (illustration courtesy of Pyramis Studios, Durham NC)

Structurally and functionally, the caudate, putamen and nucleus accumbens are similar, and they are often referred to collectively as the **striatum**, because of the stripes or “striations” of gray matter that run through a prominent bundle of white matter (the internal capsule) that otherwise separates the caudate from the putamen. (The caudate and putamen are also called the “neostriatum” to emphasize their evolutionary and functional relation to neural circuits in the neocortex.) Ventral to the caudate and putamen are additional divisions of the striatum, which are important for understanding motivated behavior and addiction. The most prominent of these structures in this so-called ventral striatum is the **nucleus accumbens**.

These three divisions of the striatum receive inputs from different portions of the telencephalon that define the functional roles of each striatal division. In general terms, the striatum (and the circuits through the basal ganglia that begin here) regulates *movement*, with the three divisions of the striatum governing different domains of movement. Thus, it should be instructive to remember that:

- the **putamen** is concerned with the regulation of *bodily movement*;
- the **caudate nucleus** (especially its large anterior ‘head’) regulates *movement of the mind* and eyes (which often indicate what we are thinking about); and
- the **nucleus accumbens** is concerned with *movement of emotion* or *motivated behavior*.

Obviously, we are speaking of the concept of movement in loose terms. Nevertheless, it is important to recognize that each striatal division (and the distinct circuits through the basal ganglia that derive from each) share common structural and functional motifs that help explain their contribution to the modulation of behavior. Each circuit is involved in the *initiation* or *suppression* of some program for behavior. To accomplish these functions, each division of the striatum projects to some division of the **pallidum**; the **globus pallidus** is the largest division of the pallidum and it receives input mainly from the putamen. The pallidum in turn regulates thalamo-cortical interactions. A full consideration of basal ganglia circuitry is beyond the scope of this tutorial; but these important circuits will be considered elsewhere in the course when we explore in some depth the functions of the basal ganglia.

Now let’s turn our attention from gray matter to white matter. There are three bundles of axons in the hemisphere that have already been identified on mid-sagittal views: the corpus callosum, anterior commissure and fornix (see the tutorial, *Medial Surface of the Brain*). One additional system of axonal fibers should now be appreciated. Many of the axons entering or leaving the cortex do not assemble into compact bundles, except in the vicinity of the thalamus and the basal ganglia, where they form a structure known as the **internal capsule**. The internal capsule lies just lateral to the diencephalon, and as mentioned briefly above, a portion of it separates the caudate from the putamen. Many of the axons in the internal capsule terminate or arise in the thalamus. Other systems of axons descending from the cortex, course through the internal capsule, and continue past the diencephalon to enter the **cerebral peduncles** of the midbrain. Between the cortex and the internal capsule, the axons of the white matter are not so tightly packed; they are sometimes called the ‘corona radiata’, a reference to the way they appear to radiate out from the compact internal capsule to reach multiple areas of cortex. (Individual groups of axons may also be indicated in this way. For example, you will hear reference to the visual radiations or the auditory radiations, axons that travel from the thalamus to the visual and auditory cortices, respectively.) We will return to the internal capsule in relation to the important deep gray matter structures as we consider cross-sectional views through the forebrain.

There are several other bundles of axons that run through the white matter of the forebrain longitudinally in each cerebral hemisphere, connecting different cortical areas (associational white matter); but you need not be concerned with identifying them now.

That is almost it for structures in the cerebral hemispheres!

There are two other gray matter structures you should know. One is a group of complex nuclei, known as the **basal forebrain nuclei**, which have become associated with the signs and symptoms of diseases such as Alzheimer's disease (see [Figure 8](#)). Like the basal ganglia, the basal forebrain nuclei are made up of clusters of cells (rather than layers); but unlike the basal ganglia, these clusters are much smaller and typically much less compact. They are located ventral to the anterior commissure and below the basal ganglia, between the ventral striatum and the hypothalamus.

The other structure you should know is the **amygdala**, which is a large mass of gray matter buried in the anterior-medial part of the temporal lobe, anterior to the lateral ventricle and the hippocampus (see [Figure 9](#)). The amygdala is an important component of ventral-medial forebrain circuitry and it is involved in the experience and expression of emotion. It was once classified as part of the basal ganglia; however, it is structurally and functionally heterogeneous, with systems of neurons and intrinsic connections that are comparable to those in striatum and the cerebral cortex. We will discuss the amygdala and its connections within the limbic forebrain in some depth in later tutorials (see *The Amygdala and Hippocampus and Neurobiology of Emotion*).

There is one slight complication that you will encounter as you begin to identify the structures of the forebrain in sections. Sometimes you see the same structures twice in the same section in the same hemisphere. To understand why this is so, refer to [Figures 5 & 6](#).

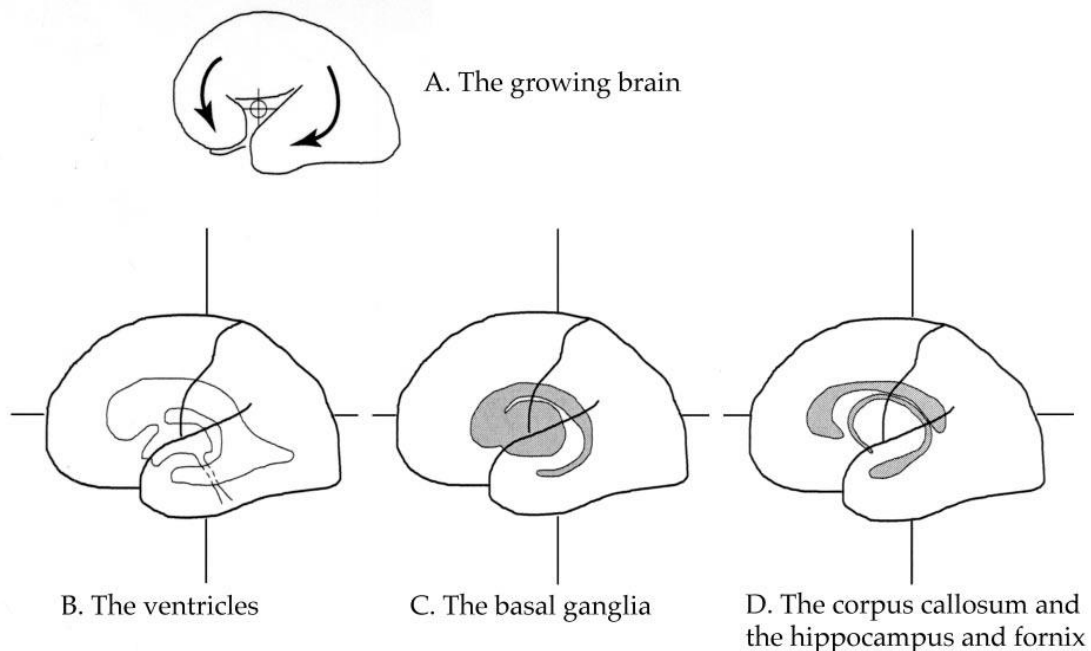
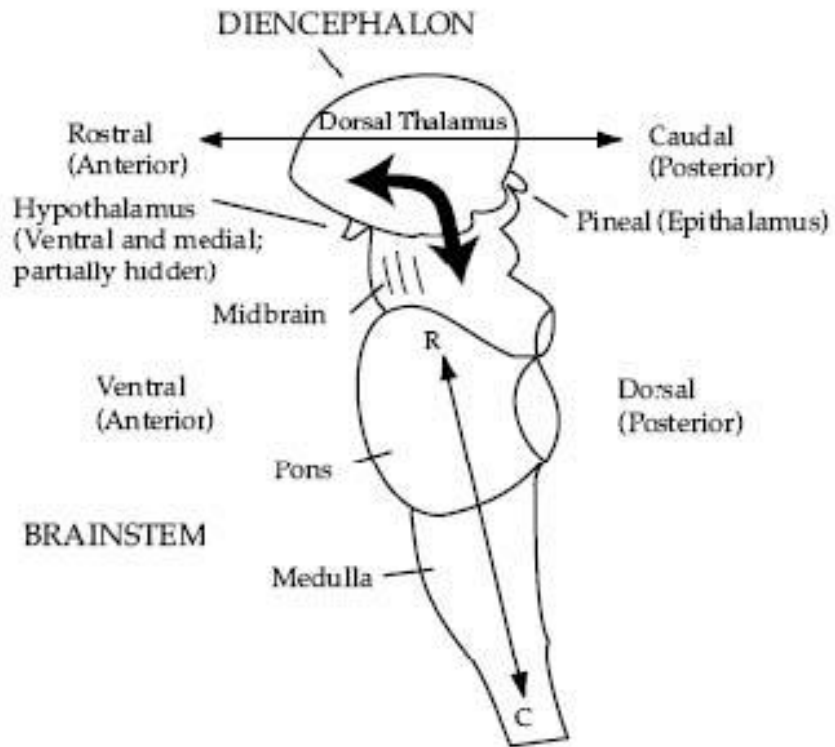


Figure 5. A. During development, the human cerebral hemispheres grow markedly in the posterior and ventral directions, forming the temporal lobe. As the temporal lobe grows, the hemisphere appears to rotate forward, beginning to form a shape something like a horseshoe. Deeper structures in the hemispheres follow this pattern of growth so that in the adult brain they also form an arch or horseshoe shape. B. The lateral ventricle curves into the temporal lobe. (The part in the temporal lobe is referred to as the inferior or temporal horn.) C. The caudate nucleus of the basal ganglia has a 'tail' which curves into the temporal lobe (cf. Figure 4). D. The corpus callosum curves slightly but does not continue into the temporal lobe. The hippocampus is located in the temporal lobe and gives rise to the fornix which arches over the diencephalon to enter it at its anterior end. The lines in B-D indicate planes of section (coronal and horizontal) that cut twice through the structures shown. (Illustration from N.B. Cant)

The diencephalon comes to lie medial to the hemispheres. The **thalamus** is the largest subdivision of the diencephalon (see **Figure 6**). It is egg-shaped and is made up of many subdivisions, some of which we shall identify later. The hypothalamus lies ventral to the thalamus. Anterior to the hypothalamus is the optic chiasm. (Clinically, the close physical proximity of the chiasm to the pituitary gland is very important, since a combination of visual and endocrine problems is a strong indication of a pituitary tumor.) The mammillary bodies are a part of the hypothalamus lying in its caudal part just at its junction with the midbrain.

Figure 6. Brainstem and thalamus drawn with the cerebral hemispheres and cerebellum removed. This figure highlights the sharp bend in the long axis of the central nervous system that occurs at the junction of the midbrain and diencephalon. This causes the dorsal diencephalon to lie almost at a right angle to the dorsal midbrain. (The epithalamus, represented here by the pineal gland, is the most dorsal part of the diencephalon, but when the brain is viewed from the side as here, it appears to lie deep, since the lateral parts of the dorsal thalamus expand greatly in size. (Illustration from N.B. Cant)



Internal capsule and deep gray matter

One of the most difficult challenges in human brain anatomy is gaining an appreciation for the **3D** arrangement of deep gray and white matter within the forebrain. But be encouraged! There is a principled means of simplifying this challenge. You must first understand the positional relations among the major components of the *basal ganglia* (caudate nucleus, putamen, nucleus accumbens, globus pallidus), *thalamus*, and the *internal capsule*. Then, you should recognize how the lateral ventricle fits in. Once you do so, you can interpret any section through the forebrain in any plane of section, be it a standard anatomical plane or an oblique plane.

Here's the key to framing your **3D** understanding: the deep gray matter structures identified above are always found on one side of the internal capsule or the other. Specifically ...

the caudate nucleus and the thalamus are medial to the internal capsule; and the putamen and globus pallidus are lateral to the internal capsule.

These relations reflect the course of the outgrowing axons that formed the internal capsule in fetal

development as they navigated through the anlage of deep gray matter in the embryonic brain. As you carefully inspect sections through the forebrain (in the next few pages and in [Sylvius4 Online](#)), note the appearance of the internal capsule and the deep gray matter. There are several additional details to observe and learn:

- (1) the **caudate nucleus**, **putamen** and **nucleus accumbens** become continuous around the rostral margin of the internal capsule;
- (2) the **globus pallidus** is a relatively small structure located near the middle of the basal ganglia;
- (3) the **globus pallidus** is located between the **internal capsule** and the **putamen**;
- (4) the **thalamus** occupies a more posterior volume of brain-space than the bulk of the basal ganglia;
- (5) the **caudate nucleus** has a long “tail” that follows the course of the lateral ventricle into the temporal lobe (see again [Figures 4 & 5](#)).
- (6) the anterior limb of internal capsule separates the head of the caudate from putamen and globus pallidus, and the posterior limb of internal capsule mainly separates thalamus from globus pallidus

So now that you are primed to interpret the internal anatomy of the forebrain, carefully inspect the images of coronal sections on the following pages (and in the video tutorial) and **identify each of the structures and relations numbered (1) to (6) above**.

Coronal sections through the brain

The five coronal sections through the brain shown, beginning on the next page ([Figures 7–11](#)), were taken from [Sylvius4 Online](#) and should resemble the brains that were shown in the tutorial. Remember, areas with little or no myelin appear dark and are considered gray matter, and areas containing myelinated axons appear light and are called white matter.

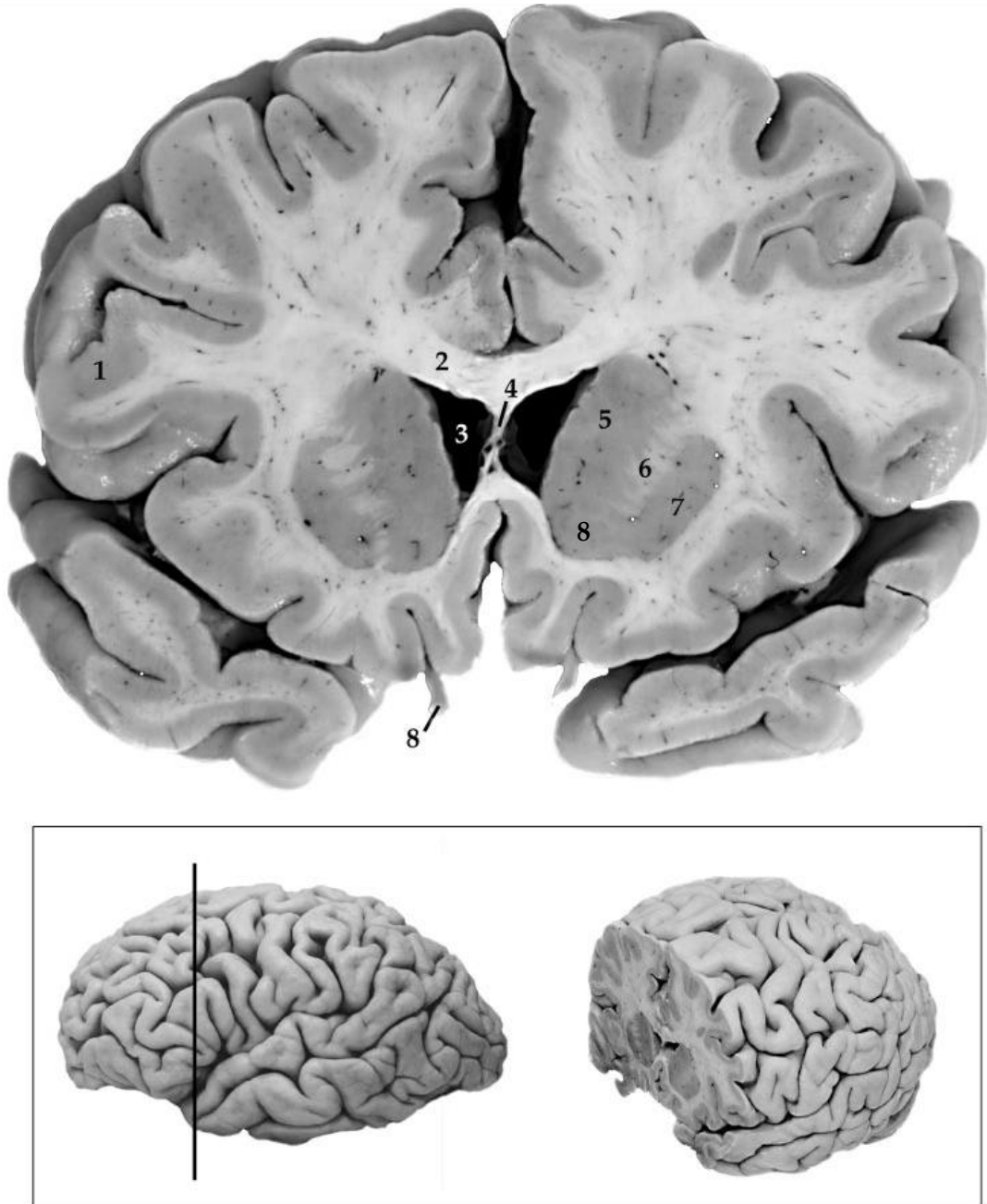


Figure 7. This first section is anterior to the region where the anterior commissure crosses the midline so only the hemispheres are present, and the diencephalon is not seen. The basal ganglia, which form part of the hemispheres, are very large here in the frontal lobes. Key: 1. Cerebral cortex of the frontal lobe; 2. Corpus callosum; 3. Lateral ventricle; 4. Septum pellucidum (which separates the two lateral ventricles); 5. Caudate nucleus (which bulges into the lateral ventricle); 6. Anterior limb of internal capsule (which separates the caudate and putamen from one another; recall that the ‘stripes’ of gray matter stretching across the internal capsule between these two nuclei are the inspiration for the term ‘striatum’); 7. Putamen; 8. Nucleus accumbens. (Image is “Coronal 3” from [Sylvius4 Online](#))

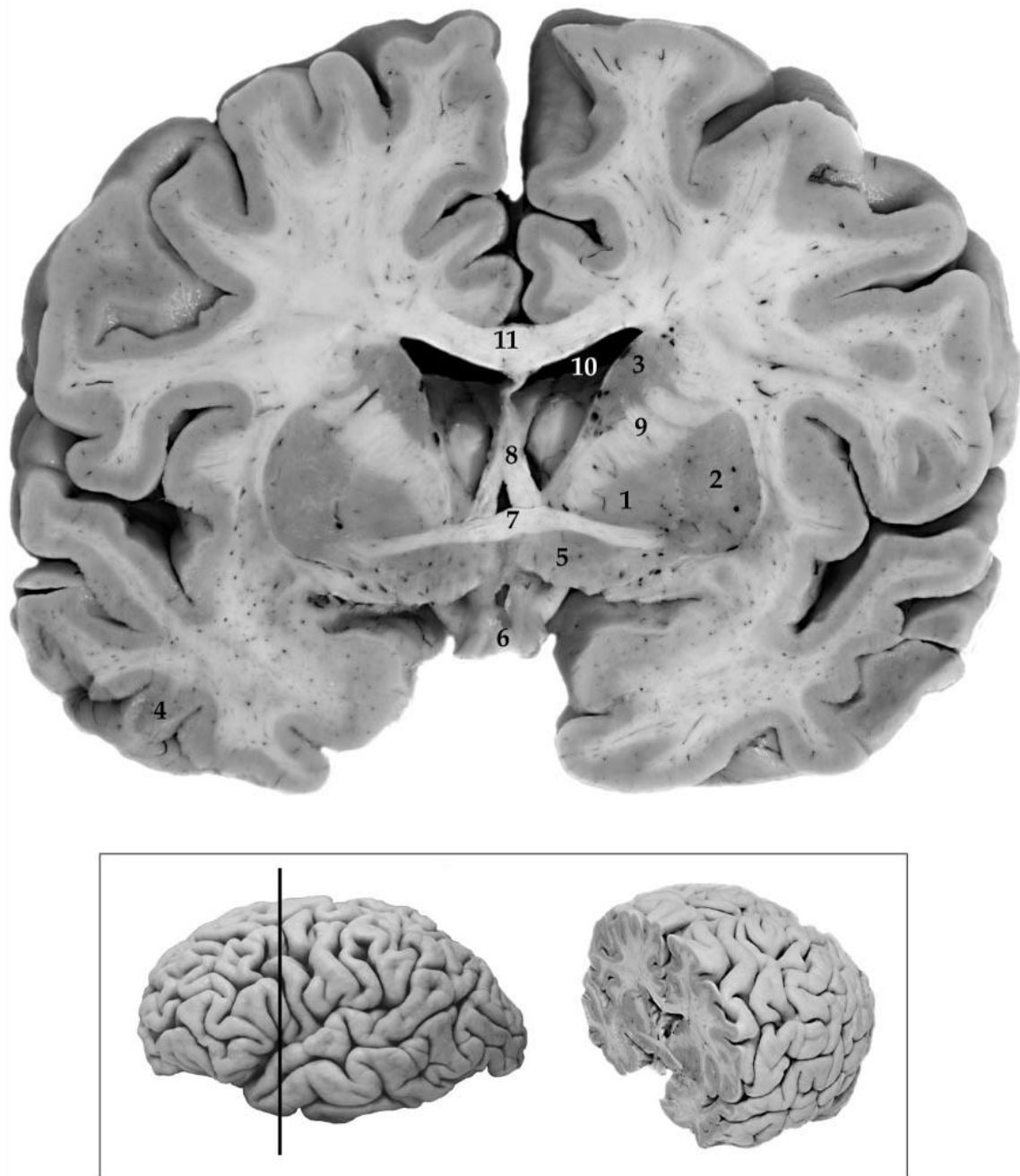


Figure 8. The second section in the series is at the level where the anterior commissure crosses the midline. Locate the caudate and putamen and the globus pallidus. Also find the internal capsule, the lateral ventricles, the corpus callosum, and the fornix. (You see the fornix only once on each side in this section. Why?) You can also see the optic chiasm. Nuclei of the basal forebrain are located in the inferior frontal lobe (below the anterior commissure). Key: 1. Globus pallidus; 2. Putamen; 3. Caudate; 4. Cortex of temporal lobe; 5. region of basal forebrain nuclei; 6. Optic chiasm; 7. Anterior commissure; 8. Fornix; 9. Internal capsule; 10. Lateral ventricle; 11. Corpus callosum. (Image is “Coronal 4” from [Sylvius4 Online](#))

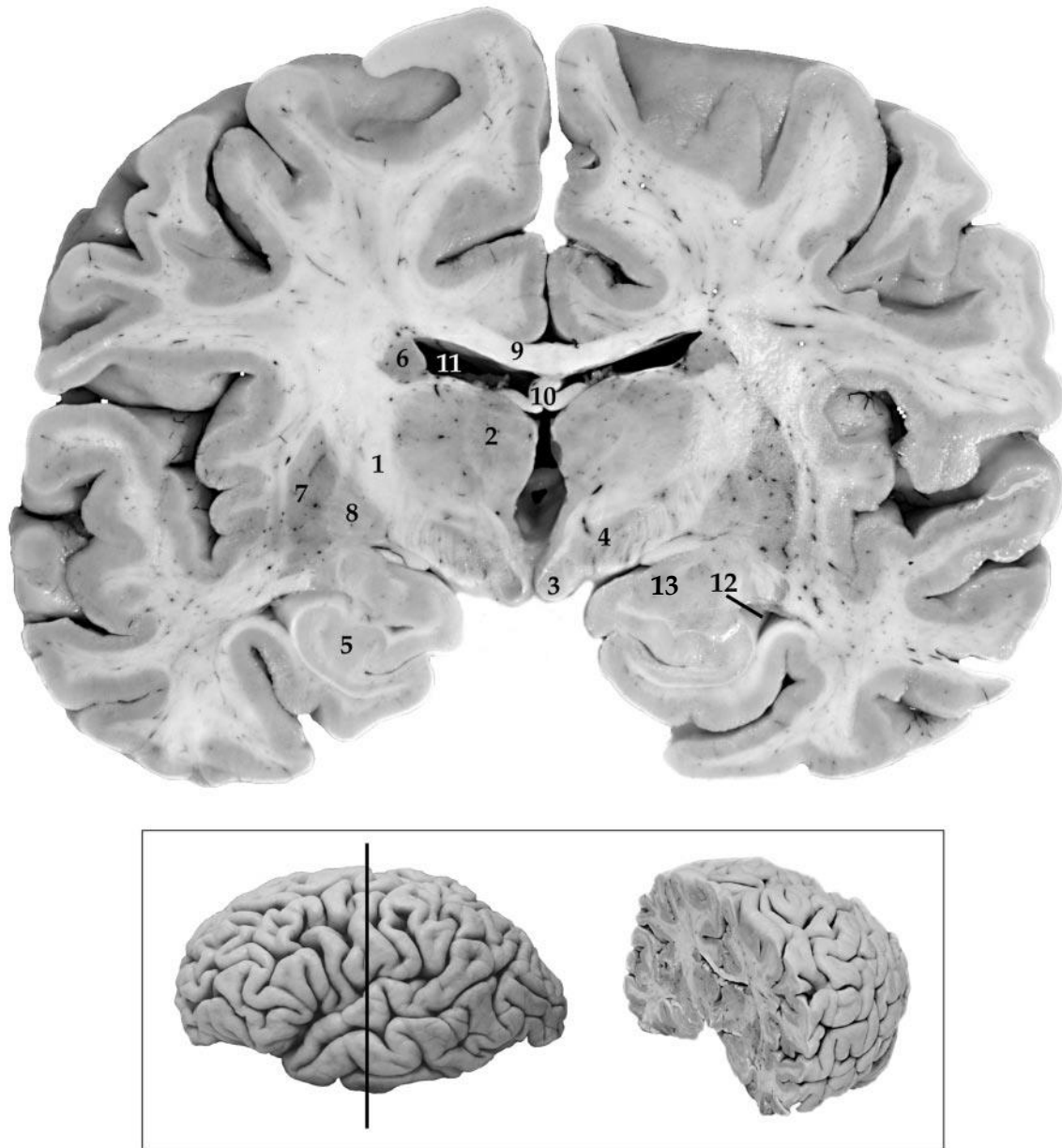


Figure 9. The third section in the series lies about halfway through the brain. Since this section lies posterior to the anterior commissure, the diencephalon appears next to the midline. The thalamus is separated from the putamen and globus pallidus by the internal capsule. The hypothalamus lies ventral to the thalamus. Lateral to the hypothalamus is the area known as the subthalamus. The cortex in the medial aspect of the temporal lobe is known as the hippocampus, which is emerging just inferior to the posterior portion of the amygdala. Key: 1. Internal capsule; 2. Thalamus; 3. Hypothalamus (mammillary body); 4. Subthalamus; 5. Hippocampus; 6. Caudate; 7. Putamen; 8. Globus pallidus; 9. Corpus callosum; 10. Fornix; 11. Lateral ventricle; 12. Lateral ventricle; 13 (posterior) amygdala. (Image is “Coronal 5” from [Sylvius4 Online](#))

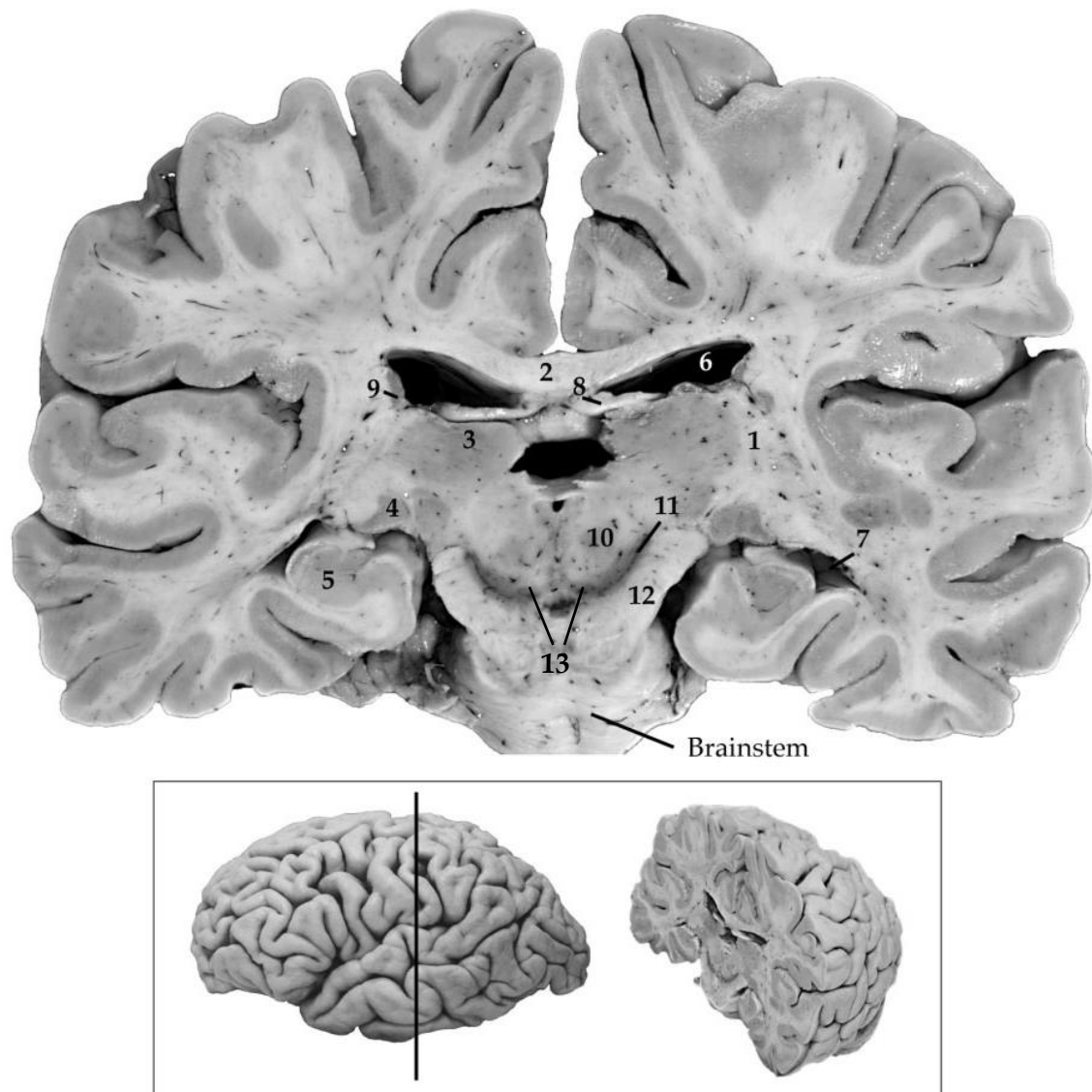


Figure 10. In this section, you can see the transition from the diencephalon to the midbrain of the brainstem. (Some of the structures of the midbrain are labeled in the figure.) In the forebrain, some of the same structures that were seen in more anterior sections can still be identified, although the basal ganglia have almost disappeared. Only a small portion of the caudate nucleus can still be seen. One important part of the thalamus, the lateral geniculate nucleus, is seen. Key: 1. Internal capsule; 2. Corpus callosum; 3. Thalamus; 4. Lateral geniculate nucleus (part of the thalamus); 5. Hippocampus; 6 & 7. Lateral ventricle; 8. Fornix; 9. Caudate; 10. Midbrain; 11. Substantia nigra (pars compacta); 12. Cerebral peduncle; 13. Ventral tegmental area. (Image is “Coronal 5” from [Sylvius4 Online](#))

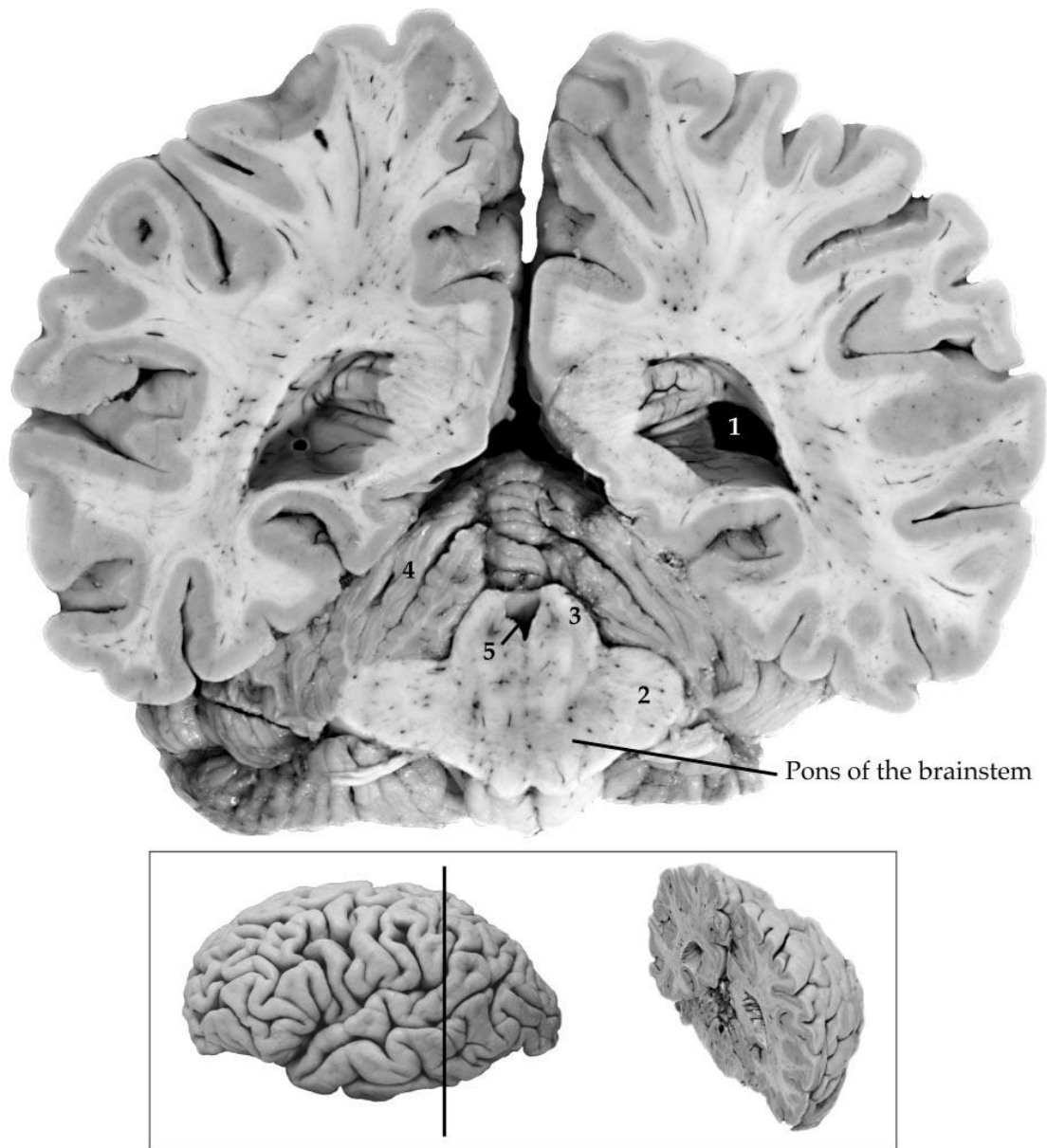


Figure 11. The most posterior section in the series is cut through the parietal lobes. Since the cut is posterior to the corpus callosum, the two hemispheres are not connected to each other. In the forebrain, only the gray and white matter and the posterior horn of the lateral ventricle are seen; none of the deep gray matter structures are present. The section also passes through the brainstem. This part of the brainstem is known as the pons; it lies ventral to the cerebellum. Key: 1. Lateral ventricle (posterior or occipital horn); 2. Middle cerebellar peduncle; 3. Superior cerebellar peduncle; 4. Cerebellum (cerebellar cortex); 5. Fourth ventricle (most rostral recess continuous with the cerebral aqueduct). (Image is “Coronal 5” from [Sylvius4 Online](#))

Optional exercise—modeling deep gray matter

Now that you have some experience with the sectional anatomy of the forebrain and a growing appreciation for the relations of deep gray matter structures in brain-space, you are ready to get your hands dirty. No sequence of neuroanatomical study is complete until learners are challenged to build or model their own brain. Obtain a set of colored modeling clay or make your own (several simple recipes are available on the [www](#)); five colors would be best, with one being white. Your goal will be to construct a simple, but accurate model of the spatial relations in the brain that you discovered in working through this tutorial. In particular, **construct a clay (dough) model of the major components of the basal ganglia, thalamus and internal capsule**, as described on pp. 10-11, with special attention to the six numbered points of detail.

How to start? Begin by constructing the internal capsule: flatten out a white (for white matter, of course) lump of clay into an elongated fan shape. In the brain, the wide end of the fan (called the corona radiata) penetrates into the subcortical white matter and the narrow end penetrates the diencephalon and brainstem, where it forms the cerebral peduncle and, eventually, the medullary pyramid; the basal ganglia and thalamus reside near the middle of the fan. Next, add a colored lump of clay for the globus pallidus (but on what side of the internal capsule, lateral or medial?). Then, encompass your 'faux' globus pallidus with the putamen and fashion at least the rostral and dorsal portions of the caudate nucleus. When ready to be more ambitious, try creating a more complete caudate nucleus that includes its temporal tail. Finally, add an egg-shaped lump for the thalamus (remember its position relative to the internal capsule?). How does it look ... anything like [Figure 4](#)? Don't worry if your first attempt(s) are less than edifying. What is most important about this exercise is the visualization of spatial relations that comes from wrestling with both substance (modeling clay) and abstraction (imagined brain-space).

One additional tip for this modeling exercise: [Sylvius4 Online](#) contains illustrations and an interactive virtual model of a standard brainstem model that is often used in neuroanatomical laboratories (including ours). This model includes the diencephalon, basal ganglion and internal capsule; refer to this model and interact with the "Atlas extras" feature (available via the folder in the navigation window in the upper left) for additional views of the relation among these structures.

Now that you have in front of you a clay model of the deep gray matter of the human brain, **try actually sectioning your model in one of the three standard neuroanatomical planes** (the coronal plane is a good starting plane for deconstruction). This should be easily done with a standard kitchen knife or a thin wire. Assuming the clay (dough) is of the proper consistency and has survived sectioning, do you recognize the spatial relations among your modeled gray matter structures that you discovered in the human brain? Try comparing different planes of section through your model with sectional views of the digital brain in [Sylvius4 Online](#). You might even try re-attaching your sections with a little gentle kneading and then re-sectioning in an orthogonal plane (try axial next).

With some persistence and patience, working through this exercise will foster a more cogent understanding of [3D](#) relations within the deepest substratum of the human forebrain. **You might even want to snap a photograph of your model and post it to the Discussion Forum!**

STUDY QUESTIONS

Q1. Which pair of structures is located on the **medial** side of the internal capsule?

- A. caudate nucleus & thalamus
- B. nucleus accumbens & putamen
- C. putamen & globus pallidus
- D. amygdala & hippocampus
- E. putamen & insula

Q2. Which pair of structures is located on the **lateral** side of the internal capsule?

- A. globus pallidus & caudate nucleus
- B. pineal gland & mammillary body
- C. third ventricle & body of lateral ventricle
- D. caudate nucleus & thalamus
- E. putamen & globus pallidus