Human Structure & Function | 2019

A Laboratory Guide for Learning Functional Human Neuroanatomy

Internal Anatomy of the Forebrain

LABORATORY PROTOCOL
1. **Examine slabs through the human forebrain** • Learning objective: ***localize the principal features of the forebrain that are visible with the unaided eye, including major gray matter and white matter structures in the cerebral hemispheres (as listed in the Table on page 2).*** • Specimens: whole brain slabs cut in the coronal, axial/horizontal or parasagittal plane • Activities: ▪ Beginning with a set of forebrain slabs cut in the coronal plane, identify in the tissue all gray and white matter structures that are identified in **Figures 4.7-4.11**. ▪ Pay particular attention to **Challenge 4.1** with a goal of identifying the internal capsule and the deep gray matter structures that surround it. ▪ Repeat **Challenge 4.1** using forebrain slabs cut in the axial/horizontal and/or parasagittal plane, referring to the Sectional Anatomy Photographic Atlas or MR Atlas in ***Sylvius4 Online***. ▪ Work through **Challenge 4.2** by focusing on the medial temporal lobe. Consider the relative location of the amygdala and the hippocampus in relation to the temporal horn of the lateral ventricle.

Overview

In this final laboratory session, we return to the forebrain (recall that the forebrain includes the derivatives of the embryonic prosencephalon). Now that you have acquired a framework for understanding the regional anatomy of the human brain and some understanding of the blood supply to both superficial and deep brain structures, you are ready to explore the internal organization of the forebrain. This lab will focus on the internal anatomy of the forebrain as seen in slabs cut through one of the standard anatomical planes (coronal, axial or horizontal, and sagittal).

Internal anatomy of the forebrain

For the rest of this chapter, we will discuss the appearance of slabs or 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 example, simply note the appearance of the **hippocampal formation** and the **lateral ventricle** in the view of a partially dissected hemisphere in **Figure 4.1**. You will soon learn why these structures appear where they do.

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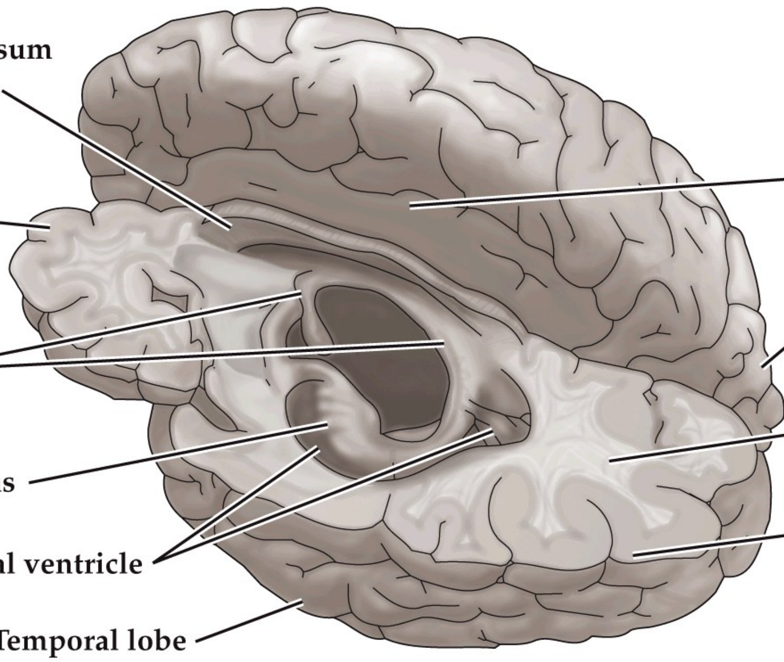

Figure 4.1. Illustration of a brain partially dissected to show the location of the hippocampus and other structures that follow the course of the lateral ventricle into the temporal lobe. The hippocampus (one component of the hippocampal formation) lies in the 'floor' of the lateral ventricle. The fornix is a bidirectional bundle of axons that arises in part from the hippocampus and travels to the diencephalon. Notice the white tract (unlabeled structure) coursing across the midline just anterior to the most anterior part of the fornix—this is the anterior commissure. (Figure A15 from *Neuroscience*, 6th *Ed.*, Oxford University Press)

As you work through the remainder of this Lab, 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 forebrain** **Basal ganglia (deep structures):** **caudate nucleus, putamen, nucleus accumbens, globus pallidus**	**Corpus callosum** **Anterior commissure** **Fornix** **Internal capsule**	**Lateral ventricle**
Diencephalon	**Thalamus** **Subthalamus** **Hypothalamus**	**Fornix**	**Third ventricle**

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Cerebral cortex

Let's begin our study of internal forebrain anatomy with the **cerebral cortex**. As you have already learned from our recent histology lab, 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 that is made up of six layers of neurons (**Figure 4.2**). Phylogenetically older cortex, which has fewer cell layers (*paleocortex* and *archicortex*), is found on the inferior surface of the temporal lobe, separated from neocortex by the rhinal fissure (**Figure 4.3**). Arguably, the most primitive and phylogenetically oldest cortex is the paleocortex, which is recognized as having the fewest layers (three). It is found in the junction of the temporal and frontal lobes and is designated as the **pyriform cortex**, which is one division of the primary olfactory cortex. Another ancient division of the cerebral mantle is the archicortex of the parahippocampal gyrus; there you will find the **hippocampus** and the **dentate gyrus**. The hippocampus and dentate gyrus form as the medial edge of temporal cortex becomes double-folded into the medial aspect of the temporal lobe; it is visible only in dissected brains (see **Figure 4.1**) 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 (more specifically, the telencephalic vesicles). Thus, despite its deep sulci and fissures and phylogenetic divisions, the entire cerebral cortex in one hemisphere is a continuous sheet of neural tissue.

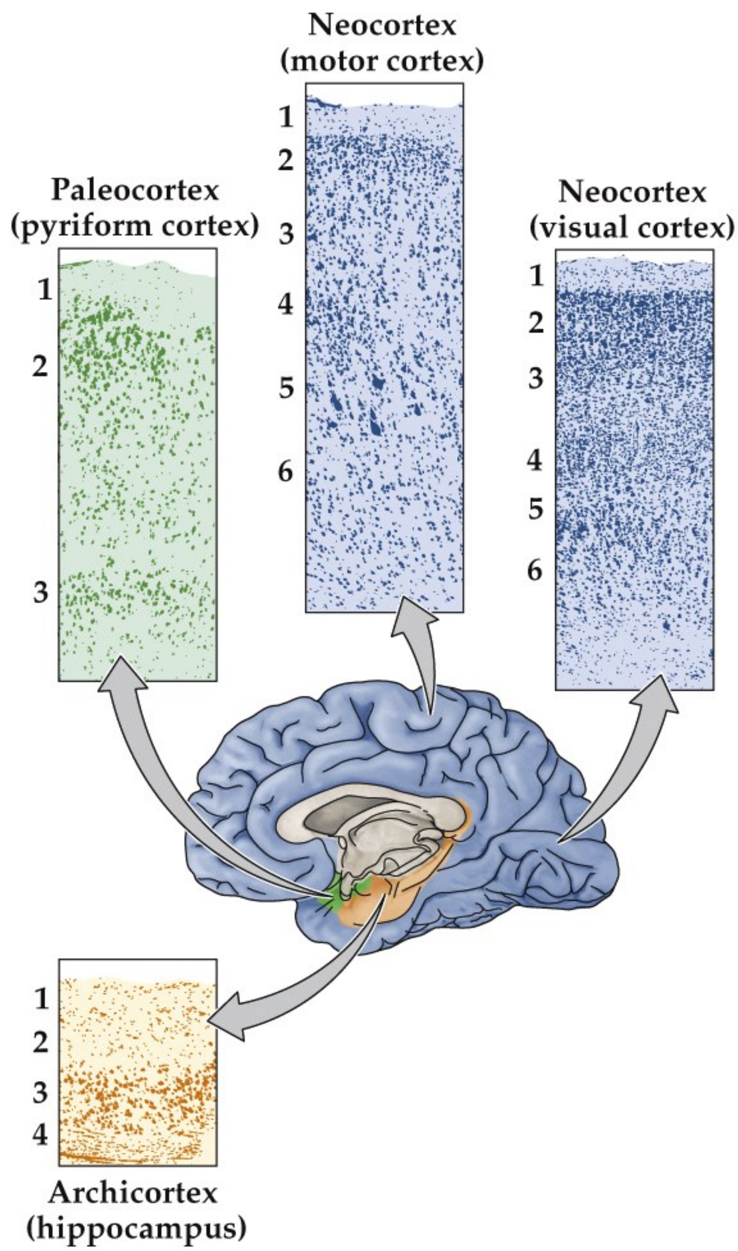

Figure 4.2. Cytoarchitecture of the human cerebral cortex. Note that much of the cerebral mantle is neocortex (shaded blue), while phylogenetically older cortex (paleocortex, archicortex) is localized to the medial temporal lobe and the junction of the frontal and temporal lobes. (Figure 26A from *Neuroscience*, 6th *Ed.*)

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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. As you have noticed, neuroscientists and neurologists 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 neural impulses (action potentials) normally propagate (regenerate) along the axons.

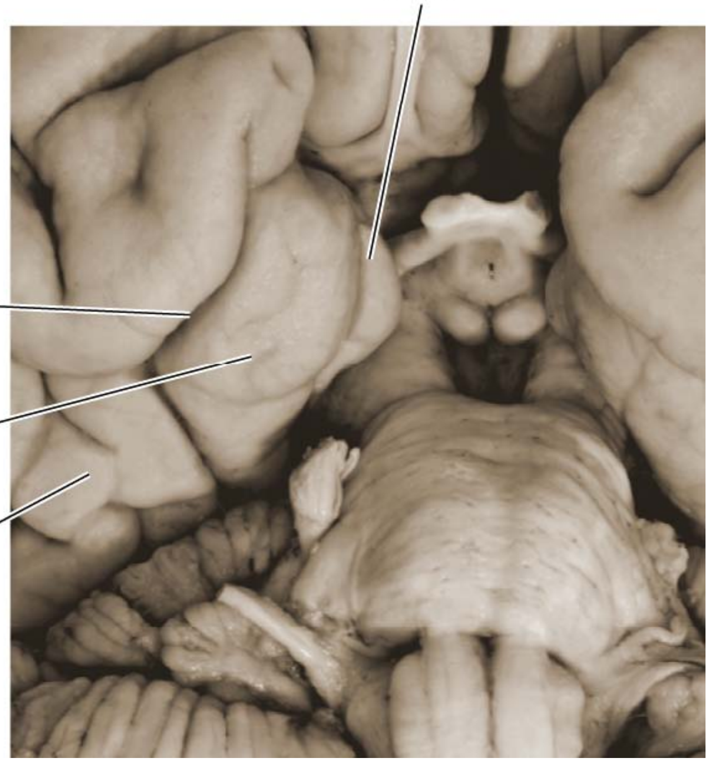

Figure 4.3. Close-up view of the ventral-medial surface of the temporal lobe to show the parahippocampal gyrus and related sulci. The rhinal fissure separates the lateral neocortex from the medial paleocortex. The medial protuberance in the parahippocampal gyrus is called the uncus, which is a cortical division of the amygdala.

Basal ganglia

Buried deep within the hemispheres are the **basal ganglia** (**Figure 4.4**), which are large gray matter structures concerned with modulating thalamic interactions with the frontal lobe (and certain brainstem circuits that interact with premotor networks, also in the brainstem). The term 'ganglion' or 'ganglia' is *not* usually used for clusters of neurons inside the central nervous system; the term "basal ganglia" is an exception. The basal ganglia lie partly rostral and partly lateral to the diencephalon (refer to the chart in the first PDF in this series for a review of their embryonic relations). They can be divided into four main structures: the **caudate**, the **putamen**, the **nucleus accumbens**, and the **globus pallidus** (with several more minor components that we will not identify here).

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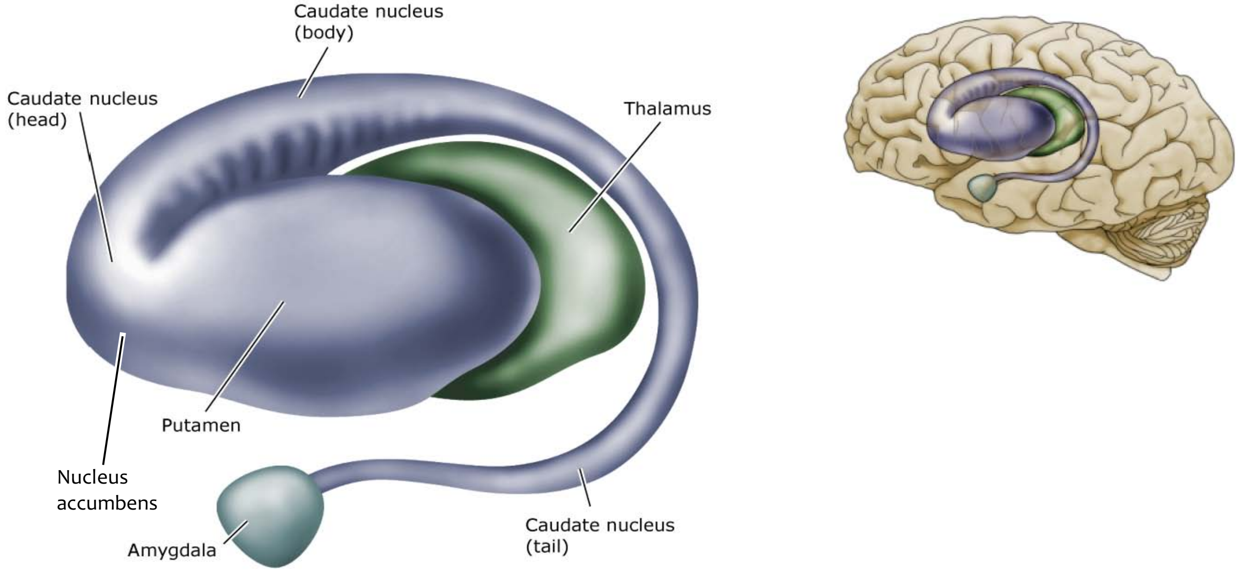

Figure 4.4. The basal ganglia and thalamus drawn with all of the cortex and white matter of the hemispheres stripped away; viewed from the side (refer to the inset for orientation). The head of the caudate is in the frontal lobe; its body lies just dorsal to the thalamus, and its tail descends into the 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 after Figure 17-4 in Carpenter, M.B. and Sutin, J., *Human Neuroanatomy, 8th Ed.*, Williams & Wilkins, Baltimore MD, 1983; courtesy of Pyramis Studios, Durham NC)

Embryologically, 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:

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- the **putamen** is concerned with the regulation of *bodily movement* (mainly limb movement);
- the **caudate nucleus** (especially its large anterior 'head') regulates *movement of thought* and *eyes* (eye movements often indicate what we are thinking about, and we often look at what captures our thoughts/attention); and
- the **nucleus accumbens** is concerned with *movement of emotion* or *motivated behavior* and is a central component of the brain's reward circuitry.

Obviously, we are speaking of the concept of movement in loose terms (consider, for example, the expression "being moved" by stirring music or your favorite tear-jerker film, or the sudden change of thought and affect that comes with an email or phone call from a dear friend). 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 selection and *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 subdivision of the pallidum, called the **substantia nigra, pars reticulata**, regulates orienting movements initiated by the superior colliculus. A full consideration of basal ganglia circuitry is beyond the scope of this chapter; but these important circuits will be considered elsewhere in the course.

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 in an earlier lab on mid-sagittal views: the corpus callosum, anterior commissure and fornix. 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 *optic radiations* or the *auditory radiations*, axons that arise in the thalamus and grow 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. These pathways and several other so-called "associational" pathways (that mediate the association of neural processing among interconnected cortical areas) are depicted in **Figure 4.5**. These images are generated by *diffusion tensor imaging* 'tractography' of cerebral white matter. This is a means for measuring the microscopic, three-dimensional

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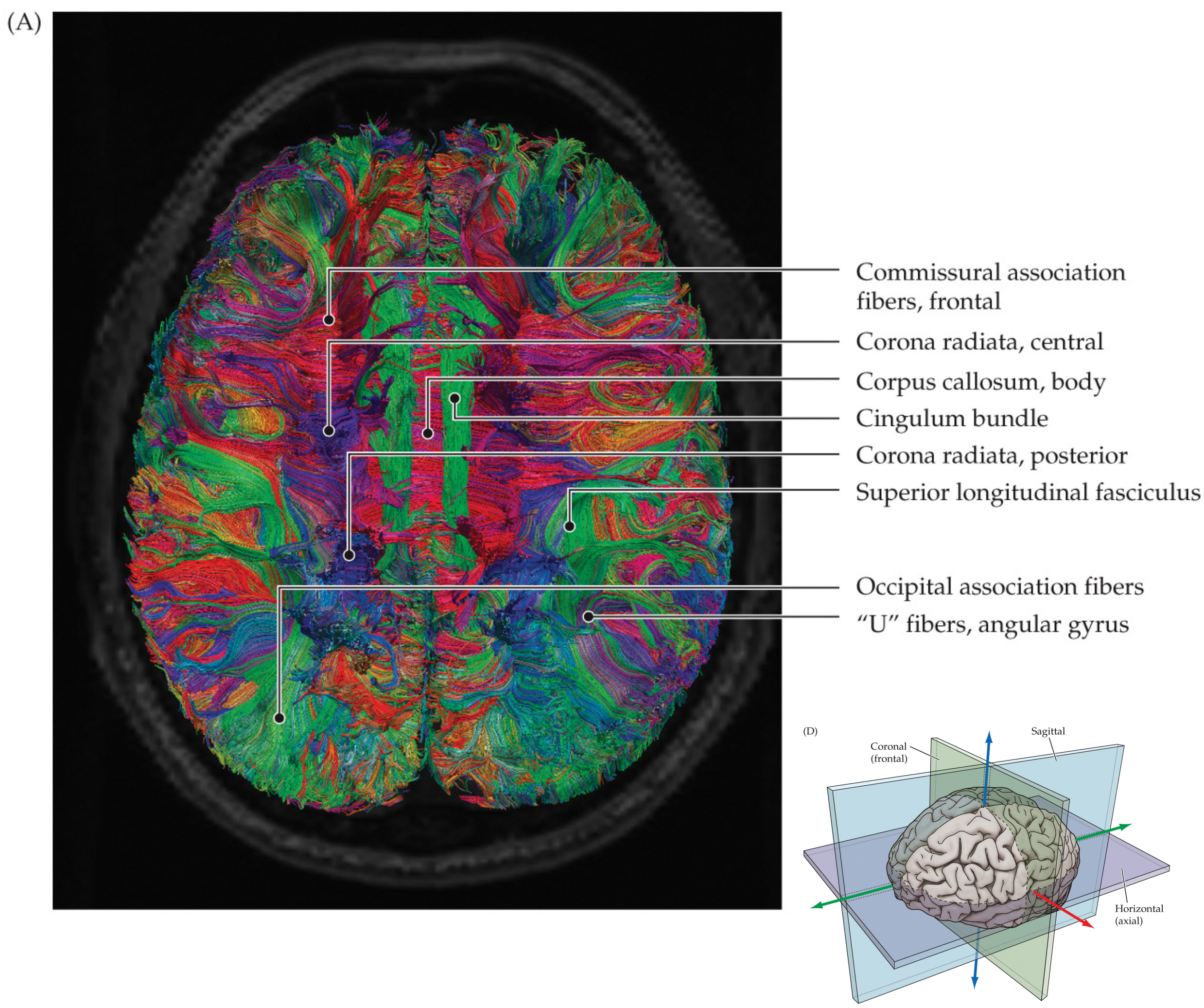
diffusion of water and how such diffusion is constrained by the ultra-anatomical structure of tissue[1]. Although the white matter of the cerebral hemisphere appears relatively featureless in preserved specimens, such depictions should convince you of the daunting complexity of this compartment of brain tissue. Thankfully, in this lab, we will only note this complexity in passing and concern ourselves mainly with the white matter structures identified in the table above.

Figure 4.5 (below and next page). **Diffusion Tensor Imaging** (A) Axial, (B) coronal, and (C) sagittal sections through a diffusion tensor imaging dataset used to compute fiber tracts, which represent the structure of white matter fibers in a human brain. Inset shows color code for spatial orientation of fiber tracts. (Images courtesy of Allen W. Song and Iain Bruce, Duke-UNC Brain Imaging and Analysis Center.) (Plate 5 from *Neuroscience*, 6th *Ed.*)



[1] Myelinated fascicles constrain the movement of water in much the same manner that fibers in a stalk of celery would facilitate greater diffusion of water along the long axis of the fibers than across fibers. This so-called "anisotropic diffusion" (diffusion anisotropy) provides a means for representing white matter in living subjects.

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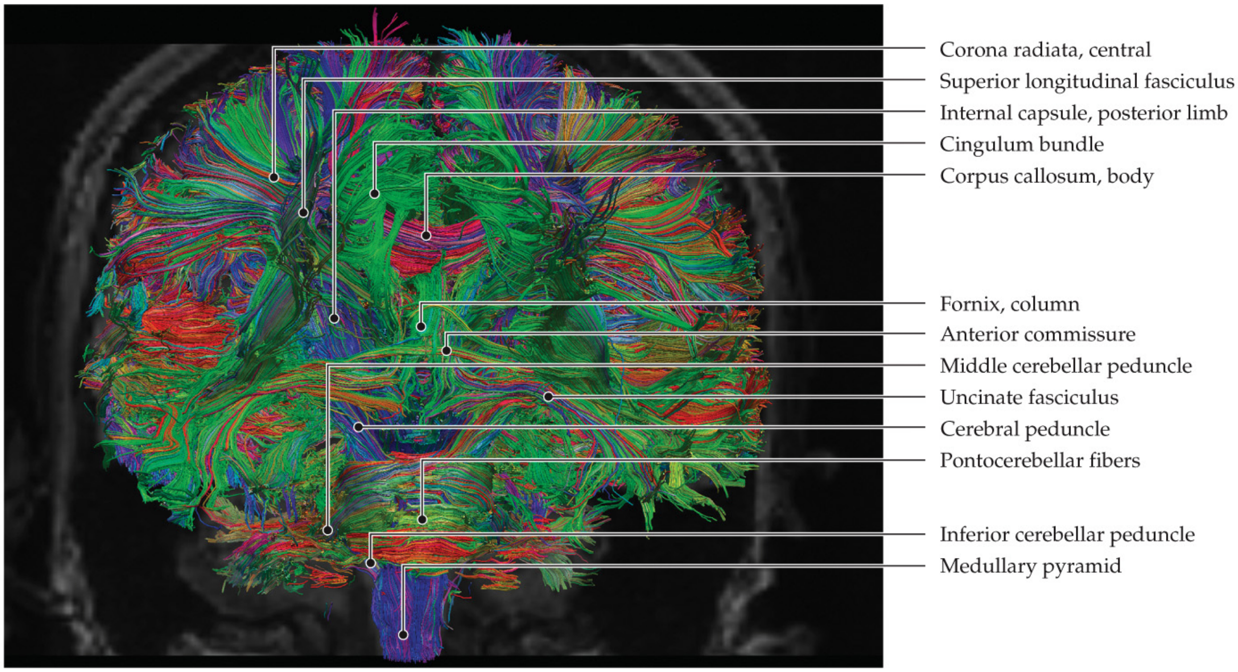
(B)



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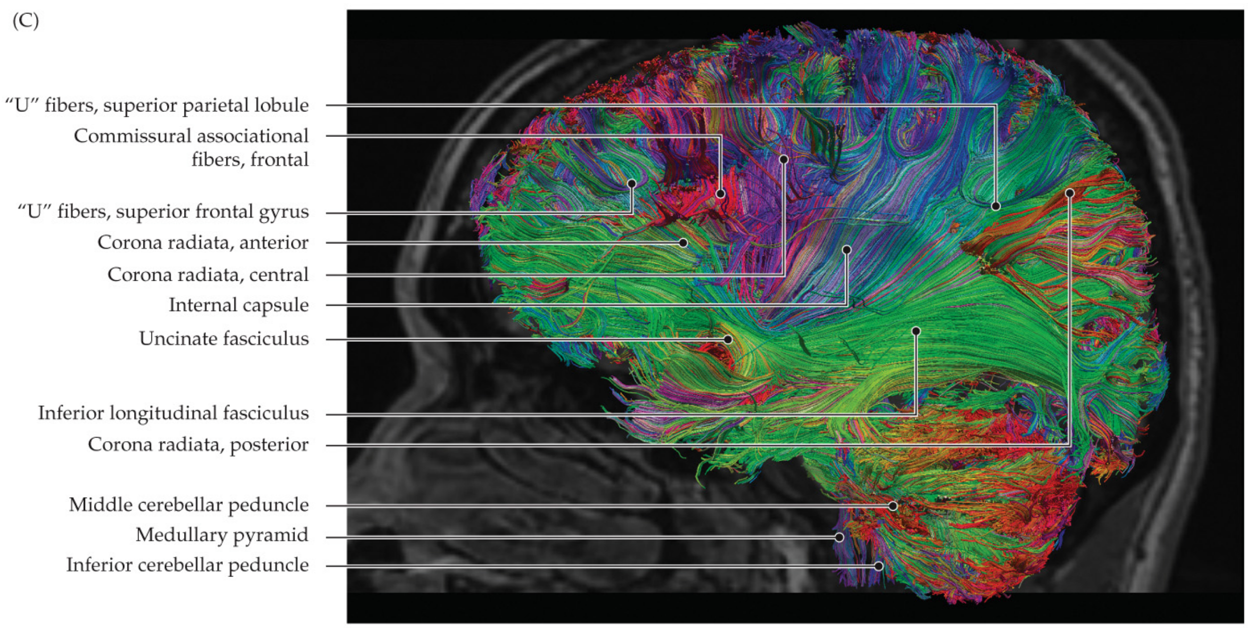

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That's almost it for structures in the hemispheres! But there are two other gray matter structures you should know.

One is a group of complex nuclei and corticoid structures known as the **basal forebrain**, which have become associated with the signs and symptoms of diseases such as Alzheimer's disease. Like the basal ganglia, the basal forebrain are made up of clusters of cells (rather than layers); but relative to the basal ganglia, these clusters are much smaller and typically much less compact. They are located inferior to the pallidal parts of the basal ganglia, between the ventral striatum and the hypothalamus. Among these nuclei are the cholinergic populations of neurons in the basal nucleus (of Meynert) and the diagonal band (of Broca) that were mentioned briefly (see above). The cortical projections of these nuclei are especially important in attentional mechanisms.

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, mostly anterior to the temporal horn of the lateral ventricle and the hippocampus. 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 the striatum and the cerebral cortex. We will discuss the amygdala and its connections within the limbic forebrain elsewhere in this course.

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 4.4** & **4.6**.

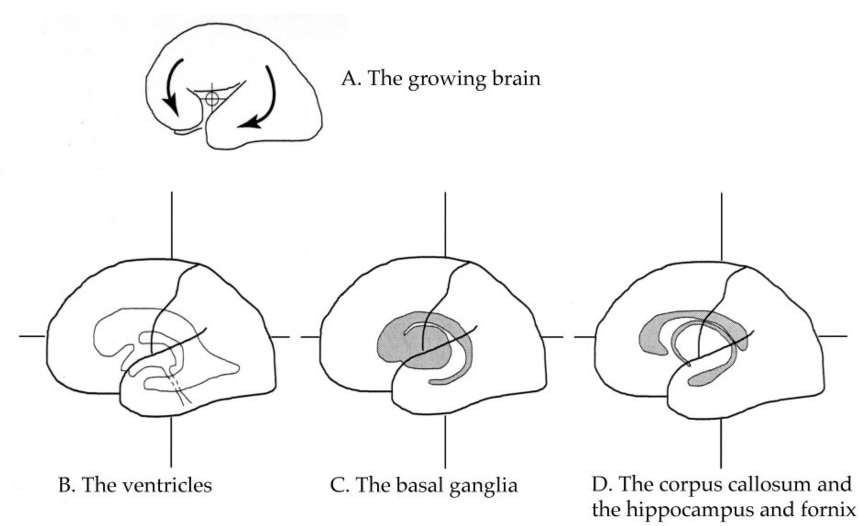

Figure 4.6. A. During development, the human cerebral hemispheres grow markedly in the posterior and ventral directions, forming the temporal lobe. As the temporal lobe grows, the hemisphere appears to rotate forward, beginning to form a shape something like a horseshoe. Deeper structures in the hemispheres 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' that curves into the temporal lobe (cf. Figure 4.4). 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 (cf. Figure 4.1). The lines in B-D indicate planes of section (coronal and horizontal) that cut twice through the structures shown. (Illustration from N.B. Cant)

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The diencephalon comes to lie medial to the telencephalic components of the cerebral hemispheres (see **Figure 4.4**). The **thalamus** is the largest subdivision of the diencephalon. It is egg-shaped and is made up of many subdivisions, some of which we will identify later. The **hypothalamus** lies ventral and anterior to the thalamus. Anterior to the hypothalamus is the optic chiasm and the preoptic area. (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, which receive an important output from the hippocampal formation via the fornix, are a part of the hypothalamus lying in its caudal part just at its junction with the midbrain.

Finally, before taking on the challenge of viewing the forebrain in cross-sections, consider again the three-dimensional configuration of the ventricular system within the forebrain and brainstem (see first PDF in this series). To help you do so, consider working through the *Sylvius Self-Study Exercise* on the next page. It is important to appreciate the relationships among the structures named in this exercise so that you will understand why cross-sections through the brain in various planes appear as they do.

Then, lean into **Challenge 4.1**. Successful completion of this challenge will go a long ways toward providing you the framework you will need to interpret any section through the forebrain in any plane of section. So it will be well worth your time to master this challenge as you prepare for today's lab and the associated readiness assurance.

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Sylvius Self-Study Exercise

–The ventricular system

With some study of the chart on embryology in the first PDF in this series and **Figures 1.1** & **1.2**, you can become quite conversant with the ventricular compartments of the human brain, their relation to surrounding subdivisions of the adult brain, and their embryological precursors from which these complex shapes arose.

As a point of emphasis, remember that the ventricles are the product of the morphogenic events that bent, pinched and expanded the lumen of the embryological neural tube and greatly increased the thickness and complexity of its walls. The objective of this exercise is to recognize the various compartments that constitute the ventricular system of the adult brain. This will entail recognizing four principal ventricles, the paired **lateral ventricles**, the **third ventricle**, and the **fourth ventricle**, as well as one narrow channel, the **cerebral aqueduct**. Along the way, you will become familiar with standard views of the forebrain in cross-section.

To begin, be sure you are familiar with the illustrations in **Figure 1.2**; they provide the foundation for your exploration of the ventricles in sectional views of the brain. Next, open ***Sylvius4 Online*** and go to **Sectional Anatomy**, **Photographic Atlas**, and then click on **Ventricles**. Now, view the most rostral coronal section ("Coronal 1" should appear if your mouse lingers over the correct thumbnail image in the navigation window). Begin sectioning this brain from rostral to caudal (click on the rightward arrowhead in the navigation window) and note the appearance of the frontal horn of the lateral ventricle in coronal section 3. With your attention on the lateral ventricle, continue sectioning and note the appearance of the temporal horn of the lateral ventricle in the medial temporal lobe (coronal sections 5 & 6). Finally, note the caudal extension of the lateral ventricle as it penetrates the occipital lobe as the occipital horn (coronal sections 7 & 8).

Now, re-slice the forebrain in the axial (horizontal) plane from dorsal to ventral (click on an axial thumbnail image or grab the dorsal-ventral slider in the navigation box to select an axial image). Look for these same compartments within the lateral ventricle. Do you notice how the lateral ventricle opens widely in its central part or body (horizontal section 2), then appears more posteriorly in a region called the atrium (horizontal section 3) before appearing more anteriorly in the temporal lobe (horizontal section 4)? Refer back to the illustrations in **Figure 1.2** as you section in the axial plane.

To appreciate the third ventricle, compare horizontal section 3 with coronal sections 4 and 5. Do you see the narrow slit-like space defined by the third ventricle at the medial base of the diencephalon? By what means does cerebrospinal fluid flow from the lateral ventricle, where it is synthesized by choroid plexus, into the third ventricle? (Refer to the first PDF in this series if you need a reminder.)

The third ventricle communicates with the fourth ventricle by means of a narrow channel through the dorsal midbrain (mesencephalon) called the cerebral aqueduct. This channel is barely visible in coronal section 6 (because of its very small diameter). To better view the cerebral aqueduct, enter the **Brainstem Cross Sectional Atlas** and select **All Structures**; then view the section labeled "2 – Midbrain" (second section from the top of thumbnail list). See the small space along the dorsal midline of the section? That's the cerebral aqueduct and it is a principal landmark that will always help you identify transverse sections through the midbrain, as inferred from the chart on embryology. From here, continue sectioning through the brainstem in the caudal direction and note the gradual expansion of the cerebral aqueduct as you enter the pons.

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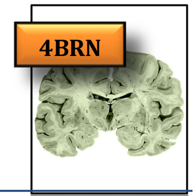
By section "6 – Pons", the cerebral aqueduct has fully opened up into the fourth ventricle (click on the fourth ventricle to highlight this space). This most caudal ventricle in the adult brain lies between the dorsal surface of the pons and the large stalks of white matter (the cerebellar peduncles; "peduncle" means stalk) that connect the cerebellum to the brainstem.

Now return to the forebrain and view the midsagittal plane (go to **Sectional Anatomy** > **Photographic Atlas** > **Ventricles**). As you view the four major components of the ventricular system again, appreciate their structural continuity, their physical relation to surrounding brain regions and consider again their embryological origins.

As one final challenge—section through the brain in the MR Atlas (go to **Sectional Anatomy** > **MR Atlas** > **All Structures**) and relate what you see in serial sections to the colorized views of the ventricles in the **Photographic Atlas** and to **Figure 1.2**.



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Challenge 4.1—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 inspect sections through the forebrain (in the next few pages and in lab), 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 anterior margin of the internal capsule;

(2) the **globus pallidus** is a relatively small structure located near the middle of the basal ganglia; it is located between the **internal capsule** and the **putamen**;

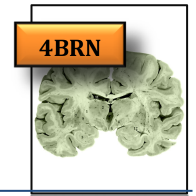
(3) the **thalamus** occupies a more posterior volume of brain-space than the bulk of the basal ganglia;

(4) the **caudate nucleus** has a long "tail" that follows the course of the lateral ventricle into the temporal lobe (see again **Figure 4.4** & **4.6**);

(5) the *anterior limb* of the internal capsule separates the head of the caudate nucleus from the putamen and globus pallidus, while the *posterior limb* of the internal capsule mainly separates the thalamus from the globus pallidus.

After gaining an understanding of these points in the set of coronal sections in **Figure 4.7–4.11**, open ***Sylvius4 Online*** and enter the **Basal Ganglia** image set of the **Photographic Atlas** in the **Sectional Anatomy** group; then view the most rostral coronal section and review these same sections (and a few not reproduced here). Next, re-slice this digital brain in the axial plane and then in the parasagittal plane. The internal capsule may be more difficult to appreciate in these other planes of section; but here's a tip: look-up the internal capsule in the **Visual Glossary** and you will see it labeled in the axial plane. In this plane, you will readily appreciate its anterior and posterior limbs.

So now that you are primed to interpret the internal anatomy of the forebrain, ***lay out a set of coronal, axial and/or parasagittal sections on a tray and identify each of the structures and relations numbered (1) to (5) above***.



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Coronal sections through the brain

The five coronal sections through the brain shown, beginning on the next page (**Figure 4.7–4.11**), were taken from ***Sylvius4 Online*** and should resemble the brains that are available for examination in the laboratory. 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.

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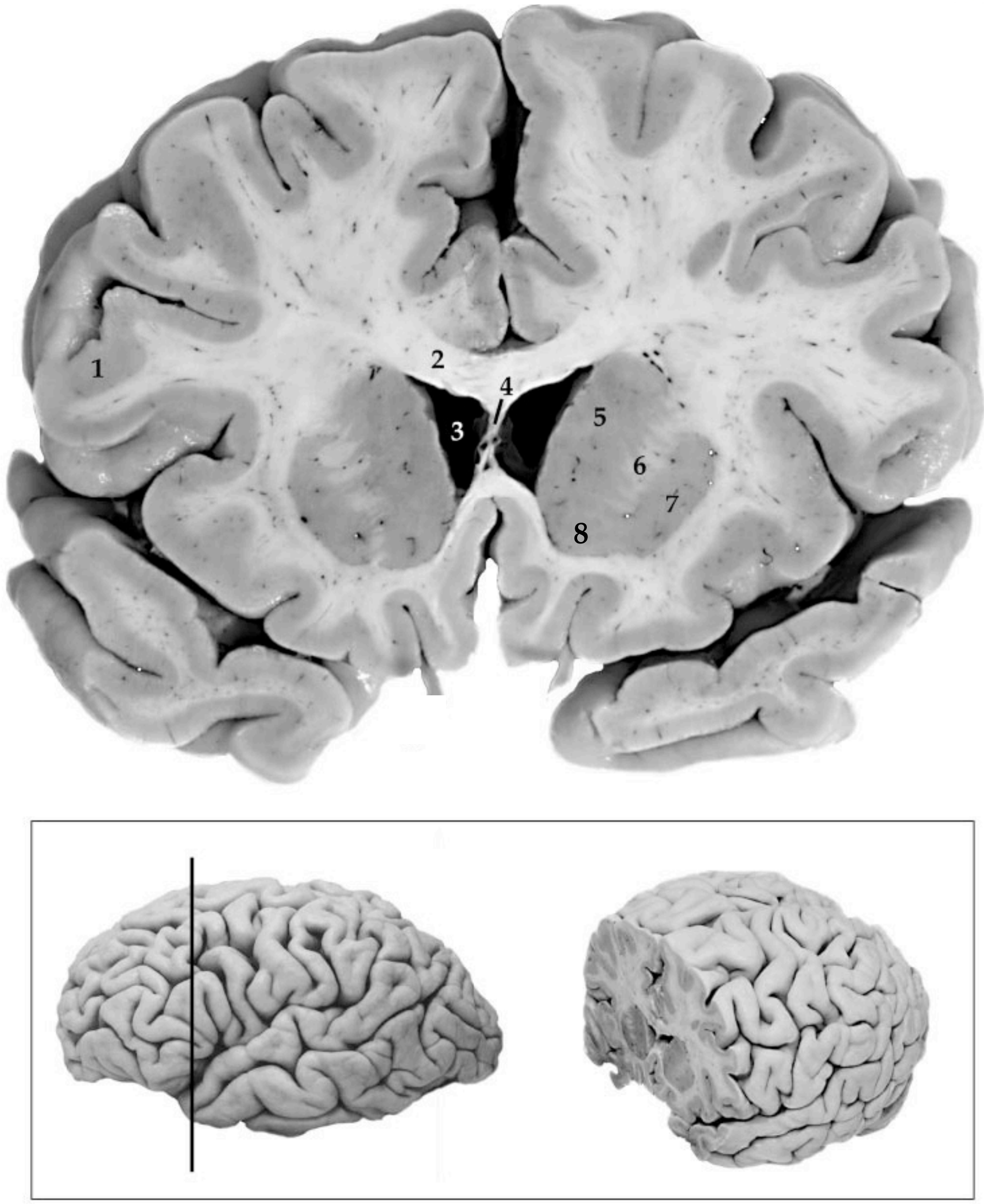

Figure 4.7. This first section is anterior to the region where the anterior commissure crosses the midline so only the cerebral hemispheres are present, and the diencephalon is not seen. The basal ganglia, which form part of the hemispheres, are very large here in the frontal lobes. Key: 1. Cerebral 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***)

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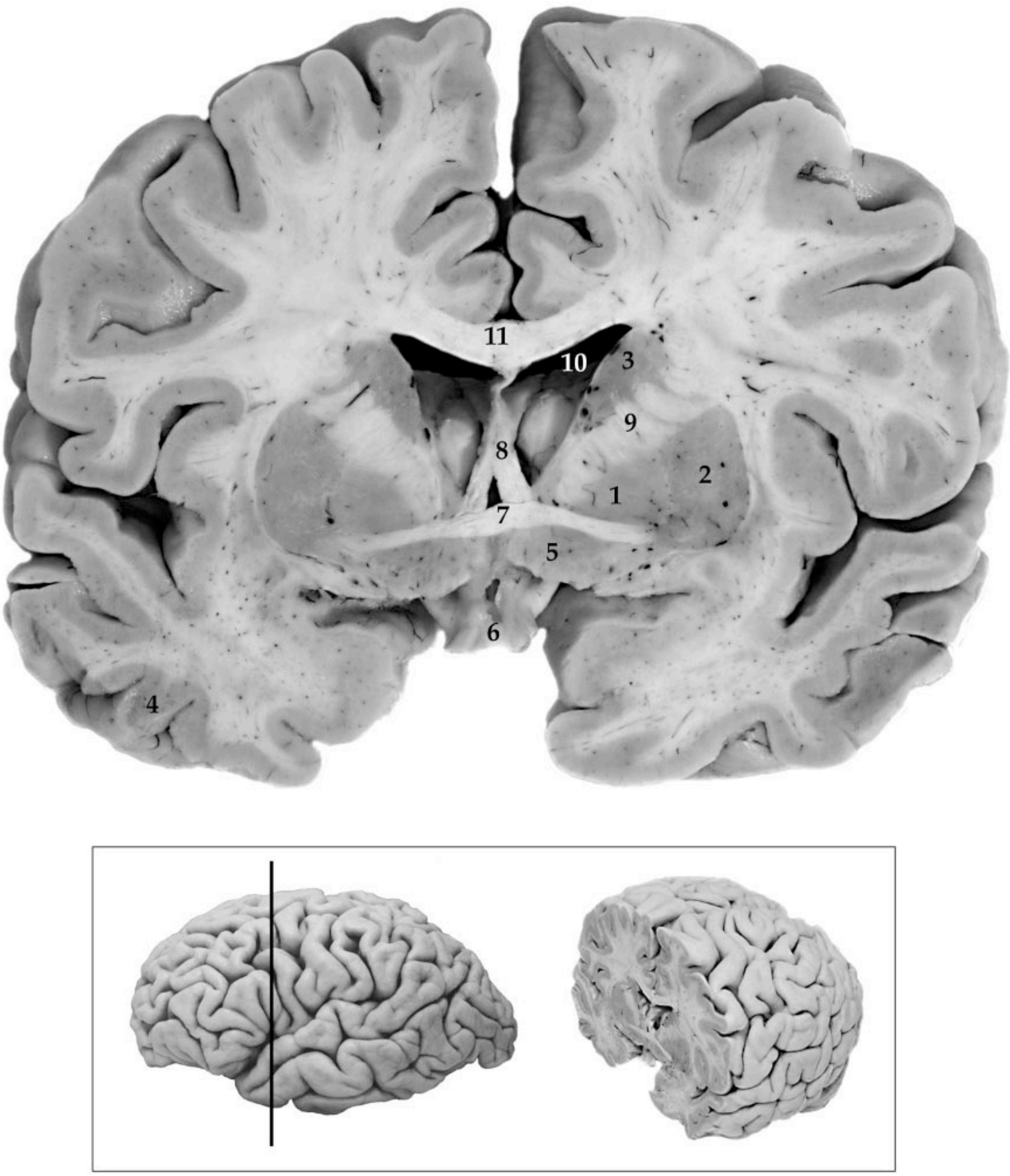

Figure 4.8. The second section in the series is at the level where the anterior commissure crosses the midline. Locate the caudate and putamen and the globus pallidus. Also find the internal capsule, the lateral ventricles, the corpus callosum, and the fornix. (You see the fornix only once on each side 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 the basal forebrain; 6. Optic chiasm; 7. Anterior commissure; 8. Fornix; 9. Internal capsule; 10. Lateral ventricle; 11. Corpus callosum. (Image is "Coronal 4" from ***Sylvius4 Online***)

Sectional Anatomy of the Forebrain

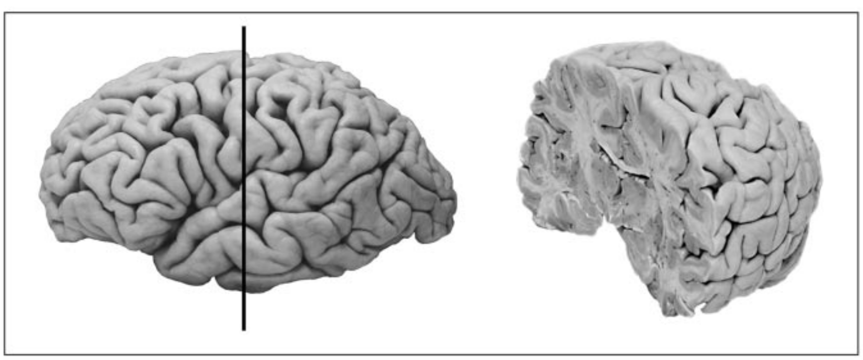

Figure 4.9. The third section in the series lies about halfway through the brain. Since this section lies posterior to the anterior commissure, the diencephalon appears next to the midline. The thalamus is separated from the putamen and globus pallidus by the posterior limb of the internal capsule. The 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. Posterior limb of the 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 & 12. Lateral ventricle; 13 (posterior) amygdala. (Image is "Coronal 5" from **Sylvius4 Online**)

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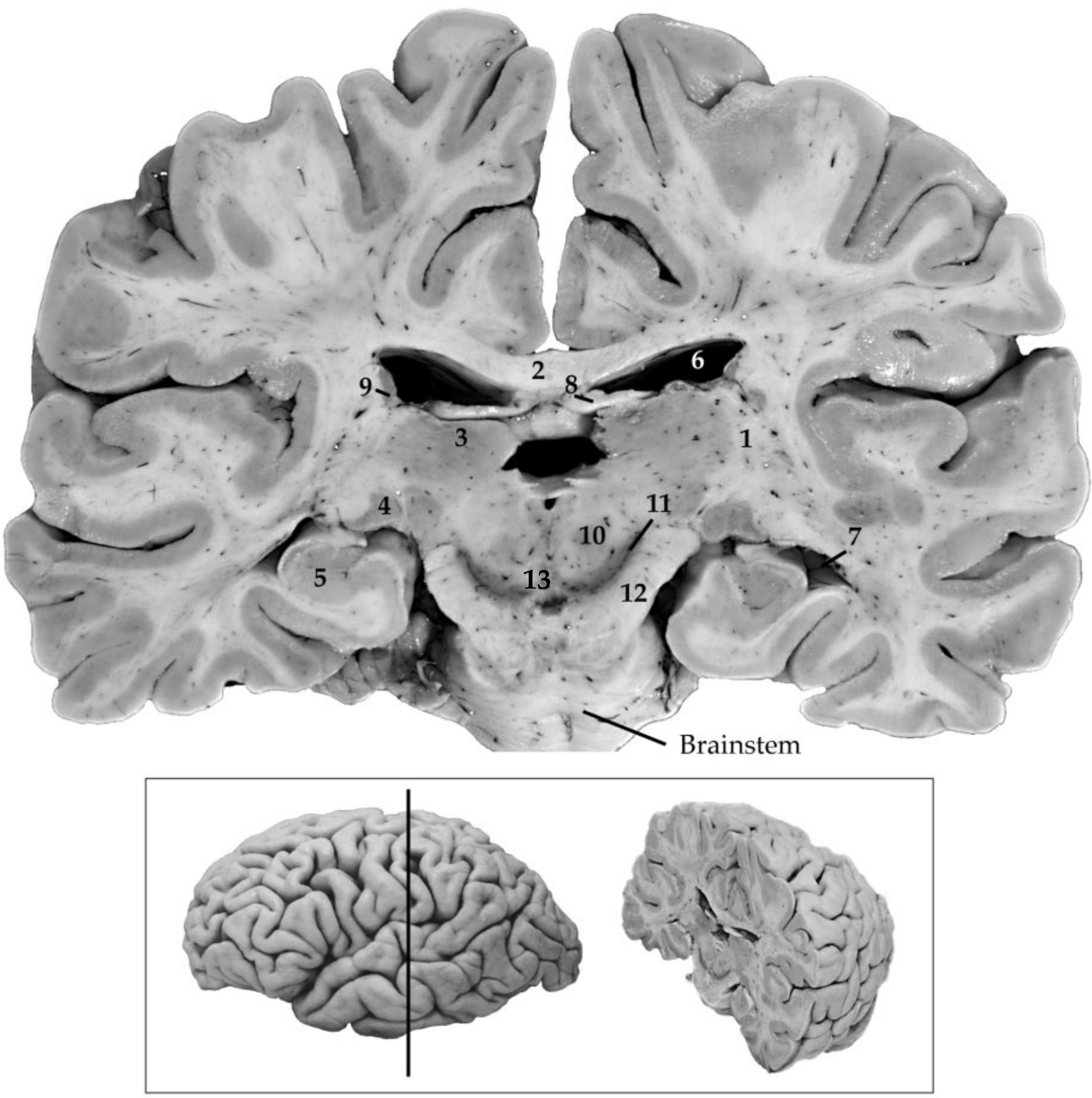

Figure 4.10. In this section, you can see the transition from the diencephalon to the midbrain of the brainstem. (Some of the structures of the midbrain are labeled in the figure.) In the forebrain, some of the same structures that were seen in more anterior sections can still be identified, although 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. Posterior limb of the 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***)

Sectional Anatomy of the Forebrain

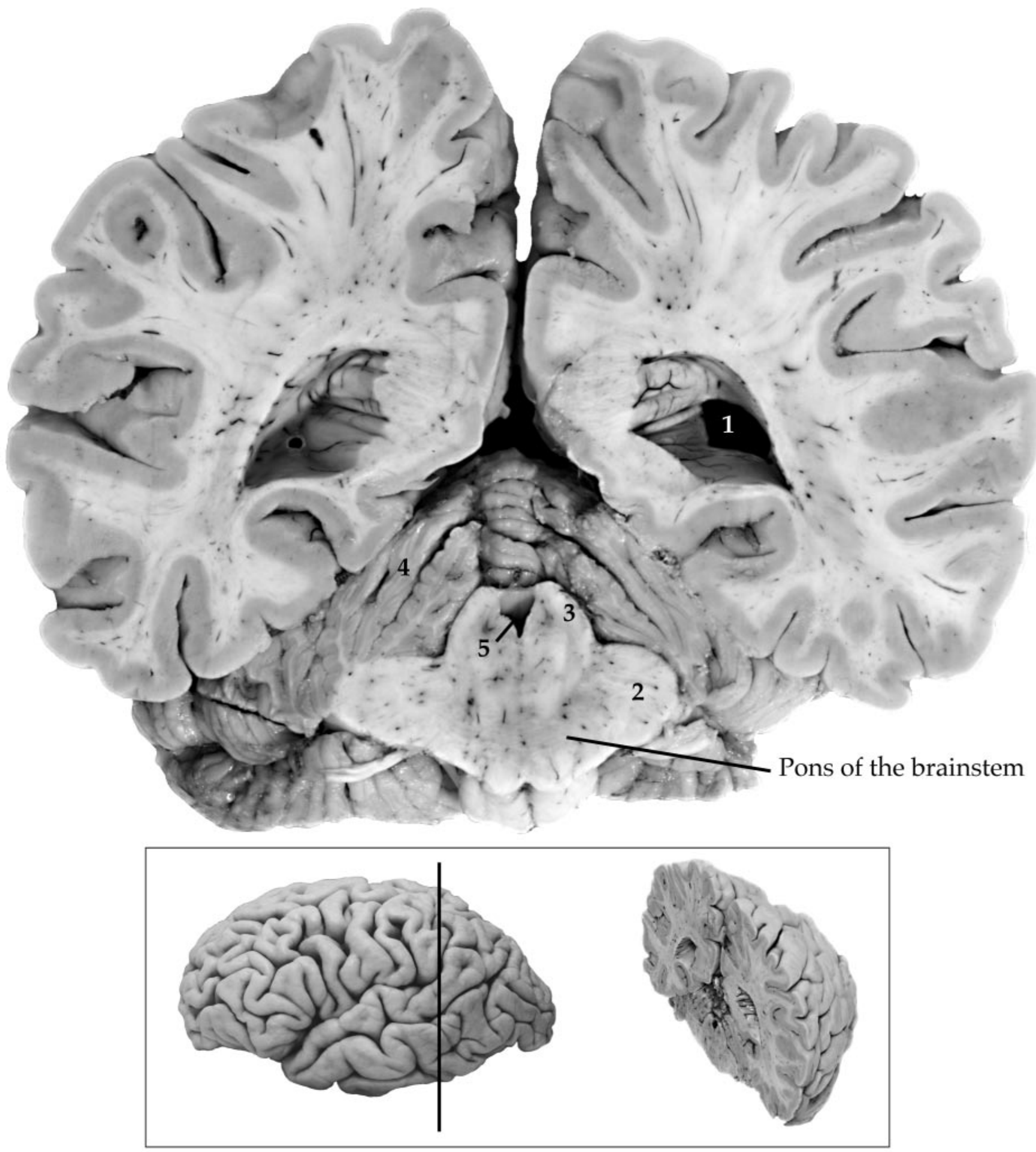

Figure 4.11. The most posterior section in the series is cut through the parietal and posterior temporal lobes. Since the cut is posterior to the corpus callosum, the two hemispheres are not connected to each other. In the forebrain, only the gray and white matter of the cerebral hemispheres and the posterior horns of the lateral ventricles are seen; none of the deep gray matter structures is present. The section also passes through the pons, which 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***)

Sectional Anatomy of the Forebrain

Sylvius Self-Study Exercise –*Different points of view*

Now that you have worked through views of the internal anatomy of the forebrain (and parts of the brainstem) in coronal sections, try identifying all of the same structures that are labeled in **Figure 4.7–4.11** in the other planes of section that are available in ***Sylvius4 Online***, namely the horizontal (axial) and parasagittal planes.

In principle, this is precisely the same type of self-study exercise that you may have worked through while studying the ventricles; only now, the challenge is to key in on a variety of structures that may not be quite so obvious as you pass through the forebrain. So open ***Sylvius4 Online*** and go to **Sectional Anatomy**, **Photographic Atlas**, and then click on one of the filter sets, depending on which structures you wish to have highlighted, such as **Ventricles**, **Limbic System**, or **Basal Ganglia**, or perhaps you simply wish to view the specimen **Unlabeled**. Now, view the most dorsal horizontal (axial) section ("Horizontal 1" should appear if your mouse lingers over the correct thumbnail image in the navigation window). Begin sectioning this brain from dorsal to ventral (click on the rightward arrowhead in the navigation window) and note the appearance of colorized structures of interest (depending, again, on which filter set you selected). After passing up and down through the specimen a few times, re-slice the forebrain in the parasagittal plane (click on a parasagittal thumbnail image or grab the medial-lateral slider in the navigational box to select a parasagittal image). Look for these same structures as you pass through the brain from medial to lateral and back again.

Try repeating the same process while passing through the **MR Atlas** (go to **Sectional Anatomy** > **MR Atlas** > **All Structures**) and find each of the numbered structures from **Figures 4.7–4.11**.

Challenge 4.2—amygdala & hippocampus

Lay out in front of you on a tray a set of coronal or axial sections through a cerebral hemisphere. Now that you are oriented to the basal ganglia, thalamus and internal capsule, you are ready for a simpler challenge. ***Turn your attention to the medial portions of the temporal lobe and identify the amygdala and the hippocampus***. As you sort out where these structures are and what they look like, address the following set of questions with your teammates:

- Which is more *anterior*, the amygdala or the hippocampus?
- Do the amygdala or the hippocampus overlap?
- Is the amygdala cortex, basal ganglia, or something different?
- What is the relationship between the hippocampus and the lateral ventricle?
- How do the amygdala and the hippocampus communicate with structures in the hypothalamus and nearby ventral-medial forebrain?

Lastly, since these two prominent structures of the medial temporal lobe have such memorable names, consider these final two questions:

- Why is the amygdala called the amygdala? (Latin for "almond")
- Why is the hippocampus called the hippocampus? (Latin—from the Greek—for "sea horse" or "sea monster")

Challenge 4.3—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 Play-Doh™ or make your own (several simple recipes are available online); 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 **Challenge 4.1**. In particular, ***construct a clay (dough) model of the major components of the basal ganglia, thalamus and internal capsule***, as described in **Challenge 4.1**, with special attention to the five numbered points of detail.

How to start? Begin by constructing the internal capsule: flatten out a white lump of clay (for white matter, of course) 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 4.4**? 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 "Interactive Brainstem Rotation" feature (available via the folder in the navigation window in the upper right) 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. 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.