The Human Brain: Dissections of the Real Brain

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Peer Review Status: Internally Peer Reviewed

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Preface and Copyright

The dissections in this electronic atlas can assist those students entering the field of human neuroanatomy for the first time to find out a great deal about the appearance and organization of the brain. It will also serve advanced students and teachers who may lack sufficient time or opportunity for carrying out the more complex and difficult dissections. It is our hope that this book will also help clinicians to refresh and improve their knowledge of neuroanatomy, especially in regard to the internal structures of the brain. Last but not least, we hope that these preparations will reveal to the reader, to a degree at least, the exceptional structural beauty of the human brain.

Chapter 1 deals with the coverings, blood vessels, and the external and internal structure of the spinal cord; Chapter 2 relates to the coverings of the brain and the blood vessels that nourish it; Chapters 3 through 5 classify the brain dissections into three major collections, illustrating the cerebellum, brainstem, and cerebral hemispheres respectively.

The authors have benefited from the excellent photographic expertise provided by Hans Kempkes of the Teaching Media Institute at the University of Utrecht and Paul Reimann of the Department of Anatomy and Cell Biology at the University of Iowa. We also wish to acknowledge the adept assistance rendered by A. M. Van Egeraat and Evelyn Jew for their work with the line drawings.
Introduction

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This electronic publication is intended to serve students of all the health and biological sciences who are seeking to understand the organization and functions of the human nervous system.

The unique feature of this book is its collection of brain and spinal cord dissections, the nature and quality of which would be virtually impossible for teachers or students to achieve in the teaching lab, where time is limited and correct identification of structures can be a trial. These dissections are offered as examples of the brain dissector's art, and provide students with visual access to an enhanced understanding of structures, pathways, relationships and concepts.

Dr. Gluhbegovic and Dr. Williams were the authors of the earlier book. Dr. Williams now gratefully acknowledges the assistance of a number of individuals who made this journey into cyberspace possible: Bin Kallan, Teresa Choi, and Dawn Finney. The completion of this new edition would not have been possible without the timeless work of Dr. Steven Zheng, Rong Wang, and Jing Wu. Valuable advice has been provided by James Duncan, and contributions have been made by Katie Fassbinder and Clint Zimmerman. He also thanks Lippincott-Raven for permission to use the images taken from The Human Brain: A Photographic Guide, published by Harper and Row.

Terence H. Williams

I am delighted to offer this exquisite collection so that this work can be savored by readers of many disciplines, including but not limited to clinicians, researchers and other students of the brain at all levels. Unfortunate though it is, I am doomed by such errors as I have introduced into the text, and take full responsibility for each and every one. I invite proposals for improving this work. Although I am opposed to flattery, a little of this will not break my heart. ----T.H.W.

Dedication
This work is dedicated to Azra and Glenys.
Methods Used in Preparing the Specimens

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For the preparations used to display the spinal cord, its covering membranes, the spinal nerve roots and ganglia, we had access to the body of a newborn male infant preserved in formaldehyde solution, together with adult material that had received prolonged treatment in the same preservative solution.

The preservation method of Klingler was utilized, with minor adaptations. In removing the brain from the skull, every effort was made to minimize damage to the delicate surface. The organ was then suspended, by means of a ligature placed around the basilar artery, in a vessel containing 10% formaldehyde solution. This fluid was replaced after 24 hours and again after an interval of two weeks. After a total period of 4 weeks or longer in the formaldehyde solution, the brain was washed for several hours in cold running water.

Next it was placed in a plastic vessel containing 10% formaldehyde solution and stored for 8 days in a freezer at -25 to -30°C. At this point the brain was thawed under running cold water for 24 hours. Repeating the freezing procedure (in 10% formaldehyde solution) two or three times has been found to facilitate the subsequent dissection. After the last freezing, the brain can be kept in 5% formaldehyde solution indefinitely.

While the freezing method is an aid to dissection and generally increases the distinction between the grey and white matter of the brain, it does not produce absolutely consistent results, as Klingler himself acknowledged. As a rule, however, the technique described above makes it easier to prepare dissections of both fiber tracts and nuclei. We have observed that, for making horizontal and coronal sections of the brain, satisfactory contrast between white and grey matter is achieved without using any stain. Fine forceps—straight or curved—were used to dissect the delicate nerve bundle preparations.
Chapter 1: The Spinal Cord

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Meninges, coverings of the brain and spinal cord, spinal ganglia, and spinal nerve roots
Blood vessels of the spinal cord
Sections through representative levels
Internal Structure

1-1 Cerebral and spinal dura mater of a newborn infant, dorsal view through the opened vertebral canal
1-2 Dural venous sinuses of a newborn infant exposed from the dorsal aspect
1-3 Dorsal view of the lower part of the medulla oblongata and the upper six segments of the cervical spinal cord of a newborn infant
1-4 Lower cervical and upper thoracic segments of the spinal cord of a newborn
1-5 Lower thoracic and lumbar segments of the spinal cord of a newborn
1-6 Conus medullaris and cauda equina of a newborn: dorsal view
1-7 Dorsal view of membranes of the spinal cord of an adult, with origins of spinal nerves and ganglia
1-8 Transverse section through the spinal cord and vertebral canal, between C2 and C3 vertebrae
1-9 Transverse sections of spinal cord at different levels: A. Cervical region, B. Thoracic region, C. Lumbar region, D. Sacral region.
1-10 Transverse section of the spinal cord at midthoracic level, showing approximate positions of the main tracts
1-1 Cerebral and spinal dura mater of a newborn infant, dorsal view through the opened vertebral canal

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*a plexus of nerves formed chiefly by the lower four cervical and first thoracic nerves, which supplies nerves to the chest, shoulder and arm.

The cerebral and spinal dura mater (hard mother) are continuous with one another at the foramen magnum of the occipital bone. At this level the outer layer of the dura is attached firmly to the margins of the foramen magnum. The pigmented areas of the outer surface of the cerebral dura mark the positions of the two venous sinuses, the superior sagittal and the transverse.

The spinal dura mater has a shiny appearance because we see only the inner, meningeal layer of the dura, there being no endosteal layer lining the vertebral canal. The roots of 31 pairs of spinal nerves emerge from the spinal cord. Attached to the dorsal, sensory roots of the spinal
nerves are the spinal ganglia. Fusion of dorsal and ventral roots to form the spinal nerves occurs at the level of the intervertebral foramina. The dura mater of the cord has tubular, sleeve-like prolongations which ensheathe the roots of the spinal nerves, together with the spinal nerves themselves, within the intervertebral foramina. These dural extensions are continuous distally with the epineurium of the spinal nerves. Note that the lower four cervical and the 1st thoracic, as well as the lower lumbar and upper sacral nerve roots and ganglia, are much larger than the rest. The larger spinal nerve roots and ganglia are associated with the cervical and lumbar enlargements of the spinal cord which provide innervation to the limbs.
**1-2: Dural venous sinuses of a newborn infant exposed from the dorsal aspect**

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The dural sinuses of the newborn infant are very large in relation to the sizes of the skull and brain. In this preparation a dural septum, located slightly to the left of the midline, splits the terminal segment of the superior sagittal sinus into two parts, resulting in two parallel channels which are continuous with the paired transverse sinuses. The latter are the largest of the venous sinuses and are very important. The opening of the straight sinus, which travels in the line of union between the falx cerebri and the tentorium cerebelli, is seen to the right of the midline in this specimen.
The dilated meeting place of the superior sagittal, straight and paired transverse sinuses, known as the confluence of the sinuses, contains an arrangement of dural septa that fail to divide it completely. The occipital sinus, which is also subdivided by dural septa, commences at the confluence or its junction with the transverse sinus to enter and descend in the falx cerebelli. The occipital lobes of the brain are exposed except for their covering of arachnoid mater and underlying pia, and they normally rest upon the tentorium cerebelli. Note the conspicuous greater occipital nerve--one of the thickest cutaneous nerves in the body*--arising from the posterior primary ramus of the 2nd cervical spinal nerve.

*In some specimens the saphenous nerve is larger.
1-3 Dorsal view of the lower part of the medulla oblongata and the upper six segments of the cervical spinal cord of a newborn infant

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The posterior white columns (funiculi) lie alongside the posterior median sulcus. Their constituent bundles in the spinal cord can be followed upward without interruption into the lower closed part of the medulla oblongata. The 6th segment of the cervical cord has not been stripped of its pia mater. On each side of the posterior median sulcus are two longitudinally running fasciculi, the gracile and cuneate, separated by the shallow posterior intermediate sulcus. These fasciculi are composed of sensory axons that arise from cell bodies in the dorsal root ganglia of the spinal nerves and enter the spinal cord via the dorsal nerve roots. At the medullary level both fascicles spread out and diverge from the median plane. Each terminates
in an elongated and often poorly defined swelling produced by the gracile or cuneate nucleus, in which the primary proprioceptive and exteroceptive fibers end, and from which secondary axons—most of them carrying sensory signals onward to the thalamus—arise. Lateral to each cuneate fasciculus an extensive series of dorsal nerve rootlets can be seen alongside the posterior lateral sulcus of the spinal cord. Each group of dorsal nerve rootlets is associated with the corresponding segmental nerve. Note that the upper rootlets run almost transversely, but that the lower ones become progressively longer and more oblique. From its beginning at the 5th cervical segment, the spinal root of the accessory nerve increases in thickness as fibers join it from higher segments. The root lies dorsal to the rootlets of the 1st cervical nerve and the vertebral artery and can be followed through the foramen magnum into the cranial cavity.

On each side a series of spinal ganglia penetrate the intervertebral foramina. The ganglion associated with the 1st cervical nerve is small and fusiform, and immediately below it is the ventral motor root of the 1st cervical nerve. The other cervical ganglia are larger. The nerve roots and ganglia are enclosed in tubular extensions of dura, which merges with the epineurium that envelops the spinal nerves. The 1st cervical nerves are related closely to the vertebral arteries. The latter ascend through the transverse foramina of the cervical vertebrae, as shown on the left side of the preparation.
1-4 Lower cervical and upper thoracic segments of the spinal cord of a newborn

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In the uppermost portion of this photograph, the pia mater has been removed to display the tracts of the posterior funiculi (gracilis and cuneatus). Below this, the spinal cord retains its thin, transparent, pial covering. In the next part, the abundant spinal veins in the subarachnoid space are also retained. These veins are tortuous and bulky, making it virtually impossible to identify the spinal arteries. In the most caudal part of the spinal cord illustrated, the arachnoid mater has been left intact. It is a thin and transparent membrane through which the spinal vessels can be seen.

The cervical enlargement of the spinal cord extends from the 4th cervical to the 2nd thoracic segments. Closely packed dorsal rootlets issue from the cervical enlargement in orderly array, coalescing to form large dorsal roots which arise from the spinal ganglia, which are also large.
If the illustration were to extend a little more laterally, one would observe that the large anterior rami of the last four cervical and the 1st thoracic spinal nerves participate in the formation of the main trunks of the brachial plexus. Below the cervical enlargement, the dorsal rootlets, roots and ganglia diminish rapidly in size.
1-5 Lower thoracic and lumbar segments of the spinal cord of a newborn

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1. Arachnoid mater
2. Dura mater
3. 8th intercostal nerve
4. Parietal pleura
5. Dorsal ramus of 9th thoracic nerve
6. Pia mater
7. 11th thoracic spinal ganglion

In the upper part of the photograph, numerous spinal vessels can be seen through the arachnoid mater. All the meninges (including the dura mater) have been preserved in the middle portion, while in the lower part all meninges have been removed (except pia mater) to show the lumbar enlargement of the spinal cord. Note the obliquity of the dorsal rootlets as well as the increased size of the spinal nerve roots and ganglia at the level of the lumbar enlargement. In most cases, both dorsal (sensory) and ventral (motor) roots can be seen, the dorsal or sensory root being consistently larger. The intercostal muscles and vessels have been removed to display the intercostal nerves. Anterior to the ribs is the thin, shiny parietal pleura of the lung.
1-6 Conus medullaris and cauda equina of a newborn: dorsal view

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The lower end of the spinal cord narrows to form the conus medullaris, seen as the pale, pointed structure in the uppermost part of the photograph. In the newborn, the conus is located at the level of the upper margin of the 3rd lumbar vertebra, whereas in the adult it is usually found at a level between the 1st and 2nd lumbar vertebrae. The filum terminale, a thin connective tissue filament which originates from the pial investment of the conus medullaris, is obscured by the cascade of descending lumbar, sacral, and coccygeal spinal nerve roots known as the cauda equina. In the lower part of the picture note the external part of the filum terminale covered by the dura. The filum descends in company with two coccygeal nerves and is connected to the 3rd, 4th, and 5th sacral vertebrae; its terminal part is fused to the periosteum at the base of the coccygeal bone.
Note the thin, cut edges of the dural sheath outside the cauda equina, and the tubular dural sleeves around individual spinal nerves and ganglia. The lumbar and upper sacral ganglia are large and in some instances are bilobular or multilobular. Features of the lumbar plexus, including the formation of its main branches, can be observed.
1-7 Dorsal view of membranes of the spinal cord of an adult, with origins of spinal nerves and ganglia

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The arches and processes of three thoracic vertebrae (6 through 8) have been removed to display a portion of the spinal cord. The mode of origin of the spinal nerve roots from a number of rootlets is shown, together with associated ganglia and the investing membranes of the spinal cord. The spinal nerves make their exit from the vertebral canal by passing through intervertebral foramina. Note the denticulate ligaments as they pass between the ventral and dorsal roots of the spinal nerves to attach to the inner surface of the dura mater. In the upper part of the preparation, the pia mater has been stripped away to expose the tracts (gracilis and cuneatus) of each posterior funiculus, which are separated from each other by the dorsal (posterior) median sulcus and dorsal (posterior) intermediate sulci. A little lower down, blood vessels can be seen ramifying in the pia mater.
The spinous process and part of the arch of the 9th thoracic vertebra have been removed to show the fatty tissue and venous plexus of the epidural space. The 10th thoracic vertebra has been left intact, together with a part of the ligamentum flavum.

1-8 Transverse section through the spinal cord and vertebral canal, between C2 and C3 vertebrae

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The cut surface of the cervical spinal cord is slightly flattened (on both anterior and posterior aspects). In this unstained preparation the gray matter of the cord is not easily recognized. The epidural fat, the subdural space, and the arachnoid trabeculae are seen. The subarachnoid space is a wide interval that in life is filled by cerebrospinal fluid, and continuous at the foramen magnum with the cranial subarachnoid space. In the subarachnoid space, note in particular the dorsal spinal nerve roots (the ventral roots are not seen) and the denticulate ligaments. The 3rd cervical spinal ganglia are large, and they are lodged in the intervertebral foramina. Immediately anterior to the spinal ganglion are the vertebral artery and accompanying veins, which ascend and descend through the transverse foramina. Two large venous spaces are seen between the posterior longitudinal ligament and the dura mater. These channels communicate with the internal vertebral venous plexus.
1-9 Transverse sections of spinal cord at different levels: A. Cervical region, B. Thoracic region, C. Lumbar region, D. Sacral region.

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Note that the myelin stain used has made the white matter appear dark gray or black. The white matter of the spinal cord is arranged around the gray matter in posterior, lateral, and anterior columns which become progressively smaller from upper to lower levels of the cord.

In transverse sections, the gray matter is shaped somewhat like a butterfly, and the different parts of this gray matter are referred to as the dorsal and ventral columns or horns. The central canal is extremely small, especially in the adult spinal cord, and is located within the central gray substance.

In the middle and lower cervical region the dorsal gray horns are long, fusiform and pointed posteriorly, whereas the ventral ones are broad and flared. Ventral as well as dorsal horns are slender in the thoracic region, and the lateral horn, containing the preganglionic neurons of the sympathetic nervous system, is usually discernible. Voluminous and rounded ventral horns characterize transverse sections through the lumbar region, and the dorsal horns are larger than at higher levels. When compared to other sections, the gray matter in the sacral region occupies the greatest proportion of the total area and the white matter has dwindled to a very small peripheral layer.
Differences in the section profiles also facilitate recognition of the level: cervical sections being both wide and large, thoracic sections smaller and oval-to-circular, lumbar sections circular and much larger than sacral sections. The reticular formation occupies the concavity between dorsal and ventral gray horns and is most distinct in the cervical cord section, although a trace is present also in the section of the thoracic cord.
1-10 Transverse section of the spinal cord at midthoracic level, showing approximate positions of the main tracts

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The gray matter of the spinal cord is composed of the somata of neurons plus an intricate lattice of nerve processes, and supporting cells or neuroglia. It is formed by symmetrical right and left gray horns connected by the intermediate gray substance, and the entire profile of gray matter resembles a butterfly or letter H. The central gray substance is pierced by the central canal, which is not always visible to the unaided eye. After 40 years of age, its lumen
is commonly obliterated. The ventral gray horn is separated from the surface of the spinal cord by the lateral portion of the anterior funiculus. The dorsal gray horn receives incoming or afferent fibers. It is narrow and pointed, and extends almost to the surface of the spinal cord. A cap of pale and almost translucent nervous tissue, the substantia gelatinosa, covers the apex of the posterior gray horn. A small, angular, lateral gray horn is located adjacent to the lateral white funiculus, and this collection of preganglionic sympathetic neurons can be found at all levels between the 1st thoracic and the 1st lumbar segment of the cord. Nerve cell groups in the gray horns are generally arranged in elongated groups or columns, but in most cases they are not easily identifiable without using special staining techniques.

The white matter of the cord consists mainly of longitudinally running nerve fiber tracts that are arranged in anterior, lateral, and posterior funiculi. It must be emphasized that delineation of the various ascending, descending, and intersegmental tracts as presented in this illustration is both approximate and simplified. Some fiber tracts extensively overlap each other. The fibers of some tracts are widely dispersed (the spinothalamic tract being a good example) whereas others are relatively compact and discrete. At different spinal cord levels and in different species, tracts vary in their relative positions.
Chapter 2: The Meninges and Blood Vessels of the Brain

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The Dura, Arachnoid, and Pia
The Subarachnoid cisterns
The Arteries

2-1 Adult brain and spinal cord with dural investments
2-2 Cerebral dura mater, with the superior sagittal venous sinus and its lateral lacunae opened to show the arachnoid granulations
2-3 Arachnoid granulations in lateral lacunae of the superior sagittal sinus: closeup view
2-4 Brain in its covering of dura mater, with branches of the middle meningeal artery: lateral view
2-5 Cerebral and spinal dura mater: basal view
2-6 Left half of bisected head
2-7 Arachnoid mater and granulations viewed from above
2-8 Vessels of the superolateral surface of the left hemisphere, seen through the arachnoid mater
2-9 Subarachnoid cisterns at the base of the brain
2-10 Arteries and anastomoses at the base of the brain
2-11 Superolateral surface of the left cerebral hemisphere, with main branches of the middle cerebral artery
2-12 Medial surface of the brain, with major arteries displayed
2-1 Adult brain and spinal cord with dural investments

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The outer surface of the cerebral dura mater is rough, especially where its outer, endosteal layer adheres to the circumference of the foramen magnum. The tough and dense tube of dura mater that loosely envelops the spinal cord extends from the foramen magnum to its blind ending at the level of the 2nd sacral vertebra, widening in two locations to accommodate the cervical and lumbar enlargements of the spinal cord.

The smooth outer surface of the spinal dura is accounted for by the absence of an outer, endosteal layer. On each side the spinal roots, ganglia, and proximal portions of the spinal nerves are enveloped by tubular extensions of the spinal dura. This preparation illustrates how the entire central nervous system is enclosed in a continuous dural investment.

It is attached above to the rim of the foramen magnum and to the bodies of the 2nd and 3rd cervical vertebrae. The thread of pia mater known as the filum terminale penetrates the lower end of the dural tube and anchors it to the posterior aspect of the coccyx.
2-2 Cerebral dura mater, with the superior sagittal venous sinus and its lateral lacunae opened to show the arachnoid granulations

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The cerebral dura mater which encloses the brain has been detached carefully from the internal surfaces of the cranial bones. Because the outer, endosteal layer of the dura was firmly adherent to the bone, the outer surface of the dura has a rough appearance (upon separation of dense dural connective tissue from bone). A pattern of dark lines produced by branches of the middle meningeal artery and vein is seen on both sides of the specimen, these vessels being enclosed within the outer, endosteal layer of the dura.

The superior sagittal sinus has been opened together with its lateral venous lacunae, and this has exposed the arachnoid granulations. Many openings in the walls of the superior sagittal sinus and in its lateral lacunae mark the sites of entry of superior cerebral veins into the superior sagittal sinus. Note how widely the lateral lacunae spread out in both parietal regions, and the relatively small extent of other portions of the lateral lacunae.
2-3 Arachnoid granulations in lateral lacunae of the superior sagittal sinus: closeup view

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The arachnoid granulations are bulb-like protrusions that show considerable variations in size, enlarging with age. Mostly arranged in clusters, they project principally into the lateral lacunae that are connected with the superior sagittal sinus. A coexisting microscopic form of arachnoid projections (arachnoid villi) cannot be seen but, on close inspection, a complex network of white collagen strands belonging to the internal meningeal layer of the dura is visible. The arachnoid granulations protrude between the trabeculae into the superior sagittal sinus and its lacunae. The granulations and trabeculae are covered by a smooth endothelium, and the intertrabecular spaces that are not occupied by granulations are usually the sites of openings of the superior cerebral veins into the superior sagittal sinus or one of its lacunae. The intimate relationship that exists between arachnoid granulations and the venous blood of the sinus emphasizes the crucial function of the granulations in transferring cerebral spinal fluid back into the blood stream.

1. Superior sagittal sinus
2. Arachnoid granulations
3. Openings of superior cerebral veins into superior sagittal sinus
The strong fibrous membrane that covers the brain is the cerebral dura mater. Its outer or endosteal layer has been detached from the cranial bones. Its inner or meningeal layer provides direct support for the brain. The outer surface of the dura is rough because its many fibrous attachments to the skull have been torn during preparation. The outer dura is most firmly attached along suture lines and around all foramina of the cranium. Embedded within the dense connective tissue of the outer dural layer are two major branches of the middle meningeal artery which make numerous anastomoses and supply the dura mater and the inner table of the cranial bones. Some very slender veins can be distinguished from their accompanying arteries by the darker coloration of the former. Outside the main skull cavity, dural sheaths cover the optic nerves, and the meningeal layer of dura is continuous with the sclera of the eyeball. Emerging from the middle part of the dural sac are the maxillary and mandibular divisions of the trigeminal nerve, and more posteriorly the hypoglossal nerve and some spinal nerves are shown. Outside the skull the dura fuses with the epineurium of these nerves. At the level of the foramen magnum the cerebral dura mater is continuous with the spinal dura mater.
2-5 Cerebral and spinal dura mater: basal view

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To display structures on the basal aspect of the brain with their coverings of dura, the outer, endosteal layer of dura mater has been detached from the base of the skull. Near the front of the brain, in the midline, a deep sagittal groove in the dura indicates the site where the crista galli of the ethmoid bone is accommodated. On each side of the groove the dura is rough, because of its attachment to the cribiform plate of the ethmoid bone and because it is pierced by numerous olfactory nerve bundles.
Somewhat further back, the dura has been separated from the body of the sphenoid bone. Near the midline, dura covers and conceals the optic chiasma and the pituitary gland; more laterally it provides a strong medial wall for the cavernous sinus. The endosteal dura that invests the optic chiasma can be traced from the chiasma along the optic nerve to the site at which the outer layer of the dura was cut at the entrance of the orbit. More anteriorly, the optic nerve is surrounded only by the smooth meningeal or inner layer of the dura, which blends with the sclera of the eyeball.

Note the internal carotid artery entering the cavernous sinus. The cut ends of the nerves that pass through the cavernous sinus are seen in the vicinity of the optic nerve. By tracing the maxillary and mandibular divisions of the trigeminal nerve backwards, the swelling that contains the trigeminal ganglion can be located. Lateral to the foregoing structures, two major branches of the middle meningeal artery produce wavy ridges in the dura. Behind the temporal regions, note the two wide and deep grooves which outline the petrous parts of the temporal bones. On the left side of the illustration the vestibulocochlear and facial nerves can be seen. The cerebral dura mater is continued without interruption as the tube of dura that invests the spinal cord. The level of emergence of the 1st cervical nerve or of the foramen magnum is the anatomic landmark for the transition from brain (brainstem) to spinal cord. The spinal dura lacks an outer, endosteal layer. Note the ventral and dorsal rami of cervical spinal nerves. (The 2nd spinal nerve is not present on the left side of the illustration).
2-6 Left half of bisected head

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The falx cerebri is a two-layered, sickle-shaped dural septum, which descends from the skull vault into the longitudinal cerebral fissure. One of the two layers is seen covering the medial surface of the left cerebral hemisphere. Anteroinferiorly, the falx is narrow and attached firmly to the crista galli of the ethmoid bone. The posterior part of the falx cerebri is broader and is attached in the median plane to the superior surface of the tentorium cerebelli, a sloping fold of the dura that overlies the cerebellum like a tent. Along its upper margin the two layers of the falx separate, to enclose the superior sagittal sinus. In the specimen this sinus is opened, exposing openings of superior cerebral veins and clusters of arachnoid granulations. The free, concave lower margin of the falx cerebri encloses the inferior sagittal sinus. The straight sinus, located at the site of attachment of the falx cerebri to the tentorium cerebelli, has been opened. The straight sinus, formed by the union of the inferior sagittal sinus and the great cerebral vein, is enclosed jointly by the falx cerebri and tentorium cerebelli at their site of attachment. The great cerebral vein can be seen curving below the splenium of the corpus callosum to empty into the straight sinus.
The cerebellomedullary cistern (cisterna magna) is the largest of the spaces containing cerebrospinal fluid between the arachnoid mater and the pia mater, and is located between the cerebellum and the medulla oblongata. It continues downwards without interruption into the subarachnoid space surrounding the spinal cord, and upwards and laterally into the subarachnoid space of the posterior cranial fossa. The cistern is traversed by delicate connective tissue trabeculae, which bridge across the interval between the arachnoid mater and the pia mater. The shallow pontine cistern on the ventral surface of the pons houses the basi
2-7 Arachnoid mater and granulations viewed from above

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**1. Frontal pole of cerebral hemisphere 2. Site of entry of superior cerebral vein into superior sagittal sinus 3. Arachnoid granulations 4. Longitudinal cerebral fissure 5. Occipital pole of cerebral hemisphere**

On the superolateral surfaces of both cerebral hemispheres, the arachnoid mater appears as a delicate, transparent membrane through which the contours of the cerebral gyri can be seen quite readily, together with the venous and arterial channels that traverse the subarachnoid space. Except at the site of the stem of the lateral sulcus, the meningeal arachnoid does not accompany the pia mater into the cerebral sulci, but instead bridges across them so that pia and arachnoid are in contact only on the summits of the gyri. The arteries on the brain surface possess thicker walls, are more deeply placed in the sulci, and tend to be more sinuous (particularly with advancing age) than the cerebral veins. Some of the larger veins have been cut across at their sites of entry into the superior sagittal sinus. Note the clusters of arachnoid granulations along the margins of the longitudinal cerebral fissure; these are concentrated mainly in the parietal regions.
2-8 Vessels of the superolateral surface of the left hemisphere, seen through the arachnoid mater

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The arachnoid mater is a semitransparent and delicate membrane separated from the dura mater by the subdural space. Through it, the cerebral gyri and numerous blood vessels are clearly recognizable in the subarachnoid space. The arachnoid is pushed, by the lesser wing of the sphenoid bone, into the stem of the lateral sulcus.

Elsewhere on the superolateral surface, the arachnoid bridges across the sulci. The arachnoid covers the superficial middle cerebral vein, which passes through the lateral sulcus, receiving numerous tributaries. The branches of the middle cerebral artery are more rounded, more deeply placed, and of smaller caliber than the veins. On the portion of the cerebellum that is shown, numerous veins and arteries occupy the subarachnoid space.
2-9 Subarachnoid cisterns at the base of the brain

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At certain sites on the base of the brain, the subarachnoid space is much wider than elsewhere. Some of these large spaces between the arachnoid and the pia mater—the subarachnoid cisterns—can be seen. In particular, note the voluminous subarachnoid cerebellomedullary cistern (cisterna magna). The pontine cistern located on the ventral aspect of the pons is also large, and contains the basilar artery and some of its branches. In this preparation, numerous stretched strands of connective tissue belonging to the arachnoid mater can be distinguished between the two temporal lobes. The arterial circle (of Willis) lies within the large interpeduncular cistern, which is continuous rostrally with the chiasmatic cistern, and envelops the optic chiasma. The pituitary gland itself is not surrounded by arachnoid, but by a dural covering, part of which dips in between the anterior and posterior lobes. The chiasmatic cistern is continuous laterally with the cistern of the lateral fossa, which bridges across the lateral fissure and accommodates the middle cerebral artery. The arachnoid mater is carried by the lesser wing of the sphenoid bone into the stem of the lateral fissure.
2-10 Arteries and anastomoses at the base of the brain

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The arterial circle of Willis surrounds the optic chiasma and lies mainly in the interpeduncular cistern. The anterior communicating artery links together the two anterior cerebral arteries. Each middle cerebral artery is very large and has the appearance of being a direct continuation
of the internal carotid artery. The oculomotor nerve passes between the posterior cerebral and superior cerebellar arteries.

A central system of arterial branches penetrates the surface to supply deep structures of the brain, including the basal ganglia. The majority of these branches enter the brain through the anterior and posterior perforated substance, and they do not anastomose with one another. The cortical system of arterial branches ramifies over the cerebrum to supply the cortex with arterioles that anastomose in the pia mater.

The posterior inferior cerebellar artery (PICA) arises from the vertebral artery and is its largest branch. It pursues a course on the lateral aspect of the upper part of the medulla oblongata, giving branches to the medulla, the posterior part of the inferior cerebellar surface, and the inferior vermis. On each side, the anterior spinal artery is a branch of the vertebral artery. The origins of the anterior spinal arteries are not seen in this preparation, but their common trunk can be traced down the ventral (anterior) median fissure of the medulla oblongata and the 1st segment of the spinal cord.

The large basilar artery is formed at the lower border of the pons by the union of the two vertebral arteries. In this preparation it occupies the midline groove on the ventral aspect of the pons, to which it supplies numerous slender pontine branches. Other branches that arise from the basilar artery are the labyrinthine or internal auditory, the anterior inferior cerebellar (AICA), and the relatively large superior cerebellar artery.
2-11 Superolateral surface of the left cerebral hemisphere, with main branches of the middle cerebral artery

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The middle cerebral vessels run in the stem of the lateral sulcus, and branches of the artery emerge from the stem and three (anterior horizontal, anterior ascending, and posterior) rami of the lateral sulcus. The branches run in all directions over the superolateral surface of the hemisphere. The main trunk of the middle cerebral artery cannot be seen in this preparation because it is located deep inside the lateral sulcus near the surface of the insula. Orbital branches pass on to the inferior orbital surface of the hemisphere where they anastomose with orbital branches of the anterior cerebral artery. Small branches of the anterior and posterior cerebral arteries extend from the superomedial margin of the hemisphere to supply the adjoining portion of the superolateral surface. Frontal and parietal rami of the middle cerebral artery meet and anastomose with some of these offshoots from the anterior and posterior cerebral arteries. At the lower margin of the temporal lobe, vessels derived from the middle cerebral artery anastomose with temporal branches of the posterior cerebral artery. The middle cerebral artery supplies very important cortical areas, including motor, premotor, sensory, auditory and association regions of the cerebral cortex.
2-12 Medial surface of the brain, with major arteries displayed

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The final segment of the left vertebral artery is seen at the lower border of the pons, close to the union with its fellow where the two vessels form the basilar artery. After giving off pontine and other branches, the basilar artery divides into two posterior cerebral arteries at the upper border of the pons. The posterior cerebral arteries give rise to branches that supply the medial surface of the occipital lobes. Other branches assist in supplying the superolateral and inferior surfaces of the hemisphere. Note the parieto-occipital and calcarine branches, the latter being of great importance because it supplies primary visual cortex.

The anterior cerebral artery can be seen running on the medial surface of the hemisphere, first beneath and then around the genu of the corpus callosum. Its branches are cortical and central (the latter supplying structures in the interior of the brain). Some of the frontal branches of the anterior cerebral artery ramify on the medial surface of the frontal lobe; others pass to the inferior surface as orbital branches, which anastomose with orbital branches of the middle cerebral artery. Both frontal and parietal branches of the anterior cerebral artery traverse the cingulate sulcus and the surface of the medial frontal gyrus, and terminal twigs supply a strip
on the adjoining part of the superolateral surface of the hemisphere. After giving off the branches described above, the anterior cerebral artery continues backwards as an artery of greatly diminished caliber deep in the callosal sulcus. The distribution of the branches of the anterior cerebral artery can be examined by using arteriograms of the internal carotid artery.

Many arterial branches arise from the vertebral and basilar artery to supply the medulla oblongata and the pons. In addition, relatively small branches of the posterior cerebral and posterior communicating arteries penetrate the posterior perforated substance to reach the midbrain tegmentum.
Chapter 3: The Cerebellum

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External features
Nuclei and associated fiber tracts

3-1: Superior surface of the cerebellum
3-2: Cerebellum: posterosuperior view
3-3: Cerebellum: inferior view
3-4: Cerebellum: anteroinferior surface
3-5: Cerebellum sectioned sagittally to show the entire vermis
3-6: Inferior surface of the cerebellum
3-7: Deep cerebellar nuclei and associated fiber tracts: dorsal view
3-8: Deep cerebellar nuclei and associated nerve bundles: ventral view
3-9: Left side: horizontal section through the cerebellar hemisphere at the level of the dentate nucleus. Right side: dorsal view of deep cerebellar nuclei and associated outflow tracts.
3-1: Superior surface of the cerebellum

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Laterally, the two large masses are the cerebellar hemispheres, joined to each other by the narrow median vermis. The laminations of the cerebellar cortex are very distinctive. Parallel fissures and sulci are interposed between the thin, transversely running folia of the cerebellar cortex. The median portion or vermis forms a low ridge from which the lobules of the hemispheres slope gently downwards and laterally. The primary fissure is deep and sharply delimits the culmen from the declive of the vermis; then it extends anterolaterally across the superior surface of the hemisphere, separating the quadrangular lobule from the more posterior lobulus simplex. The voluminous superior semilunar lobule occupies the area posterior to the lobulus simplex, whereas only a thin strip of the inferior semilunar lobule appears at the posterior edge of the surface.
3-2: Cerebellum: posterosuperior view

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The superior vermis forms the apex or median ridge, and is not clearly demarcated from the corresponding portions of the cerebellar hemispheres which slope downwards toward the margins. Anteriorly, the culmen of the vermis and the declive behind it are associated respectively with the quadrangular lobule and the lobulus simplex of the cerebellar hemisphere. Note that the two extensive superior semilunar lobules are related across the midline by the diminutive folia of the vermis. Below the latter is the tuber of the vermis, which connects the two inferior semilunar lobules. The deep horizontal fissure separates between the inferior and superior semilunar lobules.
3-3: Cerebellum: inferior view

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The inferior folia of the vermis project from the floor of a deep hollow known as the vallecula of the cerebellum, which separates the two cerebellar hemispheres. The pyramis of the inferior vermis is a prominent eminence composed of about six folia, lodged in a deep sulcus or furrow which sets it apart from its lateral extensions - the massive biventral lobules. Posterior to the pyramis, the few folia of the tuber can be seen, flanked by the inferior semilunar lobules. The portion of the vermis immediately anterior to the pyramis, the uvula, is overlapped by the prominent tonsils, which are lobules of cerebellar hemisphere. The tonsils are continuous with the uvula across the floor of the vallecula and well separated from the remainder of the inferior surface of the hemisphere. On each side, the cerebellar hemisphere fits into the posterior cranial fossa. (Branches of the anterior inferior and the posterior inferior cerebellar arteries, derived from the basilar and vertebral arteries respectively, are lodged in the numerous shallow grooves seen in the surface of the cerebellum.)
3-4: Cerebellum: anteroinferior surface

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Several parts of the vermis (together with corresponding parts of the cerebellar hemispheres) are shown, as well as the general arrangement of the inferior, middle and superior cerebellar peduncles. The lingula of the vermis is a rather thick structure, firmly attached to the superior medullary velum. Immediately above the lingula, four or five folia constitute the central lobule of the vermis, which is continuous laterally with the ala of the central lobule. In the midline, above the central lobule, the culmen projects above the rest of the superior surface of the cerebellum.

Separated from the lingula by a deep, wide fissure - the superior recess of the 4th ventricle - are the folia of the nodulus. Attached to each side of the nodulus is a thin, white lamina, the inferior medullary velum. The inferior medullary velum connects the nodulus to the peduncle of the flocculus and to the flocculus itself, the scalloped margin of which protrudes from the remainder of the cerebellum. The lingula and the flocculo-nodular complex are related topographically and functionally, all of them being archicerebellar and all of them making predominantly vestibular connections.

Below the nodulus and separated from it by the posterolateral fissure is the uvula of the vermis, and the pair of prominent tonsils that partially overlap the uvula. In this preparation the tonsils are somewhat irregular and asymmetric masses of cerebellar cortex.

Lateral to the tonsils lie the large, irregular biventral lobules. Superomedial to each flocculus is the oval profile formed by the cut surfaces of the middle and inferior cerebellar peduncles, which are not clearly demarcated from one another in this preparation. Most of the fibers in
the superior cerebellar peduncle, which is more medially placed, are ascending to project to the thalamus and to the red nucleus of the midbrain.

3-5: Cerebellum sectioned sagittally to show the entire vermis

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White matter that constitutes the core of the vermis is a narrow white zone from which primary white strips diverge; these in turn give rise to secondary white processes, more or less at right angles to the primary ones. Secondary processes may give rise to other processes, all of which reach the cortical gray matter. The whole structure has the appearance of a tree with branches, and is known as the arbor vitae. The lingula of the vermis is slender, and applied closely to the superior medullary velum. The nodulus of the vermis is more bulky, and attaches on each side to the inferior medullary velum. There is a deep, transverse fissure between the lingula and the nodulus, producing a recess in the roof of the 4th ventricle. The wide and deep primary fissure is an easily recognizable landmark, separating the culmen from the declive.
The tonsils and a large part of the biventral lobules have been removed. In the midline, the tuber, pyramis, uvula, and nodulus are seen on the inferior aspect of the vermis. In the lower part of the illustration is the cut surface of the medulla oblongata and a view of the ventral pons from below. Lateral to the nodulus is a thin, white lamina - the inferior medullary velum - which extends in a lateral direction into the peduncle of the flocculus.

The thin, dark, and highly vascular tela choroidea of the 4th ventricle is attached to the posterior margin of the inferior medullary velum and the peduncle of the flocculus. Two processes of the tela choroidea constitute the choroid plexuses of the 4th ventricle, and these can be seen near the midline through the transparent tela choroidea. The choroid plexuses extend in a lateral direction across the inferior cerebellar peduncle, and they protrude through the lateral apertures of the 4th ventricle (foramina of Luschka).
3-7: Deep cerebellar nuclei and associated fiber tracts: dorsal view

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The deep (intra-) cerebellar nuclei and outflow tracts have been isolated and are seen against a white background provided by the medullary substance of the cerebellum. The dentate nucleus is characterized by well-defined, almost parallel bars of gray matter, which are separated from each other by deep grooves, the contours having been filled with white, medullary substance. The main bulk of the superior cerebellar peduncle issues from the ventral aspect of the dentate nucleus.

The other smaller cerebellar nuclei are situated medial to the dentate. The fastigial nucleus is most medially placed, incorporated in the white substance of the anterior part of the superior vermis and forming a part of the roof of the 4th ventricle. On each side, ventrolateral to the fastigial nucleus, two small globose nuclei can be identified, while the emboliform nucleus occupies a more lateral position. In this preparation the right emboliform nucleus is concealed by the medial margin of the right dentate nucleus. Delicate fiber tracts from these small cerebellar nuclei join together and subsequently merge with the main part of the superior cerebellar peduncle. The thin but distinct fiber bundle proceeding from the fastigial nucleus travels within the lateral margin of the superior medullary velum, presumably constituting the uncrossed component of the superior cerebellar peduncle, destined for the brain stem reticular formation. Note the fibers of the lateral and medial lemnisci arching around the dorsolateral aspect of the superior cerebellar peduncle to enter the midbrain tegmentum. Each trochlear
nerve makes its exit through the caudal tectum (the dorsal portion of the midbrain), immediately lateral to the frenulum of the superior medullary velum.

3-8: Deep cerebellar nuclei and associated nerve bundles: ventral view

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The ventral parts of the vermis and cerebellar hemispheres have been dissected away. On each side, the dentate nucleus possesses numerous nodules of gray matter, arranged somewhat unevenly. These form the ventral terminations of gray columns which are seen in longitudinal array on the dorsal aspect of the dentate nucleus. A profusion of white fibers issuing from the ventral aspect of the dentate nucleus converge rostrally to form the main part of the superior cerebellar peduncle.

The other cerebellar nuclei are seen more medially. Near the midline, isolated in the white matter of the roof of the 4th ventricle, are the rather large, spherical fastigial nuclei. Two globose nuclei are present on each side; one is immediately lateral to the fastigial nucleus and the other is located more posteriorly against the elongated emboliform nucleus. A delicate fiber bundle emerges from each nucleus and joins the superior cerebellar peduncle. The bulky superior cerebellar peduncles cross each other to form the decussation of the superior cerebellar peduncles, located within the midbrain tegmentum.
3-9: Left side: horizontal section through the cerebellar hemisphere at the level of the dentate nucleus. Right side: dorsal view of deep cerebellar nuclei and associated outflow tracts.

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The cerebellar nuclei are presented in contrasting ways. On the left side, the gray laminae of the dentate nucleus surround the myelinated outflow tract which, issuing from the hilus, forms the bulk of the superior cerebellar peduncle.

The dissected right cerebellar hemisphere illustrates the deeply fluted columns of the dentate nucleus together with the smaller, more medially located globose, emboliform, and fastigial nuclei. These smaller nuclei are not easily observed in sections. Note that the main outflow pathways of all the deep cerebellar nuclei tend to be in alignment, and that the dentate nucleus makes the largest contribution to the superior cerebellar peduncle.
Chapter 4: The Brainstem

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Surface views of the brainstem and some special dissections
Sections through representative levels

4-1: Left cerebellar hemisphere and brainstem: lateral view
4-2: Basal aspect of cerebellum and brainstem, showing cranial nerve attachments and some internal features of the medulla oblongata
4-3: Ventral surface of medulla oblongata and pons
4-4: Brainstem: dorsal view
4-5: Medulla oblongata, pons, midbrain and insula: lateral view
4-6: Cerebellum and rostral portion of the brainstem: dorsal view
4-7: Transverse section of lower medulla oblongata through the pyramidal (motor) decussation (Weigert stained)
4-8: Transverse section of medulla oblongata, through the decussation of the medial lemnisci (Weigert stained)
4-9: Transverse section of medulla oblongata through midolivary region (Weigert stained)
4-10: Transverse section through lower pons, at the level of the facial colliculi (Weigert stained)
4-11: Transverse section of pons, through the trigeminal nerve (Weigert stained)
4-12: Transverse section through the upper part of the pons (Weigert stained)
4-13: Transverse section through midbrain at the level of the inferior (caudal) colliculi and through the ventral pons (Weigert stained)
4-14: Transverse section through upper midbrain at the level of the superior (cranial) colliculi (Weigert stained)
4-1: Left cerebellar hemisphere and brainstem: lateral view

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The middle cerebellar peduncle, which passes backwards and laterally from the pons into the cerebellar hemisphere, has been removed. The inferior cerebellar peduncle crosses the superior cerebellar peduncle. Most of the hemispheric terminations of the inferior cerebellar peduncle have been removed, but its branches of distribution to the cortex of the vermis remain. The dorsal surface of the dentate nucleus has been cleaned. Its efferents pass in a cranial direction into the midbrain through the superior cerebellar peduncle.

The descending fibers of the spinal tract of the trigeminal nerve can be observed ventromedial to the inferior cerebellar peduncle. The lateral and medial lemnisci are gathered together in a large bundle that passes around the dorsolateral surface of the superior cerebellar peduncle to reach the midbrain tegmentum. In the lower pontine region, fibers of the trapezoid body can be seen emerging from the lateral aspect of the medial lemniscus (which they have pierced); these turn upwards to form the lateral lemniscus, which ascends through the pons and midbrain to terminate in the inferior colliculus in the midbrain. At the medullary level, the medial lemniscus (which contains the 2nd neuron axons in the pathway for proprioceptive and
tactile sensations) is found dorsal to the pyramidal tract and medial to the olivary nucleus. The disposition of the medial lemniscus alters in the upper part of the medulla so that, as it enters the pons, it spreads out horizontally (that is, from side to side), as can be seen in the photograph of a transverse section through the lower pons (4-10).

The olivary nuclear complex has been dissected out from its capsule of myelinated fibers (sometimes referred to as the amiculum of the olive). Note the longitudinal grooves on the surface of the olivary nucleus. The lower part of the olive has been left undisturbed. The external arcuate fibers curving backwards across its surface converge to join the inferior cerebellar peduncle.
4-2: Basal aspect of cerebellum and brainstem, showing cranial nerve attachments and some internal features of the medulla oblongata

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The pyramidal tracts in the ventral portion of the medulla oblongata have been exposed. Traced caudalward, the tracts begin to reorganize in the pyramidal decussation (see section 4-7 through the medulla). At the level of decussation, the ventral (anterior) gray column of the spinal cord is separated from the central gray matter by the bundles of decussating fibers. The ventral gray matter of the cord continues cranialward uninterrupted into the hypoglossal nucleus. The surface of the olivary nucleus on the right side has been cleaned to display the longitudinally and obliquely placed gray ridges on its convex outer surface. The olivary nucleus extends upwards almost to the pontine level.
4-3: Ventral surface of medulla oblongata and pons

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Removal of the meninges and some cranial nerve roots allow salient features of the ventral or anterior aspect of the medulla and pons to be examined more easily. The deep anterior median fissure of the spinal cord is continued into the medulla oblongata, but is interrupted in the lower part of the medulla by descending corticospinal fibers which leave the pyramids in successive bundles to cross obliquely to the opposite sides, thereby forming the pyramidal decussation. These decussating bundles can be seen distinctly between the lips of the ventral median fissure. The pyramids rapidly diminish in size at the level of the decussation, reflecting the fact that the great majority of corticospinal fibers leave the pyramids at the decussation. On the surface of the left pyramid (right side of the illustration), a ridge is created by a large group of fibers that leave the pyramid and arch around the lower end of the olive. This ridge is the surface landmark for the circumolivary bundle, which forms part of the so-called aberrant corticopontocerebellar pathway. The latter terminates on the nucleus of the
circumolivary bundle, which lies against the dorsolateral surface of the inferior cerebellar peduncle.

Note the great girth of the pons, caused by transversely oriented pontocerebellar fibers which enter the thick, compact middle cerebellar peduncles. The shallow midline basilar sulcus marks the position of the basilar artery and is accounted for by the presence, on each side, of descending corticospinal fibers which tunnel through the ventral pons to reach the pyramids of the medulla.

4-4: Brainstem: dorsal view

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Dorsal surfaces of the medulla oblongata, pons, midbrain, and part of the diencephalon are shown after removal of the cerebellum. Key features are the cut surfaces of the cerebellar peduncles and the diamond-shaped floor of the 4th ventricle with its striae medullares. The
posterior part of the pineal body is seen above and between the two superior colliculi of the midbrain. Between the two inferior colliculi the frenulum of the superior medullary velum is attached to the lamina tecti. On each side of the frenulum, just caudal to (below) the inferior colliculus, the trochlear nerve emerges. Medial and lateral geniculate bodies are located against the inferior aspect of the pulvinar of the thalamus.
4-5: Medulla oblongata, pons, midbrain and insula: lateral view

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The insula is a portion of the cerebral cortex that is not visible until the margins of the lateral sulcus are opened up, or, as in this case, removed. The insular cortex is roughly triangular. Branches of the middle cerebral artery and the deep cerebral veins have been removed to display the sulci and gyri. Originally part of the superficial cortex, in higher mammals it became submerged beneath the expanding cortex around it, thereby remaining relatively close to the basal ganglia of the hemisphere. Complete submergence of the insular cortex is a feature of the human brain and is not found even in other primates. Between the superior cerebellar peduncle and the basis pedunculi, the fibers of the lateral lemniscus ascend at the surface of the midbrain tegmentum. The majority of nerve fibers in the superior cerebellar peduncle arise from cell bodies in the deep cerebellar nuclei. The middle cerebellar peduncle

is much the largest of the three cerebellar peduncles and is situated lateral to the other peduncles. It is composed of the transverse pontocerebellar fibers, which arise from pontine nuclei, the second neurons of the extensive corticopontocerebellar pathway. The inferior cerebellar peduncle connects the spinal cord and medulla to the cerebellum, entering through the slot between the middle peduncle (laterally) and the superior peduncle (medially). The superior cerebellar peduncles travel into the tegmentum of the midbrain. Prominent in a lateral view of the medulla is the oval, circumscribed elevation known as the olive. The fibers of the circumolivary bundle arch around its lower end.
4-6: Cerebellum and rostral portion of the brainstem: dorsal view

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The primary fissure cuts deep into the dorsal surface of the cerebellum, separating the culmen and quadrangular lobule from the decline and its hemispheric extension, the lobulus simplex. The folium and the tuber of the vermis, together with the superior and inferior semilunar lobules of the hemispheres, are readily seen. Immediately in front of the pineal body is the thin white habenular commissure. On each side, the habenular nucleus causes a protrusion at the surface of the habenular trigone. Extending anteriorly from the habenular trigone is a white matter fiber tract - the stria medullaris thalami - which connects the habenular nucleus.
with hypothalamic and septal nuclei. Removal of the crura and the body of the fornix has left 
the medial part of the dorsal surface of the thalamus rather rough, whereas the lateral part is 
cov- ered by the smooth lamina affixa. The sharp medial margin of the lamina affixa - the 
tenia choroidea - marks the line of attachment of the tela choroidea of the lateral ventricle. 
More anteriorly, note the lamina of the septum pellucidum on each side of the cavum of the 
septum pellucidum.
4-7: Transverse section of lower medulla oblongata through the pyramidal (motor) decussation (Weigert stained).

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At the level of the foramen magnum, where the spinal cord ends and the medulla oblongata begins, the gray matter undergoes a marked reorganization. In the decussation of the pyramids, the bundles of corticospinal fibers are interposed between the ventral gray matter and the central gray substance. The central canal and surrounding gray matter appear as though pushed dorsally by the decussating bundles of axons. The great majority of the pyramidal fibers which arise in the cerebral cortex and descend through the pyramids of the medulla cross in the decussation, most of the remainder forming the uncrossed ventral corticospinal tract. The latter peters out in the thoracic spinal cord as its axons gradually cross to reach the ventral gray horn of the opposite side.
Adjacent to the dorsal median septum is the gracile nucleus, skirted by the gracile fasciculus, which comes to an end as its primary sensory axons terminate in the nucleus of the same name. Projecting posteriorly from the dorsal horn is the most caudal part of the cuneate nucleus, which becomes more prominent at higher levels. The cuneate fasciculus covers its nucleus and occupies the area immediately lateral to the gracile fasciculus. The spinal (inferior) nucleus of the trigeminal nerve - which extends from the upper cervical spinal cord, throughout the whole length of the medulla oblongata, and into the lower pons - is a much expanded counterpart of the substantia gelatinosa found in the dorsal gray horn of the spinal cord. The spinal tract of the trigeminal nerve is a narrow band of primary sensory nerve fibers interposed between the spinal nucleus of the trigeminal and the periphery of the medulla oblongata.
4-8: Transverse section of medulla oblongata, through the decussation of the medial lemnisci (Weigert stained)

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The gracile nucleus is located in the gracile tubercle (clava), medial to the dorsal median septum, and surrounded by a thin rim of nerve fibers belonging to the gracile fasciculus, which terminates in the nucleus. The more lateral cuneate nucleus has a wider fringe of fibers at this level - the cuneate fasciculus.

The sensory decussation is the key feature of this section. Numerous internal arcuate fibers arise from gracile and cuneate nuclei, take a semicircular course through the reticular
formation and around the central gray substance, and decussate with the corresponding fibers of the opposite side to form the sensory decussation. The curving internal arcuate fibers pass between the spinal (inferior) nucleus of the trigeminal nerve and the central gray matter. After decussating, these fibers ascend in a compact, ribbon like tract called the medial lemniscus. Dorsolateral to the pyramidal tract, the medial accessory olivary nucleus, which is not present at lower levels, has just appeared. In the ventral part of the central gray is the hypoglossal nucleus, the main source of motor fibers to the tongue. Some fibers of the hypoglossal nerve can be traced through the reticular formation as they course towards the ventrolateral sulcus.
The inferior olivary nucleus is conspicuous, and the dorsal and medial accessory nuclei are seen also. The inferior olivary nucleus is a crenated, thin gray lamina with a well defined hilus through which a multitude of olivocerebellar tract fibers issue, traversing the medial lemnisci and the olivary nucleus of the opposite side to enter the contralateral inferior cerebellar peduncle.
Several nuclei can be recognized in the floor of the 4th ventricle. Most medial is the circular profile of the hypoglossal nucleus, representing the somatic motor column of brainstem nuclei. Fibers of the hypoglossal nerve take a ventrolateral course and emerge between the olive and pyramid. More laterally placed are the dorsal motor nucleus of the vagus (a general visceral motor nucleus) and the medial and inferior vestibular nuclei (special somatic afferent nuclei). Ventrolateral to the dorsal motor nucleus of the vagus is the solitary nucleus of the solitary tract, concerned with visceral sensation (general visceral afferent component) and taste (special visceral afferent component). It is thought that axons from nerve cells of the solitary nucleus project to the thalamus, with subsequent relay of information to the cerebral cortex. The spinal nucleus of the trigeminal nerve, with its tract placed lateral to it, is classified as a general somatic afferent nucleus.

The medial longitudinal fasciculus and the tectospinal tract are located close to the median raphe, ventromedial to the hypoglossal nucleus. Dorsal to the olivary nuclei is the extensive reticular formation of the medulla, composed of diffusely disposed neurons interspersed by ascending and descending myelinated axons belonging to a variety of pathways.
4-10: Transverse section through lower pons, at the level of the facial colliculi (Weigert stained)

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Transverse sections through the pons show that it consists of two parts - the basilar, or ventral pons, and the dorsally located pontine tegmentum.

The facial colliculi are marked prominences in the floor of the 4th ventricle. Each facial colliculus is produced by the underlying nucleus of the abducens nerve together with the genu of the facial nerve curving around the nucleus. The facial nucleus itself is placed more
ventrally, and the unusual course of its axons--prior to their emergence from the brain at the cerebellopontine angle--is worthy of attention.

The medial longitudinal fasciculus occupies its characteristic paramedian position. The ascending fibers of the medial lemniscus are intersected by transversely running fibers of the trapezoid body, which then turn upwards and become aggregated to form the lateral lemniscus. The spinal and trigeminal lemnisci are also located in the ventral part of the pontine tegmentum.

Lateral to the abducens nucleus is the lateral vestibular nucleus, which gives rise to the vestibulospinal tract; ventrolateral to the abducens nucleus are the spinal nucleus and spinal tract of the trigeminal nerve. In the ventral portion of the pons are the scattered nests of cells that constitute the pontine nuclei, together with transverse pontine fibers which come together dorsolaterally in the massive middle cerebellar peduncles. Corticospinal and corticobulbar fibers descend in large bundles at this level, destined for the pyramids of the medulla oblongata.
4-11: Transverse section of pons, through the trigeminal nerve (Weigert stained)

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In the ventral pons, bundles of motor fibers - corticopontine, corticobulbar, and corticospinal - continue their descent from the basis pedunculi. In addition to these corticofugal fibers, the ventral pons contains the transversely oriented pontocerebellar fibers and the widely scattered pontine nuclei that give rise to them. The transverse pontocerebellar fibers arising from each side cross the midline to enter the cerebellum via the contralateral middle cerebellar peduncles. The mingling of gray and white matter in the ventral part of the pons produces a striped appearance which is similar at all pontine levels.
The dorsal part of the pons - pontine tegmentum - varies in its internal structure at different levels. The level illustrated contains both sensory and motor trigeminal nuclei. The sensory trigeminal nucleus lies ventral to the superior cerebellar peduncle and medial to the middle cerebellar peduncle. The motor nucleus is medial to the sensory nucleus, and both nuclei are in line with the oblique axis of the trigeminal nerve which pierces the ventrolateral part of the pons. In this section the medial lemniscus is located near the ventral border of the pontine tegmentum, separated by a short interval from the median raphe. Note the locations of the trigeminal, spinal, and lateral lemnisci. The medial longitudinal fasciculus retains its paramedian position, and the central tegmental tract is surrounded by the loose substance of the reticular formation, situated dorsal to the medial lemniscus.
4-12: Transverse section through the upper part of the pons (Weigert stained)

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The 4th ventricle is diminished compared to its size in lower sections through the pons. This ventricle is continued cranially into the cerebral aqueduct of the midbrain. The superior medullary velum constitutes the thin roof of the ventricle, which stretches between the two superior cerebellar peduncles. In the lateral margin of the central gray matter is the slender mesencephalic tract of the trigeminal nerve, with the mesencephalic nucleus placed on its medial side. The medial longitudinal fasciculus is found in its characteristic paramedian position. The central tegmental tract is a large bundle cut transversely as it passes through the pontine reticular formation.

In the lateral part of the tegmentum of the pons are four lemnisci (ribbons of white matter). At this level the medial lemniscus is oriented transversely and lies against the ventral part of the
tegmentum. The spinal lemniscus lies lateral to the medial lemniscus, and the trigeminal lemniscus lies dorsolateral to it. The lateral lemniscus is a vertically oriented strip of white matter ascending close to the lateral margin of the pontine tegmentum. These four pairs of lemnisci proceed rostrally into the tegmentum of the midbrain.

The ventral (basilar) pons contains chiefly pontine nuclei and white matter comprising transverse pontocerebellar fibers intersecting longitudinal bundles of corticospinal, corticopontine and corticobulbar fibers. The pontocerebellar fibers connect pontine nuclei with the cerebellar cortex of the opposite side, via the middle cerebellar peduncles.
4-13: Transverse section through midbrain at the level of the inferior (caudal) colliculi and through the ventral pons (Weigert stained)

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When sections are made through the brainstem, elements of the ventral part of the pons (which in man is very extensive) are commonly included with lower midbrain sections. At this level the most valuable aid to identification of the brainstem level is the decussation of
the superior cerebellar peduncles, which occupies a large part of the lower midbrain tegmentum. Situated more dorsally is the cerebral aqueduct and, in the ventral margin of the gray matter surrounding the aqueduct, the trochlear nucleus. Just ventral to this nucleus is the medial longitudinal fasciculus which extends throughout the brainstem in this characteristic paramedian position. More laterally is a wide area occupied by the reticular formation of the midbrain tegmentum. This area is interrupted by the longitudinally directed central tegmental tract. The peripheral part of the tegmentum accommodates four pairs of lemnisci. The medial lemniscus is detectable in this preparation as a narrow, dark strip; the trigeminal lemniscus (trigemino-thalamic fibers) and spinal lemniscus (spinothalamic fibers) being located dorsoiateral to it. The medial and spinal lemnisci are pathways by which sensory information is transmitted from one half of the body to the thalamus of the opposite side; the trigeminal lemnisci convey sensations from the head region primarily to the thalamus of the opposite side. The lateral lemniscus carries auditory information, and is a narrow ribbon of fibers all of which eventually synapse in the gray matter of the inferior colliculus. The brachium of the inferior colliculus emerges from the inferior colliculus, carrying fibers to the medial geniculate body.
4-14: Transverse section through upper midbrain at the level of the superior (cranial) colliculi (Weigert stained)

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The superior colliculi are a pair of ovoid masses composed of alternating layers of gray and white matter. They are centers for visual reflexes and ocular movements, and their connections to other structures in the brain and spinal cord are varied and complex. Some of these include the retina, visual and nonvisual cerebral cortex, inferior colliculus, paramedian pontine reticular formation, thalamus, basal ganglia, and spinal cord ventral gray horn. The large nucleus of the medial geniculate body is lodged between the superior colliculus and the basis pedunculi, and receives the fibers of the brachium of the inferior colliculus. The motor nucleus of the oculomotor nerve is located in the ventral part of the central gray substance, and the fibers of the medial longitudinal fasciculus form a fringe on its ventrolateral side. The red nucleus is a landmark that distinguishes this brainstem level. Running through the medial part the red nucleus are axons that originate in the oculomotor nerve nuclei. These darkly staining fibers of the oculomotor nerve then pass through the medial part of the substantia nigra to enter the interpeduncular fossa. Note the positions of the three lemnisci in the lateral
part of the midbrain tegmentum, the medial lemniscus being ventrally placed. The basis pedunculi contains corticospinal and corticobulbar fibers which occupy the middle third of the basis, and corticopontine fibers which occupy the medial and lateral portions.
Chapter 5: The Cerebral Hemispheres

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External and Internal Structure of the Cerebral Hemispheres
Basal Ganglia, Major Fiber Systems, Nuclei, and Ventricles
Horizontal and Coronal Sections of the Brain

5-1: Cerebral hemispheres from above (meninges and blood vessels removed). In this view, the cerebrum conceals other parts of the brain.
5-2: Superolateral surface of right cerebral hemisphere, showing sulci and gyri
5-3: Medial surface of the brain, with blood vessels removed
5-4: Medial surface of right cerebral hemisphere, with blood vessels removed
5-5: Inferior surface of the brain with cranial nerve attachments, after removal of meninges and superficial blood vessels
5-6: Inferior surface of the brain after transection through lower midbrain and removal of cerebellum
5-7: Association tracts in the medial part of the cerebrum: right hemisphere
5-8: Caudate nucleus, thalamus and upper brainstem structures: right side of brain, from the medial aspect
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5-11 Caudate nucleus, amygdaloid body, stria terminalis, corona radiata, and internal capsule: right cerebral hemisphere from the medial side
5-12 Corona radiata, internal capsule and basis pedunculi arising from the left cerebral hemisphere
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5-17 Globus pallidus of lentiform nucleus, internal capsule, and corona radiata: left hemisphere from the lateral aspect
5-18 Corona radiata, internal capsule, anterior (rostral) commissure, and some association tracts: left hemisphere from the lateral aspect
5-19 Basal ganglia; dissection of left cerebral hemisphere from the lateral aspect
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5-21 Corpus callosum, its radiation, and indusium griseum displayed from above
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5-23 Internal features of cerebellum, midbrain, diencephalon, and telencephalon: ventral aspect of dissected brain
5-24 Visual pathway from optic chiasma to occipital lobes, viewed from the basal aspect
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5-26 Dentate gyri, amygdaloid bodies
5-27 Horizontal section through the dorsal lateral nucleus of the thalamus
5-28 Horizontal section through middle of thalamus
5-29 Horizontal section through middle of corpus striatum
5-30 Coronal section through the anterior part of the corpus striatum
5-31 Coronal section through the anterior (rostral) commissure and optic chiasma
5-32 Coronal section through the tuber cinereum and lentiform nucleus
5-33 Coronal section through mamillary bodies
5-34 Coronal section through thalamus, temporal horn of lateral ventricle, and posterior limb of internal capsule
5-35 Coronal section through thalamus, choroid fissure, basis pedunculi, and ventral part of pons
5-36 Coronal section through posterior (epithalamic) comissure
5-1: Cerebral hemispheres from above (meninges and blood vessels removed). In this view, the cerebrum conceals other parts of the brain.

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The brain is ovoid, broader behind than in front. The longitudinal cerebral fissure is a narrow cleft that normally contains the falx cerebri (made of dura), arachnoid, pia, and cerebral arteries and veins, in particular the anterior cerebral vessels. The superolateral surface of each cerebral hemisphere is markedly convex and fits into the corresponding half of the skull vault. In this specimen, some atrophy of the cortex has resulted in separation of the gyri, so that the convolutions of the cerebral cortex are readily appreciated. There is considerable individual variation in the patterns of gyri, and even the two sides of a brain differ in the arrangement of their convolutions. Interlocking gyri belonging to the right superior frontal gyrus are seen on the right side of the brain. In the central sulcus of the left hemisphere, a short transverse gyrus is seen. Note: This specimen shows considerable atrophy, which enhances demonstration of the sulci.
5-2: Superolateral surface of right cerebral hemisphere, showing sulci and gyri

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The stem of the lateral sulcus is a deep transverse furrow, from which the middle cerebral vessels have been removed. Above the temporal pole of the hemisphere, the posterior ramus of the lateral sulcus is a long cleft that runs backwards with an upwards inclination, and it enters the inferior parietal lobule where it may terminate in a T-shaped manner. The anterior horizontal and anterior ascending rami of the lateral sulcus are well developed, although in other specimens they may be less easy to identify. On the left side of the brain (in most individuals), the opercular and triangular parts of the inferior frontal gyrus are referred to as Broca's area, which is associated with motor elements of speech. The lower part of the precentral gyrus is very wide and incompletely subdivided by longitudinal sulci. To some extent the same applies to the lower portion of the postcentral gyrus. The supramarginal and angular gyri are located respectively around the terminal parts of the posterior branch of the lateral sulcus and the superior temporal sulcus. The cortex of the angular gyrus is important because it is involved in relating visual impressions to stereognostic impressions (appreciation
of the nature of objects by means of touch). Two temporal sulci divide the temporal lobe into three temporal gyri. The superior temporal gyrus is continued without interruption into the transverse temporal gyrus, these areas of cortex being regions for receiving and processing auditory sensations. Note: The atrophy in this specimen, especially in the frontal, parietal, and temporal lobes, emphasizes the appearance of the sulci.

5-3: Medial surface of the brain, with blood vessels removed

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The cingulate sulcus begins below the rostrum of the corpus callosum and arches in front of the genu of the corpus callosum, about a finger's breadth distant from it. Above the splenium of the corpus callosum, the cingulate sulcus turns abruptly upwards to reach the superior margin of the hemisphere.

Where the precentral and postcentral gyri come together, the central sulcus cuts into the paracentral lobule. Voluntary control over defecation and micturition reflexes is ascribed to this lobule.

The cingulate gyrus is a long strip of cortex that curves around the corpus callosum. Posteriorly, it becomes very narrow under the splenium of the corpus callosum and is continuous with the isthmus, which separates the splenium from the calcarine sulcus or
fissure. The cingulate gyrus has profuse reciprocal connections with the anterior thalamic nuclei and is an important constituent of the limbic system. Note the deep parieto-occipital sulcus, running downwards and forwards to the calcarine sulcus. The cuneus is a wedge of cortex enclosed by the parieto-occipital and the calcarine sulci and the superomedial margin of the hemisphere. It contains part of the center for vision. In the brainstem, the medial longitudinal fasciculus is a well-defined white bundle, descending through the midbrain tegmentum, adjacent to the central gray matter. As it approaches the pontine region it gradually adopts a more dorsal position.
5-4: Medial surface of right cerebral hemisphere, with blood vessels removed

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1. Medial frontal gyrus  2. Cingulate gyrus  3. Central sulcus

Most of this surface is separated from the left hemisphere by the falx cerebri (dura mater), but the subcallosal area (which is below the rostrum of the corpus callosum) is separated from that of the other side by pia-arachnoid only, so that the gyri of the two sides may interlock. The anterior part of the cingulate sulcus is somewhat foreshortened and narrow in this specimen, with a corresponding increase in the paracentral lobule. The paracentral lobule is cut very deeply by the central sulcus (of Rolando). The motor and sensory areas for the lower part of the left lower limb are, respectively, anterior and posterior to this (medial) segment of the central sulcus.

The paraterminal gyrus is closely applied to the anterior surface of the lamina terminalis, and is separated from the cingulate gyrus by a shallow furrow. Primitive in its cytoarchitecture, the thin cortex of the paraterminal gyrus extends on to the inferior surface of the rostrum of the corpus callosum, spreading out to form part of the indusium griseum, which is found on the superior surface of the corpus callosum and is widely regarded as a primitive cortex and a hippocampal vestige. Beneath the splenium of the corpus callosum, the parahippocampal gyrus bifurcates. The upper part extends over the isthmus to become the cingulate gyrus. The
lower part expands backwards to become the lingual gyrus, which is the cortical area below the calcarine sulcus or fissure. The posterior part of the calcarine sulcus has been referred to as an "axial sulcus" because it runs longitudinally through the visual striate area and its margins contain much of the center for vision. The anterior part of the calcarine sulcus, after it has been joined by the parieto-occipital sulcus, has been referred to as a "limiting sulcus," because it separates the visual striate area from the cortex of the cingulate gyrus, which is believed to function in emotion.
5-5: Inferior surface of the brain with cranial nerve attachments, after removal of meninges and superficial blood vessels

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The slightly concave inferior surfaces of the frontal lobes rest on the floor of the anterior cranial fossa. The irregularly arranged orbital gyri and sulci include well developed olfactory gyri, which adjoin the anterior (rostral) perforated substance. There is a clear view of the
temporal lobes with their characteristic convolutional pattern. The center and posterior portions of the preparation are occupied by the ventral surfaces of the brain stem and cerebellum, respectively. Note the large bundles of pyramidal fibers decussating within the anterior median fissure.
5-6: Inferior surface of the brain after transection through lower midbrain and removal of cerebellum

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1. Olfactory bulb 2. Orbital sulci and gyri 3. Olfactory tract

The brainstem has been cut through the inferior (caudal) colliculi and the decussation of the superior (cranial) cerebellar peduncles. The inferior surfaces of the frontal lobes are separated from those of the temporal lobes by the lateral fissure. On each side, the gyrus rectus of the frontal lobe is well developed and the orbital gyri are arranged irregularly around the H-shaped orbital sulci. The parahippocampal gyri are separated laterally from the rest of the temporal lobe by the collateral sulci, and their medial margins bound the midbrain. The rhinal sulcus is not present as a separate sulcus in this specimen, but is represented as a direct
continuation of the collateral sulcus. The rhinal sulcus and the anterior part of the collateral sulcus separate olfactory and paleocortical areas on their medial side from neocortical regions of the temporal cortex on their lateral side. The parahippocampal gyrus continues backwards, uninterrupted, into the lingual gyrus. The isthmus of the cingulate gyrus is seen as a continuation of the parahippocampal gyrus only in the left hemisphere in this figure, where a small part of the isthmus projects inferior to the splenium of the corpus callosum.
5-7: Association tracts in the medial part of the cerebrum: right hemisphere

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The cingulum is an association tract that commences below the rostrum of the corpus callosum in the region of the olfactory cortex, and arches around the entire corpus callosum. It has been dissected out from the inferior part of the cingulate gyrus in which, for the most part, it is embedded. After curving round the splenium of the corpus callosum, the bundle proceeds forward within the parahippocampal gyrus to reach the uncus and nearby cortical areas of the temporal lobe. A large proportion of fibers in the cingulum traverse only relatively short segments of this rather compact bundle, and this is due to arrival and departure of many fibers linking different cortical areas. The outer border of the cingulum has a rather irregular appearance. Between the cingulum and the periphery of the specimen, note the mingling of short and long association fibers with projection and commissural fibers.
After the ependyma covering its ventricular surface is stripped away, the elongated caudate nucleus is exposed. Immediately above the anterior (rostral) perforated substance, the pear-shaped head of the caudate nucleus is confluent with the putamen of the lentiform nucleus. The lateral surface of the caudate nucleus is in contact with the closely packed bundles of the internal capsule. A well-defined bundle of nerve fibers occupies the furrow between the caudate nucleus and the thalamus. This is the stria terminalis, which arches along the course of the caudate nucleus, closely applied to its medial margin. In its anterior course it diverges slightly from the head of the caudate nucleus, passes beneath the ventral margin of the internal capsule, and--as the main efferent pathway from the amygdaloid nuclear complex--innervates septal nuclei, anterior hypothalamic nuclei, the anterior perforated substance, and the habenular nucleus (via the stria medullaris).

On the dorsal surface of the thalamus, a small portion of the dorsal lateral thalamic nucleus is located most laterally. The anterior nuclear group is situated more medially. Its anterior
portion is thickened, and its tapering posterior part sweeps across the dorsal aspect of the thalamus. In partial view only are the medial thalamic nuclei, and (along their medial edge) the stria medullaris. The posterior thalamic or pulvinar nuclei project backwards over the superior (cranial) colliculi of the midbrain.

The stria medullaris is prolonged backwards as far as the habenular nuclei, thought to function in some olfactory reflexes. The habenulo-interpeduncular tract, the main outflow path from the habenular nuclei, descends across the medial surface of the red nucleus to terminate in the interpeduncular nucleus, situated in the midbrain tegmentum. Anterolateral to the red nucleus is the oval subthalamic nucleus. The darkly pigmented substantia nigra is situated just dorsal to the basis pedunculi. A thin, transversely oriented ribbon of fibers, the medial lemniscus, ascends from the lower brainstem into the midbrain tegmentum where it occupies a ventrolateral position.

The column of the fornix has been divided a short distance above the anterior (ventral) commissure. The fibers of the mamillothalamic fasciculus (Vicq d' Azyr) arise from the mamillary body and travel upwards and backwards to the anterior, expanded part of the anterior nuclear group of the thalamus.
5-9 Thalamus and thalamic radiations in left cerebral hemisphere: medial view

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The thalamus is an important integrating center which receives sensory signals of various modalities, and transmits processed information to appropriate areas of the cerebral cortex. In this preparation the corpus callosum, caudate nucleus, and most brainstem structures have been removed. The thalamus is large and gray, and the constituent nuclei on its medial aspect are displayed. The anterior thalamic nuclear group arches across the dorsal thalamic surface and consists of the expanded anterior part and a narrow, attenuated posterior part, or tail. The delicate stria medullaris thalami can be traced backwards between the dorsal and medial surfaces of the thalamus towards the habenular trigone. In addition to the latter, the following components of the epithalamus can be distinguished: the habenular commissure, the pineal body, and the posterior (epithalamic) commissure. The posterior thalamic nucleus, known as the pulvinar, has been partially excised. Normally it extends caudally over the superior colliculi of the midbrain.

An extensive accumulation of axons connecting various thalamic nuclei to practically all cortical areas is seen in fan-like array and this, in three dimensions, reflects the profusion of the thalamic radiations. For descriptive purposes, different parts of the thalamic radiations are grouped into four thalamic peduncles. All known connections between thalamus and cerebral cortex are reciprocal, two-way radiations (thalamocortical and corticothalamic), and they contribute conspicuously to the formation of the internal capsule and corona radiata. Fibers that originate chiefly from the medial and anterior thalamic nuclei produce the anterior thalamic peduncle, which runs towards the anterior and inferior frontal cortical areas. Axons
of the superior thalamic peduncle run more or less vertically to connect the thalamus with posterior frontal and parietal cortical areas. The posterior thalamic peduncle and the optic radiation plunge backwards together in a parasagittally-oriented stratum of axons that joins the thalamus to occipital and inferior parietal areas of cortex. The fibers designated as the inferior thalamic peduncle follow a ventrolaterally-oriented course towards the temporal lobe cortex. Fibers of the auditory radiation, which originate in the medial geniculate body and travel to the transverse temporal gyri, share with other thalamotemporal and temporothalamic fibers in the formation of the inferior thalamic peduncle. The temporal genu of the optic radiation is situated lateral to the inferior thalamic peduncle. The latter intersects various projection and commissural fibers, including those crossing to the opposite hemisphere in the anterior commissure.
5-10 Cortical projection systems of left cerebral hemisphere: medial aspect

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Components of the corona radiata and internal capsule are displayed, showing the convergence of corticofugal fibers as they descend to brainstem levels. Almost the entire corpus callosum with its radiation has been removed. The splenium and a small part of the body are all that is left of the massive callosal system of commissural fibers. From the splenium, commissural fibers radiate towards the cortex, interdigitating with both projection and association fiber bundles. A compact bundle of fibers from the splenium sweeps backwards into the occipital lobe, forming the left half of the occipital forceps (forceps major). In front of and below the splenium is a small part of the body of the caudate nucleus, which receives an input of corticostriate fibers. More anterior and somewhat more deeply placed are bundles of the massive thalamic radiations, which have a particularly large component that links the thalamus to the sensory cortical areas in the postcentral gyrus.

Removal of the medial and part of the lateral thalamic nuclei has exposed a stalk of corticorubral tract fibers, converging upon the red nucleus from many cortical areas, including the frontal regions. The red nucleus has been cleaned so that its larger, spherical mesencephalic part can be distinguished from the more rostral, ovoid diencephalic part. Rostral and lateral to the red nucleus is the subthalamic nucleus which also possesses profuse
cortical connections. Ventrolateral to the red nucleus and subthalamic nucleus is the substantia nigra, which is a thin, curved sheet of darkly pigmented tissue. The adjoining ventral region of the midbrain is represented by the basis pedunculi packed with groups of corticofugal fibers. Some of these white myelinated fiber bundles can be followed downwards through the ventral part of the pons. Ascending from the medulla and curving dorsolaterally into the tegmentum of the midbrain is the medial lemniscus, on its way to the thalamus.
5-11 Caudate nucleus, amygdaloid body, stria terminalis, corona radiata, and internal capsule: right cerebral hemisphere from the medial side

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The parts of the caudate nucleus and the amygdaloid body appear in relief after removal of the corpus callosum and brain stem. The striking rounded head of the caudate nucleus extends downwards and, immediately above the anterior (rostral) perforated substance, its gray matter continues uninterrupted as the putamen of the lentiform nucleus, which is concealed from view by the internal capsule. The body and tail of the caudate nucleus form an incomplete circle, the end of the tail widening as it sweeps forwards, into a footlike expansion that attaches to the amygdaloid body anteriorly and the putamen of the lentiform nucleus laterally. A ribbon of white fibers emerges from the posterior aspect of the amygdaloid body, and from the conjoined footlike expansion of the caudate tail. This ribbon becomes consolidated into a bundle of fibers-the stria terminalis-which is the main efferent pathway from the amygdaloid nuclear complex. The stria terminalis runs continuously alongside the medial border of the caudate nucleus, from tail to head. On approaching the anterior (rostral) commissure, the stria terminalis acquires a succession of small patches of gray matter (bed nucleus of the stria terminalis). The main postcommissural part of the stria terminalis descends in the direction of the anterior (rostral) perforated substance and ends in the septal nuclei, the anterior olfactory nucleus, and the habenular nuclei via the stria medullaris thalami.
5-12 Corona radiata, internal capsule and basis pedunculi arising from the left cerebral hemisphere

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The internal capsule and corona radiata have been exposed by removal of the corpus callosum, caudate nucleus, and diencephalon. The most striking feature of this preparation is the convergence of great masses of corticofugal fibers from extensive areas of cerebral cortex into the relatively narrow, but thick, basis pedunculi. Some torn fibers of the thalamic radiation can still be identified. At the anterior margin of the pons, groups of fibers from the frontal, parietal, occipital, and temporal lobes (corticopontine fibers), which traverse the medial and lateral parts of the basis pedunculi, terminate in the pontine nuclei. Most of the intermediate fibers of the crus (corticospinal and corticonuclear fibers) continue through the ventral part of the pons and medulla oblongata, giving off fibers that synapse in cranial nerve motor nuclei, and into the spinal cord as the corticospinal tracts. In the medulla, note the elongated gray olivary nucleus, with its slit-like hilus, directed dorsomedially. The olivary nucleus is larger and rounded at its upper end, whereas its lower portion is attenuated. The corrugated surface of the olivary nucleus is not apparent when viewed from this aspect.
5-13 Insula of right cerebral hemisphere

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The insula is a substantial portion of cerebral cortex that forms the floor of a fossa that can be opened up by removing the lips bounding the lateral sulcus and its rami. These lips are known as the frontal, parietal, and temporal opercula. After their excision, the insula appears as a triangular eminence that is marked by a number of sulci and gyri. The so-called circular sulcus surrounds the insula, except inferomedially where the cortex of the insula is continuous, at the limen insulae, with the cerebral cortex lateral to the anterior (rostral) perforated substance on the basal aspect of the brain. The insular cortex is indented by a number of sulci, one of which - the central sulcus of the insula - is deeper and more prominent than the rest. The central sulcus of the insula runs in an upwards and backwards direction, almost parallel to the cerebral central sulcus that delimits the frontal lobe from the parietal lobe. In front of the central sulcus of the insula, a few short gyri tend to radiate from the vicinity of the limen insulae. Behind the central sulcus one long gyrus of the insula is present in this specimen, partially divided by a shallow sulcus near its upper and posterior end.
5-14 Insula and association bundles of left cerebral hemisphere

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The insular cortex has been exposed by removing the portions of cortex that bound the stem and three rami of the lateral sulcus. It is triangular in shape. The circular sulcus surrounds the insula, except anteroinferiorly where the insular cortex continues uninterrupted on to the inferior cerebral cortex via the limen insulae. The central sulcus of the insula runs upwards and backwards, dividing the insular cortex into a precentral lobule with short gyri and a postcentral lobule with one or two long gyri.

A thick bundle of long association fibers skirts the upper margin of the insula. This, the superior longitudinal fasciculus, is the largest association bundle, and connects frontal lobe cortex to the parietal, occipital, and temporal lobes. As it pursues its arched course, the superior longitudinal fasciculus gathers and sheds nerve fibers from various cortical areas, and so links them to each other. The inferior longitudinal fasciculus, together with the inferior occipitofrontal fasciculus, runs in the inferior part of the hemisphere. It becomes associated with descending fibers of the superior longitudinal fasciculus that, for the most part, end in the occipital cortex. Many arcuate or short association bundles can be seen near the cut margins of the hemisphere. Those connecting neighboring cerebral gyri are clearly seen. Additionally—but not visible in this preparation—short intracortical association fibers exist, linking parts of the same gyrus and sometimes remaining within the cortical gray matter.
5-15 Short and long association tracts: lateral aspect of right hemisphere

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The superior longitudinal fasciculus is composed of fiber bundles of very different lengths. The longer fibers connect the cortical areas far removed from each other, but the majority are somewhat shorter axons that join the fasciculus (in multitudes, from overlying gyri) and mingle with the other fibers of this thick tract. Near the middle of the superior longitudinal fasciculus, some of its fibers - coming from both directions - turn abruptly upwards into the somatomotor and somatosensory areas of the cortex.

The long association fibers of the uncinate fasciculus connect the orbital and inferior frontal gyri of the frontal lobe to the cortex in the anterior part of the temporal lobe, and the fasciculus hooks around the bottom of the stem of the lateral sulcus to do so. The middle portion of the uncinate fasciculus is extensively interconnected with the bulky middle part of the inferior occipitofrontal fasciculus. The latter fans out in both directions, radiating on the one hand towards the frontal and parietal lobes, and on the other streaming into the occipital and temporal lobes. The posterior part of the inferior occipitofrontal fasciculus joins the inferior longitudinal fasciculus, and then both of them intermingle with the descending part of the superior longitudinal fasciculus. The fibers in these fasciculi form the lateral part of a vast stratum of white matter that connects the whole of the occipital cortex with the rest of the brain.

Close to the perimeter of the hemisphere, many bundles of short association, or arcuate, bundles run into the white matter where they intersect and exchange axons with long as well as other short association bundles. This intersecting and mingling is characteristic of association bundles, and contrasts with the orderly formation of projection tracts found in the internal capsule and crus cerebri.
5-16 Putamen of lentiform nucleus and corona radiata: right hemisphere from the lateral aspect

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The long association bundles and external capsule have been removed to display the lateral aspect of the putamen, which appears as a dark gray oval mass with a slightly concave ventral margin. It is highly vascular, and the relatively large anterolateral and posterolateral central arteries (not shown) ascend in grooves over the lower part of the lateral surface of the putamen before piercing successively the lentiform nucleus, internal capsule, and caudate nucleus.

Narrow bridges of gray matter are present between nerve fiber bundles of the internal capsule and bring together the putamen and the head and body of the caudate nucleus, which—except for the bridges—are separated from the putamen by the internal capsule. The anterior commissure occupies a deep groove in the lower surface of the putamen. Its fiber bundles are twisted like a thick string. Below the anterior limb of the internal capsule, the most rostral part of the putamen becomes directly continuous with the head of the caudate nucleus.

Internal capsule fibers radiate via the corona radiata to practically all cortical areas. These projection fibers consist largely of ascending fibers of the thalamic radiation and descending corticofugal fibers. They intersect a major population of commissural fibers that traverse the corpus callosum and, closer to the cortex, they pass between the short association fibers. An extensive sheet of sagittally running fibers extends posteriorly and includes fibers of the posterior thalamic peduncle, anterior commissure, and optic radiation.
5-17 Globus pallidus of lentiform nucleus, internal capsule, and corona radiata: left hemisphere from the lateral aspect

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The putamen of the lentiform nucleus has been removed to expose the more medially situated globus pallidus, which is so named because it is paler than the putamen. The globus pallidus is a nuclear mass which is closely applied to the lateral surface of the internal capsule. Just anterior to the globus pallidus, the many narrow grooves between internal capsule fiber bundles are occupied by gray matter joining the putamen (removed) to the head of the caudate nucleus (covered by the anterior limb of the internal capsule). Just ventral to the globus pallidus the anterior (rostral) commissure, which is composed of twisted fiber bundles, intersects fibers of the optic radiation, before the commissural axons stream into the temporal and occipital lobes.

The corona radiata and its continuity with the internal capsule can be seen in this dissection, since the ends and upper margin of the putamen mark the junction of the internal capsule with the base of the corona. From this base, projection fiber bundles diverge towards cortical areas and intersect with commissural fibers of the corpus callosum. Near the periphery of the hemisphere there is also an intermingling of projection and commissural fibers with short association fibers. A contrasting appearance is afforded by the long, parallel, closely packed fibers of the sagittal stratum, the fibers of which remain rather discrete as they pursue their long and wavy course towards the occipital cortex.
5-18 Corona radiata, internal capsule, anterior (rostral) commissure, and some association tracts: left hemisphere from the lateral aspect

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Examples of the three major classes of axons (projection, commissural, and association) in the white matter of the brain are seen here. A multitude of projection fibers are gathered together in the corona radiata, and can be followed as they converge and continue without interruption in the internal capsule and the basis pedunculi. The constituent parts (putamen and globus pallidus) of the lentiform nucleus have been removed, providing better exposure of the anterior (rostral) commissure seen in the lower part of the preparation. These commissural fibers connect parts of the cortex of the two hemispheres, in particular, the anterior and inferior portions of the temporal lobes.

Two association tracts are also displayed. The rounded bundle known as the uncinate fasciculus is named for its hooklike configuration as it curves beneath the stem of the lateral sulcus to connect areas of cortex in the lower frontal and anterior temporal regions. The long association fibers of the inferior occipitofrontal fasciculus mingle with the internal capsule and the corona radiata, and also with the anterior commissure and the temporal genu of the optic radiation.

The vertical extent of the inferior occipitofrontal fasciculus is considerable, and it is a major component of the sagittal stratum (which is a fiber sheet of great complexity). The sagittal stratum contains commissural fibers that have crossed from the opposite side of the anterior commissure, association fibers that extend anteroposteriorly in the inferior occipitofrontal fasciculus, and projection fibers belonging to the posterior thalamic peduncle, the optic radiation and the occipitopontine tract.
5-19 Basal ganglia; dissection of left cerebral hemisphere from the lateral aspect

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The extreme, external, and internal capsules have been dissected away to show the basal ganglia (caudate and lentiform nuclei and the amygdaloid nuclear complex), which are related to the various parts of the lateral ventricle. The irregular empty spaces between the putamen and the caudate nucleus were occupied by fiber bundles of the internal capsule. Bridges of gray matter pass across the internal capsule, producing the striped appearance from which the corpus striatum derives its name. The gray bridges connect the putamen with the head and, occasionally, the body of the caudate nucleus, reflecting through their conjoined structure in the adult that they arise as a single nuclear mass in development. In the evolutionary process, these neostriatal nuclear masses grow in association with expanding areas of neocortex and the increase in projection fibers converging on the internal capsule. The caudate nucleus has the form of a highly arched comma, and its head, body, and tail are related throughout to the curvature of the lateral ventricle. The pear-shaped head of the caudate nucleus bulges into the floor and lateral wall of the anterior horn, the body of the nucleus is in contact with the floor of the central part of the ventricle, and the tail of the nucleus is located in the roof of the inferior horn, just lateral to the stria terminalis. The gray matter of the tail of the caudate nucleus continues without interruption into the amygdaloid nuclear complex, and also into the gray substance of the lentiform nucleus by way of a small, horizontally placed connecting
piece (the "foot" of the lentiform nucleus described by earlier anatomists). The pulvinar of the thalamus can be distinguished just posterior to the putamen.

Commissural fibers in the corpus callosum stream across the roof of the frontal horn and central part of the lateral ventricle. The medial wall of the occipital horn is marked by two swellings. The upper one, known as the bulb of the occipital horn, owes its existence to the white matter of the occipital forceps, consisting of fibers that cross in the splenium of the corpus callosum. The lower swelling, the calcar avis, is produced by the calcarine sulcus, located on the medial surface of the occipital lobe. The hippocampal sulcus invaginates most of the medial wall of the inferior horn of the lateral ventricle to produce the prominent curved elevation called the hippocampus. The blunt anterior part of the hippocampus (pes hippocampi) possesses characteristic digitations. The collateral eminence and trigone are located in the floor of the inferior and posterior horns, produced by the collateral sulcus.
On the right is seen the large, medullary area of the cerebral hemisphere, surrounded by a layer of gray cortical matter. The medullary area is packed with myelinated nerve fibers which are arranged, according to their courses and connections, into commissural, association, and projection fibers. In the cut surface of the right hemisphere are a few bundles of commissural fibers which cross the midline in the corpus callosum.

The left hemisphere has been sliced at a slightly lower level. A rectangular piece of cerebrum adjacent to the midline has been removed to display part of the upper surface of the corpus callosum. The latter is covered by the indusium griseum, a thin sheet of rudimentary cortex containing (on each side) the delicate medial and lateral longitudinal striae. Lateral to the indusium griseum, densely packed, transversely running commissural fibers of the corpus callosum are apparent. In the posterior part of the left hemisphere, the commissural fibers of the splenium of the corpus callosum curve sharply backward to form the left part of the occipital forceps. The upper surface of the left superior temporal gyrus is visible in the floor of the posterior ramus of the lateral sulcus. The superior temporal gyrus is subdivided into two or more obliquely running, short, transverse temporal gyri. The anterior transverse
temporal (Heschl's) gyrus and the adjacent part of the superior temporal gyrus together constitute the cortical auditory area which are subject to individual variation.

### 5-21 Corpus callosum, its radiation, and indusium griseum displayed from above

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These structures have been exposed by partial removal of the cerebral hemispheres. The trunk, or intermediate, portion of the corpus callosum consists of closely packed bundles of transversely oriented commissural fibers. The anterior and posterior portions of the corpus callosum curve sharply downwards to form its genu and splenium, respectively. The commissural fibers traversing the genu and splenium form characteristic arches—the frontal and occipital forceps, respectively—in order to reach the anterior and posterior poles of the hemispheres. Traced laterally, the fibers of the corpus callosum become widely dispersed as they radiate towards the various lobes of the hemispheres, and difficulty is experienced in following callosal fibers more laterally because they interdigitate with association and projection fibers. To display the commissural fibers better, some of the projection fibers have been dissected away, their removal having enlarged the spaces between bundles of callosal fibers.
The upper surface of the intermediate portion of the corpus callosum is covered by a thin veil of gray substance—the indusium griseum. Two pairs of medial and lateral longitudinal striae of white matter are embedded within the gray matter of the indusium, creating four fine ridges. The lateral ridges are somewhat more prominent, and they demarcate the transition between the indusium griseum medially and the gray matter of the cingulate gyrus (which has been removed) laterally.

The corpus callosum and its overlying indusium griseum exhibit striking developmental and functional contrasts. The latter is a thin sheet of gray matter representing a vestigial cerebral convolution and is a residue of the primitive archipallial cortex. The corpus callosum is a typical neocortical development; in man it is a highly developed commissure that reciprocally interconnects the neopallial cortex of the two hemispheres.
5-22 Tela choroidea of third and lateral ventricles, viewed from above

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A fold of the pia mater enters the brain to produce the tela choroidea of the 3rd ventricle. Arteries carried in with the pial fold provide the choroid plexuses of the 3rd and lateral ventricles. The upper parts of both cerebral hemispheres, the body of the corpus callosum, and most of the fornix have been removed. The tela choroidea of the 3rd ventricle is located immediately beneath the body of the fornix. It is a double fold of highly vascular pia mater and triangular in outline. Its anterior angle approaches the columns of the fornix, adjacent to the interventricular foramina, and its broad base is beneath the splenium of the corpus callosum. Each lateral margin of the tela choroidea contains the highly vascularized choroid plexus of the body of the corresponding lateral ventricle. Thus the choroid plexuses of the lateral ventricles are in fact only lateral expansions of the tela choroidea of the 3rd ventricle, and they extend into the lateral ventricles by way of the choroid fissures.
The choroid fissure is a potential slit only, located between the fornix and the lamina affixa on the dorsal side of the thalamus. The choroid fissure also follows the curve of the fimbria and the stria terminalis, between which the choroid plexus gains entry into the inferior horn of the lateral ventricle. The choroid plexus of the lateral ventricle therefore continues uninterrupted from the interventricular foramina backwards within the central part of the ventricle. Then, after sweeping round the posterior end of the thalamus, the plexus extends downwards and forwards in the temporal horn of the lateral ventricle. The choroid plexus does not extend into the frontal and occipital horns of the lateral ventricles. The choroid plexus of the 3rd ventricle is much smaller and bulges downward from the tela choroidea into the ventricles.

Each internal cerebral vein is formed at the anterior angle of the tela choroidea by the union of the thalamostriate vein, the choroid vein (which issues from the choroid plexus) and the vein of the septum pellucidum. Numerous tributaries from the thalamus and caudate nucleus converge upon the thalamostriate vein, which is partially obscured by the stria terminalis. The two veins of the septum pellucidum are of small caliber and emerge from between the two laminae of the septum pellucidum. The two internal cerebral veins join beneath the splenium of the corpus callosum to form the great cerebral vein, but the site of union is not visible in this preparation.
The deep cerebellar nuclei have been dissected out. The large dentate nuclei are deeply fissured and subdivided into toothlike agglomerations of gray matter, the longest ones being
near the middle of each nucleus. From each subdivision arise fine bands of white fibers which
together contribute the greater part of the superior cerebellar peduncle. The fastigial nucleus is
the most medially placed cerebellar nucleus. It is a small, slightly elongated gray mass
situated in the roof of the 4th ventricle. A small fiber bundle issuing from its rostral part runs
alongside the medial margin of the superior cerebellar peduncle and then disappears from
view (heading for the ipsilateral vestibular nuclear complex and reticular formation). There
are two globose nuclei in each cerebellar hemisphere, the anterior one just dorsolateral to the
fastigial nucleus and the posterior one attached to the emboliform nucleus. Slender bundles
arising from the globose and emboliform nuclei traverse the main part of the superior
cerebellar peduncle.

Due to removal of the basis pedunculi, substantia nigra, and greater part of the midbrain
tegmentum, the decussation of the superior cerebellar peduncles can be seen. This decussation
occurs in the midbrain tegmentum at the level of the inferior (caudal) colliculi. After crossing,
these efferent fibers from the cerebellar nuclei pursue two courses. Many from the globose
and emboliform nuclei terminate in the red nucleus, which in this preparation appears as a
large, rounded nuclear mass. Fibers predominantly from the contralateral dentate nucleus
bypass the red nucleus and head directly for the ventral lateral thalamic nucleus. It may be
noted that the rostral end of the red nucleus receives the substantial corticorubral tract.

Lateral to the midbrain are the medial and lateral geniculate bodies. The former is rounded,
whereas the lateral geniculate body resembles an inverted cup. The ventrally placed notch in
the lateral geniculate body is readily seen, with optic tract fibers terminating on both sides of
this deep ventral groove. Lateral to the geniculate bodies, sharply curved fibers of the optic
radiation make their diversion into the temporal lobes. (This is shown to better advantage on
the right side of the illustration). A little lateral to the posterior end of the optic tract, the thick,
slightly curved, highly vascular putamen is seen with the smaller globus pallidus on its medial
side. Fibers of the external capsule and the lateral and medial medullary laminae have been
removed to display the putamen and medial and lateral divisions of the globus pallidus.
5-24 Visual pathway from optic chiasma to occipital lobes, viewed from the basal aspect

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Each optic tract can be traced backwards and laterally, its initial segment passing between the anterior (rostral) perforated substance laterally and the tuber cinereum and mamillary body medially. After arching across the basis pedunculi, it terminates in the lateral geniculate body which has a distinct notch in its ventral surface. The larger part of the lateral geniculate body is lateral to this notch, and is responsible for the swelling seen ventral to the pulvinar of the

thalamus. The medial part of the lateral geniculate body is commonly confused with the medial root of the optic tract. (The ventral notch in the lateral geniculate body was filled with optic tract fibers and these have been removed to show the nucleus.) Many optic tract fibers proceed in a medial direction as the brachium of the superior (cranial) colliculus, destined for the pretectal area and the superior (cranial) colliculus.

The fibers of the optic radiation, or geniculocalcarine projection, emerge from the dorsal surface of the lateral geniculate body and can be traced as part of a sagittal stratum of white fibers that runs forwards and downwards into the temporal lobe. Subsequently, optic radiation fibers sweep backwards and terminate in the region of the calcarine sulcus. More dorsally placed fibers of the optic radiation (not seen) pursue a shorter and more direct path to the visual cortex. Note that the anterior (rostral) commissure, and the inferior occipitofrontal fasciculus form, with the optic radiation, the sagittal stratum of white fibers that consists of both afferent and efferent connections to the occipital cortex.

The medial geniculate body is located dorsomedial to the lateral geniculate body. The midbrain has been cut at the level of the inferior (caudal) colliculi. The cut surfaces of the decussating superior cerebellar peduncles are more ventral. Two small white areas found in the dorsal tegmentum are the medial longitudinal fasciculi. On each side, the ventral aspect of the claustrum and the subdivisions of the lentiform nucleus (putamen, medial and lateral parts of globus pallidus) are seen lateral to the optic tracts. The claustrum is a layer of gray matter that lies on the medial aspect of the insular cortex, from which it is separated by a sheet of white fibers known as the extreme capsule (not displayed here). Only a narrow interval separates the anteroventral parts of these basal ganglia from the anterior (rostral) perforated substance. The medial and lateral olfactory striae define the anterior limit of the anterior perforated substance.
5-25 Components of limbic system and cerebral hemispheres, seen from below

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The cerebellum, brainstem, thalamus, and most of the basal ganglia have been removed. Hippocampal structures can be examined on both sides. The fornix, mammillary bodies, and part of the anterior (rostral) commissure can also be seen.

The two halves of the cerebrum have been dissected from below to different depths, to allow study of the dentate gyrus (left side of illustration) and the upper cortical layer of the parahippocampal gyrus (right side) which covers the inferior aspect of the dentate gyrus. On the right side the superficial gray matter and medullary white substance of the parahippocampal gyrus have been cleaned away to expose cortical substance on the deep aspect of the gyrus. Fine digitations are characteristic of this deep cortical substance. The cut edge of the alveus can also be seen. Note the hook or uncus of the parahippocampal gyrus. On
the smooth inferior surface of the uncus is the delicate, transversely running tail of the dentate gyrus that runs into the cleft of the uncus. More anterior is the amygdaloid body.

On the left side of the illustration (right side of the specimen), the parahippocampal gyrus has been removed to expose the dentate gyrus. Note the characteristic, toothlike appearance of the inferior surface of the dentate gyrus. Traced backwards around the splenium of the corpus callosum, the dentate gyrus is continuous with the gyrus fasciolaris (or subsplenial gyrus) which continues on the superior surface of the corpus callosum as the indusium griseum. Anteriorly, the dentate gyrus abruptly turns, medially and posteriorly, thereby forming the tail of the dentate gyrus. Two gray elevations located anterior and anteromedial to the tail of the dentate gyrus are parts of the deep cortex of the uncus. Note the broad white sheet of the alveus and, just medial to the dentate gyrus, the fimbria of the hippocampus, a thick white bundle of axons that runs first backwards, then forwards and superiorly to form the highly arched crus of the fornix.

Between the two crura of the fornix is a white, triangular lamina, known as the fornical commissure. Follow the body and the columns of the fornix to observe that most of their fibers travel to the mamillary bodies. Anterior and dorsal to the mamillary bodies, find the transversely oriented cylindrical white band which is the anterior (rostral) commissure. In the depths of the specimen it is possible to see the inferior surface of the corpus callosum, to which the body of the fornix is firmly attached.
5-26 Dentate gyri, amygdaloid bodies

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A study of these structures has been made possible by removing the cerebellum, most of the brain stem, and the parahippocampal gyrus of each side, together with the subiculum (through which the hippocampus is continued into the cortex of the parahippocampal gyrus). At its anterior end, the dentate gyrus, named for the supposed resemblance of its notched medial margin to a row of teeth, turns abruptly in a posterior and medial direction to become the tail of the dentate gyrus. The fimbria of the hippocampus is a longitudinal band of white fibers.
which constitutes the efferent pathway from the hippocampus, including the dentate gyrus. Beneath the splenium of the corpus callosum, the dentate gyrus becomes flattened and smooth and continues on to the dorsal surface of the corpus callosum as the thin gyrus fasciolaris. The latter is continuous with the indusium griseum, which covers the dorsal surface of the corpus callosum.

Lateral to the dentate gyrus, the temporal horn of the lateral ventricle has been opened to expose its choroid plexus, which is involved in the production of cerebrospinal fluid. The amygdaloid body is an ovoid gray nuclear mass, oriented transversely and with a slight posterior concavity. Lateral to the optic tract are the anterior (rostral) perforated substance, olfactory trigone, and olfactory striae. On the right side of the illustration the intermediate olfactory stria stands out clearly.

The midbrain has been transected at the level of the inferior (caudal) colliculi. The ventral aspect of the midbrain is nearer the front of the brain; the dorsal aspect of the midbrain is closer to the occipital lobes. Dorsomedial to the substantia nigra are the superior cerebellar peduncles and their decussation, and the medial longitudinal fasciculi lie dorsal to the previously mentioned decussation. The trochlear nerve nuclei are located ventral to the mesencephalic (cerebral) aqueduct. The root fibers arising from the trochlear nuclei form a decussation dorsal to the mesencephalic aqueduct, and they are the only cranial nerves that cross completely and that leave the dorsal aspect of the brain stem. Dorsolateral to the superior cerebellar peduncles are the somewhat dispersed fibers of the central tegmental tracts. The lateral portion of the tegmentum contains four lemnisci and has been referred to as the "sensory angle." Here the medial lemniscus is most ventral, the lateral lemniscus dorsal, and the intermediate area is occupied by the spinal and trigeminal lemnisci.

The pulvinar of the thalamus is seen dorsolateral to the midbrain, and the medial geniculate body can be recognized on the ventral surface of the pulvinar. A short segment of the crus of the fornix is visible just medial to the pulvinar.
5-27 Horizontal section through the dorsal lateral nucleus of the thalamus

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The head of the caudate nucleus bulges into the frontal horn of the lateral ventricle, which is lined by ependyma. The groove between the caudate nucleus and the thalamus accommodates the thalamostriate vein and the stria terminalis. The septum pellucidum stretches across the interval between the genu of the corpus callosum and the columns of the fornix, separating the frontal horns of the two lateral ventricles. The thalamus has been cut at the level of its dorsal lateral nucleus. Although the lentiform nucleus is situated at a level inferior to this section, narrow bands of gray matter that interconnect the caudate nucleus and the putamen are readily seen, separated by fascicles of the internal capsule. As can be seen in the left hemisphere, the choroid plexus protrudes into the central part of the lateral ventricle, and the route of entry of the plexus is via the choroid fissure, between the fornix and the lamina affixa. Traced caudally, the vascular tissue of the choroid plexus expands to form the choroid glomus. Here the temporal horn commences its downwards and lateral sweep around the posterior end of the thalamus.
In observing the white matter of the hemisphere, it is possible to follow the paths of various fiber systems because they are accompanied by numerous blood vessels. Close to the midline, note the divided anterior part of the corpus callosum with the fibers of the frontal forceps curving forwards from it, and, more posteriorly, the divided splenium of the corpus callosum with some fibers of the occipital forceps curving backwards from it.

5-28 Horizontal section through middle of thalamus

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This preparation permits recognition of the main nuclear masses of the thalamus. The internal medullary lamina is a well-defined white band within the gray matter of the thalamus. This
lamina is curved, with a pronounced medial concavity, and it separates the medial thalamic nuclei from the ventrolateral and posterior nuclei. Anteriorly it bifurcates to enclose the anterior thalamic nuclear group. Posteriorly it also bifurcates and surrounds another nuclear mass of the thalamus, the centromedian nucleus. The ventrolateral thalamic nucleus is penetrated by numerous white fibers of the thalamic radiation. Its gray matter merges with that of the posterior nucleus, or pulvinar, which extends backwards.

Close to the midline, the habenular nucleus is connected anteriorly to the stria medullaris thalami. The putamen, a dark, ovoidal nuclear mass, is separated from the head of the caudate nucleus and the thalamus by the internal capsule. The retrolenticular part of the internal capsule, seen more clearly on the right side, is displaced laterally by the temporal horn of the lateral ventricle. Protruding into this horn of the lateral ventricle, through the choroid fissure, is the choroid plexus of the temporal horn, lying just lateral to the fimbria of the hippocampus. The configuration of white and gray matter of the dentate gyrus and hippocampus is distinctive.
5-29 Horizontal section through middle of corpus striatum

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The oval, dark gray head of the caudate nucleus bulges into the frontal horn of the lateral ventricle and is separated from the putamen by the internal capsule (anterior limb). The elongated putamen is equally dark, whereas the globus pallidus appears as a smaller, wedge-shaped, pale mass, contiguous with the genu of the internal capsule. The dark appearance of the caudate nucleus and putamen is attributable to their content of blood vessels and neuronal cell bodies. Numerous myelinated fibers traversing the globus pallidus make it much paler.

This section passes through the inferior part of the thalamus and only a small part of the medial nucleus is visible, together with the ventrolateral thalamic nuclear group. Note the very long retrolenticular portion of the internal capsule containing fibers of the optic
radiation; these fibers curve around the lateral wall of the temporal horn of the lateral ventricle on their way to be distributed to occipital lobe cortex.

5-30 Coronal section through the anterior part of the corpus striatum

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The septum pellucidum is a midline structure, separating the two frontal horns of the lateral ventricles. The septum is attached superiorly to the genu and body and inferiorly to the rostrum of the corpus callosum. Note that the gray matter of the caudate nucleus continues uninterrupted into the putamen, through a prolongation just inferior to the internal capsule (anterior limb). Also note the gray bridges between the caudate nucleus and the putamen, which interrupt the fasciculi of the anterior limb of the internal capsule. Putamen and caudate are one mass of gray matter, incompletely separated by these internal capsule fibers.
5-31 Coronal section through the anterior (rostral) commissure and optic chiasma

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The solid, median part of the anterior commissure is most clearly visible below the columns of the fornix. Both columns of the fornix are found, together with the median part of the anterior commissure, in the anterior wall of the 3rd ventricle with a small triangular recess between them. The lower margin of the septum pellucidum is attached to the columns of the fornix. The lateral part of the anterior commissure traverses the inferior part of the corpus striatum. On both sides note the vascular channels that pass from the anterior (rostral) perforated substance into the gray substance of the corpus striatum. These are important striate branches of the middle cerebral artery, destined for the corpus striatum, internal capsule and associated structures.
5-32 Coronal section through the tuber cinereum and lentiform nucleus

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This section passes through the central part of the lateral ventricle, close to its extension forwards as the frontal horn. In the floor of the lateral ventricle, close to the midline, is the anterior thalamic nuclear group, bounded on both sides by the internal medullary lamina of the thalamus. Just medial to the body of the caudate nucleus is the conspicuous thalamostriate vein, its medial edge overlapped by the stria terminalis. There is continuity between the choroid plexuses of the 3rd and the lateral ventricles. The 3rd ventricle is a vertically oriented slit which has a small ventral extension (the infundibular recess). Lateral to the internal capsule (genu) are the three parts of the lentiform nucleus, namely the internal and external parts of the globus pallidus and the putamen. These three are separated from each other by the medial and lateral medullary laminae of the globus pallidus. The dark putamen contrasts sharply with the globus pallidus.
5-33 Coronal section through mamillary bodies

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The hypothalamus can be divided into an anterior supraoptic zone, an intermediate infundibulotuberal zone and a posterior mamillary zone (through which this section passes). A number of thalamic nuclei can be recognized in this section, separated from each other by the internal medullary lamina, which accommodates the mamillothalamic fasciculus as the latter passes from the prominent medial nucleus of the mamillary body to the anterior thalamic nuclear group. The latter nuclear group is lodged within the cranial bifurcation of the internal medullary lamina. The medial thalamic nuclei are small, circumscribed gray masses situated adjacent to the lateral wall of the 3rd ventricle. The lateral thalamic nuclear group is much larger. Immediately lateral to this nuclear group is a relatively indistinct layer of intermingled gray and white matter termed the reticular nucleus of the thalamus. It merges ventromedially with a small collection of gray matter called the zona incerta. Note the white areas above and below the zona incerta, sometimes referred to as the H1, H2, and H3 fields (or areas) of Forel, respectively. Forel's fields contain--though not exclusively--discharge pathways from the globus pallidus to the thalamus. Immediately below the H2 field of Forel is the subthalamic nucleus, which is prominent only in primates, including man. A lesion of one subthalamic
nucleus may result in hemiballismus, which is characterized by sudden, violent movements of one or both limbs on the side opposite the lesion. Components of the lentiform nucleus (internal and external parts of the globus pallidus, and the putamen) are seen lateral to the posterior limb of the internal capsule.

In the temporal lobe the large, oval gray mass, the amygdaloid body, receives its name from its supposed resemblance to an almond. Its ventral and lateral aspects are well demarcated by white matter. More dorsally there is incomplete separation of the amygdaloid body from the putamen and globus pallidus; and the optic tract is immediately adjacent. The best known outflow tract of the amygdaloid body, the stria terminalis, emerges from the caudal end of the amygdala and follows the medial edge of the tail of the caudate nucleus backwards, upwards and then forwards. In this section it occupies the shallow groove that separates the body of the caudate nucleus from the thalamus.
 Certain thalamic nuclei can be distinguished in this section, separated from each other by the curved internal medullary lamina. The medial thalamic nucleus is dark and circumscribed, whereas the lateral nuclear group is much paler. The anterior thalamic nuclear group is small and flattened, and is situated more laterally on the dorsal surface of the thalamus. The reticular nuclei of the thalamus can be identified, but the zona incerta is difficult to see on this section. The H1 field (or area) of Forel, containing the ansa lenticularis, is a rather large zone of white matter. The ansa lenticularis contains a multitude of axons which stream out and end in the ventral anterolateral thalamic nucleus (which can also be seen in this section). The subthalamic nucleus is an identifiable nodule of gray matter that lies dorsal to the substantia nigra.

Corticofugal fibers at the base of the corona radiata pass directly into the basis pedunculi via the posterior limb of the internal capsule. Fibers of the optic and auditory radiations are interposed between the lentiform nucleus above and the temporal horn of the lateral ventricle.
below. Other structures seen in the roof of the temporal horn of the lateral ventricle are the tail of the caudate nucleus and the stria terminalis.

5-35 Coronal section through thalamus, choroid fissure, basis pedunculi, and ventral part of pons

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The fornix is seen touching the corpus callosum. The lentiform nucleus is present only on the left side of the illustration. The anterior thalamic nuclear group in this section is located more laterally than in a more anterior slice (Fig. 5-34). The anterior thalamic nuclear group can be distinguished by its location within a dorsal bifurcation of the internal medullary lamina. The ventral bifurcation of the internal medullary lamina envelops the centromedian nucleus of the thalamus. The choroid plexus of the 3rd ventricle is united with the choroid plexus of the lateral ventricle via the choroid fissure between thalamus and fornix. Note the two large internal cerebral veins in the tela choroidea of the 3rd ventricle.
The red nuclei appear as large, spherical portions of gray matter, related to the concavity of the substantia nigra. Lateral to the red nucleus, the medial, spinal, and trigeminal lemnisci show as a white area. The medial and spinal lemnisci terminate in the ventral posterolateral thalamic nucleus, and the trigeminal lemnisci terminate in the ventral posteromedial thalamic nucleus. On each side the basis pedunculi, containing corticospinal and corticopontine projection fibers, can be identified.

5-36 Coronal section through posterior (epithalamic) commissure

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The section is slightly oblique and shows the disposition of many important structures. 1) In the midline, below the crura of the fornix, is the small posterior part of the 3rd ventricle together with its tela choroidea and its vascular fringed choroid plexus, which projects downwards as an invagination of the roof of the 3rd ventricle, on each side of the midline. 2) The thalami are sectioned at the level of the posterior thalamic nucleus (pulvinar). 3) The preparation shows both habenular and posterior commissures, with the pineal recess between them. On the right side of the illustration, medial and lateral geniculate bodies—which together constitute the metathalamus—can be recognized. It may be observed that the lateral geniculate body is organized in alternating gray and white laminae. 4) The oculomotor nuclei,
together with their parasympathetic accessory nuclei (of Edinger-Westphal), are located ventral to the mesencephalic (cerebral) aqueduct and dorsal to the superior cerebellar peduncles. 5) The surfaces of the cerebral hemispheres show complex cerebral convolutions of the parietal and temporal lobes. Insular cortex is visible also, particularly on the left side of the illustration. The hippocampus and associated structures abut the medial and inferior surface of the temporal horn of the lateral ventricle.
Bibliography

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