

BMD430, NEUROSCIENCES LABORATORY MANUAL

For the next several class sessions you will be learning the gross anatomy of the human brain by studying fixed specimens. Handle the brains with care and respect; they are somewhat fragile and are donated human tissue. **Do not damage the brain tissue.** The brains are preserved in 10% formaldehyde, a toxic, potentially carcinogenic agent, but they will be immersed in water for the duration of the teaching lab. As a precaution, handle only with gloves and always wear a lab coat. Keep the specimens moist with wet paper towels; if any tissue is allowed to dry out it becomes useless for study. Read the Lab Manual before lab and follow the instructions in the Lab Manual while in lab; important terms are underlined. It helps when studying brain structures to use the wooden pointers available in class. At the end of class, return the brain to the bucket, make sure it is covered with water, clean off the tray and the study area, and dispose of your gloves (and only gloves) in the biohazard trash. There are usually variations from brain to brain so be sure to study more than one specimen. Each brain bucket will have a whole and half brains. There will be brain atlases available in the lab.

Do not remove any brain specimens or atlases from the labs (room 6128 and 6138). Only BMD 430 students are allowed in the labs. Labs are available 8-5, M-F.

Laboratory practical exams will consist of tagged specimens requiring you to identify structures and to explain their function.

MENINGES

<http://www.umanitoba.ca/faculties/medicine/units/anatomy/bmr/graphics/arachnoid.jpg>

A few demonstration brains will have part of the dura mater intact. Look for the superior sagittal sinus and arachnoid granulations or villi. The arachnoid is a thin membrane that covers the sulci and contains blood vessels. The pia is tightly adherent to

the neural tissue and closely follows gyri and sulci. Cerebrospinal fluid is in the subarachnoid space around the spinal cord and brain, between the arachnoid membrane and the pia mater.

BRAIN FIGURES

Some of the best figures of brain surfaces and coronal and horizontal sections are at <http://vertex.biostr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffp+athIndex/Master^Frame+2>. Unfortunately, it is not possible to provide links to individual figures so you will have to go to this index page and choose "Brain Surface," "Coronal Forebrain," "Horizontal Forebrain," etc.

LATERAL SURFACE

<http://vertex.biostr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffp+athIndex/Master^Frame+2>

Be familiar with the relevant orientation terms: anterior-posterior, rostral-caudal, dorsal-ventral, superior-inferior, and medial-lateral. Know the definitions of these terms for the brainstem as well.

Examine the whole brain or half brain first. It consists of two hemispheres, divided by a longitudinal fissure. The external, visible portion is the cerebrum, or cerebral cortex. The surface of the hemispheres is irregular and has fissures (deep indentations), sulci (shallower indentations), and gyri (ridges). Many of the fissures, sulci, and gyri are common to all brains and are named. Find and identify on the lateral surface the: lateral fissure, central sulcus, precentral gyrus, postcentral gyrus, parieto-occipital fissure, and the area of the preoccipital notch (an indistinct, largely imaginary structure about 2.5 cm from the occipital pole). Usually the central sulcus will run inferiorly from the superior surface of the brain, along the lateral surface, and stop just short of the lateral fissure. It should have parallel precentral and postcentral gyri anterior and posterior to it. The parieto-occipital fissure is best seen

on the medial surface; it is barely visible on the lateral surface.

The temporal lobe is located inferior to the lateral fissure and anterior to an imaginary line between the parieto-occipital fissure and the preoccipital notch.

The frontal lobe is located superior to the lateral fissure and anterior to the central sulcus.

The parietal lobe is located posterior to the central sulcus, anterior to an imaginary line between the parieto-occipital fissure and the preoccipital notch, and superior to a line extending from the lateral fissure to the posterior boundary.

The occipital lobe is located posterior to the parietal and temporal lobes. The boundary is an imaginary line drawn between the parieto-occipital sulcus and the preoccipital notch.

The insula is the surface of the cerebral cortex which forms the floor (depth) of the lateral fissure. If you gently open the lateral fissure (separate the frontal and temporal lobes), you will see gyri and sulci in the depth of the lateral fissure. They belong to the insula. You can get a good view of the insula on horizontal sections.

<http://www.vh.org/adult/provider/anatomy/BraInAnatomy/Ch5Text/Section13.html>

The part of the temporal lobe forming the superior surface of the inferior lip of the lateral fissure is a horizontal surface that has gyri running in a medial to lateral orientation.

You will need to spread open the lateral fissure gently to see these; they are the transverse temporal gyri of Heschl, representing the primary auditory cortex. On the lateral surface of the temporal lobe is a gyrus oriented parallel to the lateral fissure, the superior temporal gyrus. Inferior to this gyrus, the structures are (in order): superior temporal sulcus, middle temporal gyrus, middle temporal sulcus, inferior temporal gyrus, and inferior temporal sulcus. The inferior temporal gyrus usually forms the

“corner” between the lateral and inferior surfaces.

The lateral surface of the frontal lobe contains the precentral gyrus immediately anterior to the central sulcus. The precentral gyrus is an area whose function is devoted to motor control; upper motor neurons in this area of the cerebrum send axons to brainstem and spinal cord neurons (lower motor neurons) which form neuromuscular junctions and control skeletal muscle contraction. There is a topographical organization of the motor neurons in the precentral gyrus such that neurons which control different muscles on the opposite side of the body from foot to head occupy, in order, different parts of the precentral gyrus, from superior to inferior; this organization is called a homunculus (see p.474 of your text). The precentral gyrus is also called the primary motor cortex or area 4 of Brodmann.

On the dominant hemisphere (usually the left), the area anterior to the precentral gyrus and along the upper lip of the lateral fissure (inferior frontal gyri), contains neurons responsible for controlling muscles used for producing speech. This region is also called Broca's area, and damage to this structure results in an inability to say words, although hearing, reading, and understanding language are intact (Broca's aphasia or expressive aphasia). Broca's area is composed of the pars opercularis and the pars triangularis of the inferior frontal gyrus.

Broca's area is best found on the left hemisphere (why?). First locate the central sulcus and then the precentral gyrus and the precentral sulcus in the area of the lateral fissure. Just anterior to the precentral sulcus should be a short, vertical gyrus, the pars opercularis. The anterior boundary of the pars opercularis is a sulcus extending vertically from the lateral fissure, the vertical branch of the lateral fissure. Anterior to the vertical branch is the pars triangularis. The anterior boundary of the pars triangularis is the horizontal branch of the lateral fissure. Anterior and inferior to the horizontal branch is the pars orbitalis, which does not belong to Broca's area.

Pars opercularis, pars triangularis, and pars orbitalis compose the inferior frontal gyri. The remainder of the frontal lobe consists of the superior and middle frontal gyri, with the superior and inferior frontal sulci separating the three areas. In addition to motor control, these areas of the brain are thought to deal with future planning. Frontal lobotomies affect this area of the brain.

The parietal lobe is a sensory area of the brain. Immediately posterior to the central sulcus is the postcentral gyrus and the postcentral sulcus. Neurons making up the gyrus and lining the sulcus are the cerebral end-station for pathways conveying sensations from sensory receptors throughout the body and sending information of touch, pain, temperature, and proprioception or position sense, (the somatosensory system). This area of the parietal cortex is called the primary somatosensory cortex, or areas 3, 1, and 2 of Brodmann. Like the motor cortex, the primary somatosensory cortex is topographically organized into a homunculus, with the contralateral lower extremity superiorly and the head inferiorly.

In the dominant hemisphere posterior to the primary somatosensory cortex in the area of the termination of the lateral fissure is Wernicke's area. Wernicke's area functions in the understanding of spoken language, and damage to this area results in Wernicke's aphasia or comprehension aphasia, characterized by the inability to understand spoken words. Contrast this with Broca's aphasia.

Between the primary somatosensory area and the occipital lobe, is the somatosensory association cortex in the parietal lobe. Association cortices are believed to carry out higher cognitive functions, beyond simple sensation, such as the appreciation of music, or the combining of different sensory inputs, such as hearing, vision, smell, and touch into multimodal memories. Anatomically, this area consists of the superior and inferior parietal lobules, divided by the intraparietal sulcus. The inferior parietal lobule can be further

subdivided into the supramarginal gyrus anteriorly, and the angular gyrus posteriorly.

The supramarginal gyrus can be located by following the lateral fissure posteriorly. Typically it will angle superiorly, posterior to the postcentral sulcus, and then end blindly, surrounded by a U-shaped gyrus, the supramarginal gyrus. Similarly, the superior temporal sulcus will follow a parallel route, turn superiorly into the parietal lobe, and end blindly, surrounded by the angular gyrus. Together, the supramarginal and the angular gyri make up the inferior parietal lobule, part of which is Wernicke's area. The superior boundary of the inferior parietal lobule is the intraparietal sulcus, separating it from the superior parietal lobule. Strokes involving the right superior parietal lobule may result in neglect syndrome.

The occipital lobe is also a sensory cortex, but devoted exclusively to vision. The primary and secondary (associational) visual cortices are believed to process visual input that begins in the eye to produce color vision, to store visual memories, to enable recognition of faces and objects, to focus on particular stationary or moving objects, and other capabilities. Most of the visual area is on the medial surface. The only part of the primary visual cortex visible on the lateral surface is at the occipital pole, or posterior-most tip, surrounding the calcarine fissure (refer to the medial view). The rest of the lateral surface of the occipital lobe is part of the visual association cortices (areas 18 and 19 of Brodmann)

VENTRAL SURFACE

<http://vertex.biostr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffpathIndex/Master^Frame+2>

A ventral view of the brain shows three main areas which correspond to the three cranial fossae of the skull (review your anatomy notes). A ventral view also reveals the cut surface of the brainstem (varying from brain to brain), which connects the brain with the spinal cord, and also several cranial nerves which have been cut. Look for specimens with portions of cranial nerves

visible; on some brains cranial nerves are completely rubbed off, with no evidence of their presence. The brainstem consists of the midbrain (mesencephalon), pons, and medulla. Review the orientation of the brainstem: anterior-posterior, rostral-caudal, dorsal-ventral, and superior-inferior.

On the ventral surface of the frontal lobe, near the midline, is the gyrus rectus (straight gyrus). Lateral to the gyrus rectus is the olfactory sulcus, within which lies the olfactory bulb connected to the olfactory tract. These are specialized structures which are part of the olfactory pathway. Cranial nerve I (the olfactory nerve) consists of many small axon bundles from the olfactory epithelium traversing the cribriform plate of the ethmoid bone, and entering the olfactory bulb. Follow the olfactory tract posteriorly. It will bifurcate and disappear where the fibers merge into the cortex. Immediately posterior to this point the brain surface has several small holes. This is the anterior perforated substance, where numerous small blood vessels enter the cortical surface. The rest of the ventral surface of the frontal lobe is composed of orbital gyri.

Just posterior to the ventral frontal lobe, between the temporal lobes and anterior to the brainstem, is an area with many important structures. The cut optic nerves (CN II) can be followed posteriorly to the optic chiasm, where there is some crossing of fibers, and to the optic tracts posterior to the chiasm. Posterior to the optic chiasm is the torn infundibular stalk, which in life connected the pituitary gland to the hypothalamus; the infundibular stalk is attached to the hypothalamus at the tuber cinereum, a small mound of tissue. Behind the infundibular stalk, are two round mamillary bodies which are part of the hypothalamus.

Ventral Brainstem Figure

<http://vertex.biostr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffp+athIndex/Master^Frame+2>

There is a deep space posterior to the mamillary bodies, bordered laterally by two large bundles of axons, the cerebral

peduncles, which actually belong to the midbrain. The deep space is the interpeduncular fossa, containing the posterior perforated substance, where numerous small blood vessels penetrate the brain surface. Emerging from the interpeduncular fossa are two oculomotor nerves (CN III), also cut, which in life connect to the extraocular muscles of the eye. CN III is about the size of a pencil lead. Located near the oculomotor nerves are the thin trochlear (CN IV) nerves, which innervate the superior oblique extraocular muscle; CN IV is fragile and often destroyed. CN IV is about the size of a thread. If it is not visible, you can usually find it on a half brain, emerging from the dorsal surface of the midbrain, just posterior to the inferior colliculi and close to the midline.

View of Trochlear Nerve

<http://www.vh.org/adult/provider/anatomy/Bra inAnatomy/Ch4Text/Section04.html>

Posterior and inferior to the midbrain is the pons, a segment of the brainstem that looks like a bridge of fibers crossing the midline. The pons serves as a relay station for messages from the cerebral cortex to the cerebellum. On the lateral surface of the pons is a large, cut nerve, the trigeminal nerve (CN V), which is largely composed of fibers carrying sensory input from the face to the thalamus. It has a small motor component which innervates muscles of mastication.

A ventral view also shows that the temporal lobe curves around the lateral and posterior sides of the brainstem (where it is hidden by the cerebellum). One gyrus follows around the lateral surface of the brainstem, the parahippocampal gyrus. Deep to the parahippocampal gyrus is the hippocampus (not seen at this point, but observe in coronal sections); both structures are important parts of the limbic system of the brain. Several important functions are attributed to the limbic system: one is memory, and others involve basic drives such as sex and fear. On the medial surface of the parahippocampal gyrus, near its anterior extremity is a medial protrusion, the

uncus; deep to the uncus is an enlarged area of gray matter, the amygdala, which will not be visible except in coronal sections (see coronal section at level of anterior commissure). Lateral to the parahippocampal gyrus is the collateral sulcus. Lateral to the collateral sulcus are the occipitotemporal gyri. Lateral to the occipitotemporal gyrus is the inferior temporal sulcus and gyrus, respectively. You should now be able to name all gyri of the temporal lobe. Look for specimens with the cerebellum removed for a good view of the ventral surface of the temporal lobe.

Follow this link to see a dissection of the ventral view demonstrating the inferior horn of the lateral ventricle and the relationship with the hippocampus and amygdala.
<http://vertex.biostr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffp+athIndex/Master^Frame+2>

Posterior to the brainstem lays the cerebellum. The cerebellum consists of two hemispheres, which are clearly seen from a posterior view, where it lies beneath the occipital lobe. In the midline between the hemispheres is the vermis, located between the bulges of the two hemispheres. The cerebellar cortex has many small ridges, called folia. The normal function of the cerebellum is only partially understood. What is known is inferred, in part from patients with cerebellar degeneration or abnormalities. In these cases, unconscious motor coordination is lost, leading to the idea that the cerebellum functions in coordination of automatic movements, such as walking. One result of cerebellar dysfunction is cerebellar ataxia.

The medulla is the inferior-most part of the brainstem which is continuous with the spinal cord. Near the midline, emerging between the pons and the medulla are the abducens nerves (CN VI), which innervate the lateral rectus muscles of the eye (what is the action of these muscles?). At the angle between the pons, cerebellum, and medulla emerge two large cranial nerves. The more medial is the facial nerve (CN VII), which

controls the muscles of facial expression. Lateral to the facial nerve is the vestibulocochlear nerve (CN VIII), which carries auditory and vestibular sensory input to the brain. In summary, if you follow the pontomedullary junction from medial to lateral, you will see CN VI, VII, and VIII in order.

Along the ventrolateral surface of the medulla are cranial nerves 9-12. Two column-like structures on either side of the anterior median fissure of the medulla are the pyramids, bundles of axons from the upper motor neurons in the primary motor cortex. Lateral to the pyramids are the olives, which look like their namesake. The preolivary sulcus is medial to the olive (between the pyramid and the olive) and the postolivary sulcus is lateral. Numerous fine nerve roots emerge from the postolivary sulcus. From superior to inferior, the roots are the components of the glossopharyngeal (CN IX), vagal (CN X), and accessory cranial nerves (XI). Between the olive and the pyramid (the preolivary sulcus) are another set of nerve roots which will unite to form the hypoglossal nerve (CN XII).

Lateral to the postolivary sulcus is a longitudinal bulge, the tuberculum cinereum. It is the external landmark for the spinal trigeminal nucleus, relay neurons for the sensory input from the trigeminal nerve.

The inferior boundary of the medulla is indicated by small, interdigitating bundles of axons forming the pyramidal decussation. Examine the anterior median fissure of the medulla at levels inferior to the olives. The pyramidal decussation indicates the point of crossing of corticospinal fibers.

MEDIAL SURFACE

<http://vertex.biustr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffp/athIndex/Master^Frame+2>

Study the half brain which has been cut in the midsagittal plane in order to see its medial surface.

Parts of the frontal, parietal, occipital, and temporal lobes can be seen from a medial view.

The medial surface of the occipital lobe contains the deep calcarine sulcus, beginning at the occipital pole (the posterior-most tip), and traveling anteriorly toward the parahippocampal gyrus. On the medial surface the parieto-occipital sulcus can also be followed from the dorsal surface of the cerebral cortex until it runs into the calcarine fissure. The gyri on either side of the calcarine sulcus and within its depths constitute the primary visual cortex (area 17, striate cortex, or V1), where visual sensory information first reaches the cortex. If this area is damaged bilaterally, the patient will suffer cortical blindness and will not be able to see, although the eyes are normal. The gyrus on the superior lip of the calcarine fissure is the cuneus, and the gyrus on the inferior lip is the lingual gyrus.

The midsagittal section cuts a very large bundle of myelinated axons, the corpus callosum. The axons belong to nerve cell bodies in either right or left cortical hemisphere which communicate with neurons on the contralateral side. The three main parts of the corpus callosum are the anterior rostrum, the "beak" or tapering part, the genu, meaning knee and referring to the area of the bend, the body, comprising the bulk of the structure, and the splenium, which is the enlarged caudal portion, containing visual axons communicating between the two occipital lobes. The corpus callosum is the largest bundle of commissural fibers, those which connect the two hemispheres. The corpus callosum is not necessary for life; in fact, patients with uncontrollable epilepsy are surgically treated by cutting the corpus callosum to prevent epileptic discharges from

affecting both hemispheres. Such split-brain patients have been studied extensively to learn how the two hemispheres work together and independently. These patients will be discussed later in class when we look at the work of Roger Sperry.

Superior to the corpus callosum is the cingulate gyrus, which extends from frontal to parietal lobes, and forms part of the limbic lobe. As it curves around the splenium, the cingulate gyrus continues into the parahippocampal gyrus.

Inferior to the corpus callosum, there is a thin membrane in the midsagittal plane (it may be missing), the septum pellucidum, deep to which is a large, irregularly shaped cavity. The cavity is called the lateral ventricle, and in life it is filled with cerebrospinal fluid (CSF). Embryologically, the lateral ventricle developed as the telencephalon when it grew out of the diencephalon.

The floor (inferior boundary) of the lateral ventricle is formed by the thalamus, which is deep to the cortex, and actually belongs not to the cerebral cortical telencephalon, but to the diencephalon. These are functionally and embryologically distinct areas of the brain. In general, the thalamus serves as a relay and processing station for sensory messages before they reach the cerebral cortex, and for inputs and feedback circuits important for the control of the motor cortex.

The thalamus also forms the lateral walls of the third ventricle, which is a narrow, vertically oriented space separating the right and left thalami. The floor of the third ventricle is at the ventral surface of the brain (adjacent to the optic chiasm and infundibular stalk); at this level, the lateral walls of the third ventricle are formed by the hypothalamus. The hypothalamus has important functions in the control of the endocrine system and many other, unconscious activities of the body. You will see these diencephalic structures in coronal and horizontal sections as well. It is often possible to see a groove, the hypothalamic

sulcus, separating the thalamus from the hypothalamus. The hypothalamic sulcus runs from the interventricular foramen to the cerebral aqueduct.

Visible beneath the body of the corpus callosum are two bundles of axons, the fornix, which travel from the parahippocampal area to the hypothalamus. You should be able to follow the axons as they proceed rostrally, then bend inferiorly to travel along the thalamus, through the hypothalamus, on their way to their destination in the mamillary bodies. The part where the fibers travel ventrally is the column of the fornix. The columns are located just posterior to a small bundle of fibers cut in cross section, the anterior commissure. Also in this area, just posterior to the columns of the fornix, is the interventricular foramen (of Munro), connecting the lateral and third ventricles. The proximity of these three structures forms a landmark to look for in brain sections. During development, the interventricular foramen is the location of the outgrowth of the telencephalon from the diencephalons.

Usually the two thalami expand and contact each other, obliterating part of the space of the third ventricle. The point of contact is the interthalamic adhesion. It does not contain any commissural fibers.

At the posterior edge of the thalamus is the pineal gland, located just beneath the splenium of the corpus callosum. The pineal usually has a dark, spongy appearance, and is a small, posterior extension of the thalamus into subarachnoid space and often surrounded by loose connective tissue. It secretes melatonin and is thought to have functions related to body rhythms. At the base of the pineal gland is the small posterior commissure.

Within the lateral, third, and fourth ventricles is choroid plexus, which is responsible for the formation of cerebrospinal fluid. Choroid plexus is a specialized capillary bed that appears fuzzy. Along the ventral surface (floor) of the third ventricles are the optic chiasm, the tuber cinereum, the

infundibular stalk, and the mamillary bodies. Between the optic chiasm and the rostrum of the corpus callosum, the rostral wall of the third ventricle is a thin membrane, the lamina terminalis, which represents the rostral end of the embryologic neural tube.

The thalamus is contiguous with the upper part of the brainstem, the midbrain, or mesencephalon. Running through the midbrain is a narrow continuation of the third ventricle, the cerebral aqueduct, about the size of a pencil lead. The part of the mesencephalon dorsal to the cerebral aqueduct forms the tectum, composed of the superior and inferior colliculi. These areas are functionally important because they are centers for visual reflexes and auditory relay, respectively.

Ventral to the cerebral aqueduct are the tegmentum and cerebral peduncles of the mesencephalon, containing numerous ascending fibers which carry sensory information from the body to the cerebral cortex, and descending fibers which carry motor impulses from the cerebral cortex to all levels of the body. Look for brainstem specimens showing a cross section of the midbrain to see the fibers clearly. Obviously, injuries which interrupt these fibers result in loss of feeling (numbness) and loss of motor control (paralysis). One cause of such an injury would be occlusion of the arterial blood supply in this small region. Interspersed among the ascending and descending fibers in the mesencephalon are nerve cell bodies.

One group of them in the periaqueductal gray matter forms the oculomotor complex. Oculomotor neurons give rise to axons which travel in a ventral direction, and emerge in the interpeduncular fossa, forming the oculomotor nerve (CN III). On the ventral surface of the midbrain are two large bundles of axons, the cerebral peduncles, containing descending fibers from the cerebral cortex to the brainstem and spinal cord. The substantia nigra is located in the midbrain between the tegmentum and the cerebral peduncle. Look for a cross section of midbrain to see the substantia nigra.

Inferior to the midbrain, the brainstem continues as the pons. Axons from every lobe of the cerebral cortex terminate in the pons, which in turn sends axons into the cerebellum, via the middle cerebellar peduncle. The trigeminal nerve (CN V) emerges between the cerebellum and the middle cerebellar peduncle. The cerebellum lies dorsal to the pons, and in midsagittal section, the white matter and overlying cortex can be seen to be organized into folia.

Between the cerebellum and the pons is an expansion of the cerebral aqueduct, the fourth ventricle. Cerebral spinal fluid is a filtrate of the vascular system which is formed by the choroid plexuses in the ventricles and circulates to the fourth ventricle where it flows into the subarachnoid space surrounding the brain and spinal cord. Two openings in the lateral recesses continue into the subarachnoid space. The foramen of Luschka can usually be located on the ventral surface of the cerebellum because of the presence of choroid plexus which continues from the fourth ventricle and out through the foramen of Luschka to the subarachnoid space. One midline opening exists also, the foramen of Magendie, but its structure is usually destroyed in removing the brain. In life the foramen of Magendie is located near the inferior narrowing of the fourth ventricle, an area called the obex.

DORSAL SURFACE – BRAINSTEM

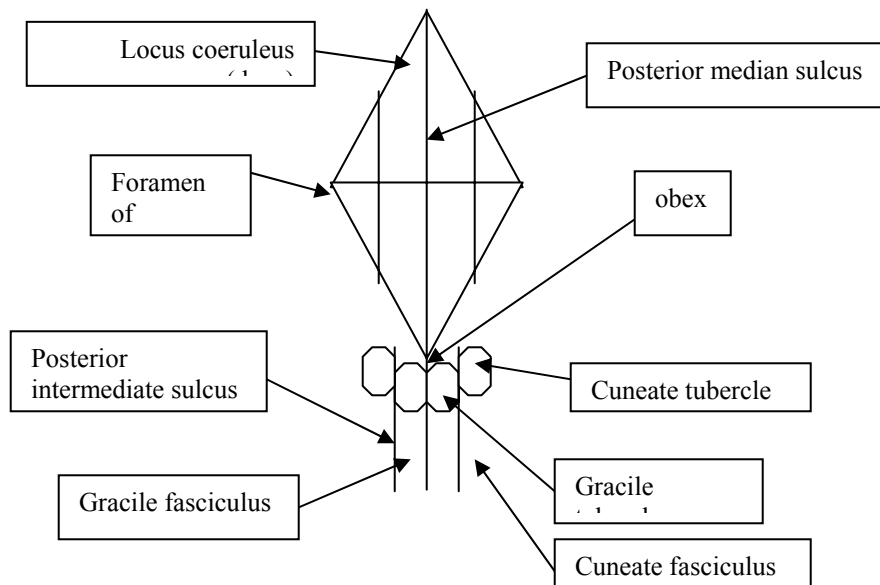
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Several dissected brainstems will be available for study in the demonstration buckets.

The dorsal surface of the mesencephalon has four projections, the two superior colliculi and the two inferior colliculi. The superior colliculi are visual reflex centers, while the inferior colliculi are auditory relay centers. Just caudal to the inferior colliculi is the location of the trochlear nerve (CN IV). After emerging, the nerve

circles around the cerebral peduncle and travels with the oculomotor nerve, eventually innervating the superior oblique muscle. This fragile nerve is often damaged during dissection because it is the size of a thread.

With the cerebellum removed look at the dorsal surface of the pons and medulla which forms the floor of the fourth ventricle, a diamond shaped area. The two lateral corners continue into the foramen of Luschka. At the inferior corner the fourth ventricle continues into the central canal of the medulla and spinal cord. This V-shaped area is called the obex. Inferior to the obex is the posterior median sulcus. Immediately lateral to the posterior median sulcus in the area of the obex is the gracile tubercle, a small bump. Lateral to the gracile tubercle is the posterior intermediate sulcus, separating the gracile tubercle from the more lateral cuneate tubercle. The gracile and cuneate tubercles are external landmarks for the gracile and cuneate nuclei, relay nuclei in the dorsal column - medial lemniscal system pathway for discriminative touch and proprioception. Just inferior to the gracile and cuneate tubercles are the gracile and cuneate fasciculi, respectively. These are incoming bundles of sensory axons that synapse in the tubercles.



CORONAL SECTION THROUGH ANTERIOR COMMISSURE

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When studying horizontal and coronal sections, use the half brain as a reference and visualize the location of the section so that the three dimensional relationships of structures can be interpreted.

At this level, only the body of the lateral ventricle will be seen. The corpus callosum forms the roof of the ventricle, while the septum pellucidum separates right and left cavities. Why is the fornix not seen? Find the lateral ventricle and the insular cortex.

The lateral wall of the ventricle is formed by the head of the caudate nucleus. The thalamus forms the floor of the lateral ventricle.

The anterior limb of the internal capsule separates the caudate nucleus from

the lentiform nucleus (globus pallidus and putamen).

The anterior commissure contains fibers connecting right and left sides; it is located just ventral to the anterior limb of the internal capsule and the lentiform nucleus.

The third ventricle is located ventral to the anterior commissure. Its lateral walls are formed by the hypothalamus, and its floor is formed by the optic chiasm.

In the temporal lobe look for the uncus and a mass of grey matter deep to it, the amygdala. The amygdala is part of the limbic system and functions in emotions.

CORONAL SECTION THROUGH THE INTERTHALAMIC ADHESION

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The "C" shape of the lateral ventricle causes it to be sectioned twice, in the body of the lateral ventricle dorsally, and in the inferior horn of the lateral ventricle in the temporal lobe. The third ventricle is located at the midline, interrupted by the interthalamic adhesion (variable). Find the level and orientation of the section on a half brain.

The corpus callosum forms the roof of the body of the lateral ventricle. Separating right and left cavities is the septum pellucidum, with the fornix at its ventral border.

The thalamus forms the floor of the body of the lateral ventricle, and the lateral wall of the third ventricle. Lateral to the thalamus is the posterior limb of the internal capsule. The lentiform nucleus (globus pallidus and putamen) is lateral to the posterior limb of the internal capsule, and the insular cortex and lateral fissure are lateral to the lentiform nucleus.

Ventral to the thalamus is the hypothalamus, which also contributes to the lateral wall of the third ventricle.

Ventral to the lentiform nucleus, and forming the floor of the inferior horn of the lateral ventricle is the hippocampus. At the anterior end of the temporal lobe, anterior to the hippocampus and the inferior horn of the lateral ventricle is the amygdala, composed of grey matter and located deep to the uncus of the parahippocampal gyrus. Damage to the hippocampus results in memory deficits. One of the major efferent pathways from the hippocampus forms the fornix.

On the ventral surface of the brain look for the optic tract, the cerebral peduncles, and the mamillary bodies.

HORIZONTAL SECTION THROUGH THE ANTERIOR COMMISSURE

<http://vertex.biostr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffp/athIndex/Master^Frame+2>

From an overall perspective, the white and gray matter of the cerebral cortex can be seen to surround internal structures. The longitudinal and lateral fissures and the insula can be identified, as well as the anterior region of the corpus callosum. Posteriorly, the cut should go through the cerebellum and the midbrain (look for the cerebral aqueduct and colliculi).

Locate the lateral ventricles in both frontal and occipital lobes; the ventricles are sectioned twice because of their "C" shape.

The anterior commissure runs across the midline through the third ventricle, just posterior to the columns of the fornix. If the section missed the anterior commissure at midline, there may be parts of it more laterally.

Deep gray structures are the basal ganglia, roughly comprised of the caudate nucleus, putamen, and globus pallidus. The caudate nucleus is located in the lateral wall of the anterior part of the lateral ventricles. It is separated from the putamen and globus pallidus by the anterior limb of the internal capsule.

Together, the putamen and globus pallidus in horizontal sections look like a triangle, with the globus pallidus located medially; together they form the lenticular nucleus. Generally, the globus pallidus is paler than the putamen because there are myelinated fibers traversing it. As we shall see later, the globus pallidus receives input from caudate and putamen and forms an output pathway to the thalamus. The posterior-medial border of the lenticular nucleus is formed by the posterior limb of the internal capsule. The basal ganglia, like the cerebellum, are incompletely understood. It is known, however, that lesions or deficits in this area produce movement disorders such as Parkinson's disease and Huntington's

chorea, indicating that normal functions involve coordination of movement.

At this inferior level, the walls of the third ventricle are formed by the hypothalamus (check the level of cut on a half brain).

The internal capsule is the major pathway for ascending and descending projection axons between the cerebral cortex and subcortical structures, including thalamus, brainstem, cerebellum, and spinal cord. Continuous with the posterior part of the internal capsule are fibers of the visual pathway from the lateral geniculate nucleus of the thalamus to the cuneus and lingual gyrus of the primary visual cortex, the visual (optic) radiations. In section you should be able to trace these fibers toward the edges of the calcarine fissure. The optic radiations are located just lateral to the temporal (inferior) horn of the lateral ventricle.

Posterior to the basal ganglia and posterior limb of the internal capsule you may see the gray matter of the medial and lateral geniculate nuclei. These are relays along the auditory and visual pathways, respectively. The lateral geniculate nuclei give rise to the optic radiations.

The close relationship between the hypothalamus and midbrain can be seen in this section.

HORIZONTAL SECTION THROUGH THE SPLENIUM

<http://vertex.biostr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffp athIndex/Master^Frame+2>

This level is superior to the previous horizontal section. The corpus callosum is cut anteriorly and posteriorly. The lateral ventricles are cut in the expanded anterior horn and in the posterior horn.

The head of the caudate nucleus forms the lateral wall of the anterior horn of the lateral ventricle. The septum pellucidum separates the right and left anterior horns of the lateral ventricle. At the free edge of the

septum pellucidum are the columns of the fornix. The hippocampus is absent but the fornix is located in the posterior wall of the posterior horn of the lateral ventricle.

The anterior and posterior limbs of the internal capsule are present. The anterior limb separates the head of the caudate from the putamen (there is no globus pallidus at this level), and the posterior limb of the internal capsule separates the putamen from the thalamus.

The thalamus forms the lateral walls of the third ventricle.

In the vicinity of the splenium of the corpus callosum and between the thalami you may see the pineal body.

The superior portions of the optic radiations are visible lateral to the posterior horn of the lateral ventricles, traveling through the parietal lobe on their way to the primary visual cortex.

BLOOD SUPPLY

<http://vertex.biostr.washington.edu/cgi-bin/DA/PageMaster?atlas:Neuroanatomy+ffp athIndex/Master^Frame+2>

The major arterial supply to the brain comes from the vertebral and internal carotid arteries, branches of the brachiocephalic and subclavian arteries and the aortic arch. The two vertebrals ascend through the foramen magnum and join to form a single basilar artery at the midline on the ventral surface of the pons. Branches of the basilar supply the brainstem and cerebellum. The terminal branches of the basilar artery are the two posterior cerebral arteries, which supply the medial and inferior surfaces of the occipital lobe. Just prior to forming the posterior cerebral arteries, the basilar gives off two superior cerebellar arteries. The oculomotor nerve emerges from the interpeduncular fossa between the posterior cerebral and superior cerebellar arteries.

The internal carotid arteries terminate by forming the anterior cerebral and the middle cerebral arteries. The anterior

cerebral arteries from the two sides and travel toward the midline and then run parallel to each other in the longitudinal fissure along the superior surface of the corpus callosum, giving off branches that supply most of the medial surface of the brain. The two anterior cerebral arteries are joined together by an anterior communicating artery, located at the rostral end of the corpus callosum. The middle cerebral artery travels in the lateral fissure and gives off branches which emerge from the lateral fissure and supply most of the lateral surface of the brain. Explain how an arterial occlusion could cause paralysis and numbness to the contralateral lower limb while the rest of the body remains unaffected. One branch of the middle cerebral artery is the posterior communicating artery which joins the posterior cerebral arteries. The communicating arteries help to form the arterial Circle of Willis, which is composed of anterior communicating, anterior cerebral, internal carotid-middle cerebral, posterior communicating, and posterior cerebral arteries on each side. Variations in the Circle of Willis are common. The existence of the Circle of Willis enables the brain to adjust for slowly developing occlusions of the major arteries.

SPINAL CORD

There are few specimens to study, so study your text (p. 231-232) and web-atlases.

Be familiar with a representative cross section of spinal cord and be able to identify: dorsal, ventral, and intermediate horns, central canal, dorsal, lateral, and ventral columns, dorsal and ventral roots, dorsal root ganglia, anterior and posterior median fissures, posterior intermediate sulci, and pia, arachnoid, and dural meninges.

BRAIN ATLASES (see class website also)

<http://www.vh.org/Providers/Textbooks/BrainAnatomy/BrainAnatomy.html>

http://anatomy.uams.edu/HTMLpages/anatomyhtml/neuro_atlas.html

<http://www.indiana.edu/~m555/coron/coron.html>

MRIs and Demonstration posters

After your study of brain specimens, try to identify structures on the MRIs in the lab. A few illustrations of pathological conditions are also available.

KEY TERMS (not inclusive)

LATERAL VIEW

angular gyrus
Broca's aphasia
Broca's area
Brodmann's areas
calcarine fissure
central sulcus,
comprehension aphasia
expressive aphasia
frontal lobe
homunculus
horizontal branch of lateral fissure
inferior frontal gyri
inferior parietal lobule
inferior temporal gyrus
inferior temporal sulcus
insula
intraparietal sulcus
lateral fissure
longitudinal fissure
middle frontal gyri
middle temporal gyrus
middle temporal sulcus
occipital lobe
occipital pole
parietal lobe

parieto-occipital fissure
pars opercularis
pars orbitalis
pars triangularis
postcentral gyrus
postcentral sulcus
precentral gyrus
preoccipital notch
primary motor cortex
primary somatosensory cortex
primary visual cortex
somatosensory association cortex
superior frontal gyri
superior parietal lobule
superior temporal gyrus
superior temporal sulcus
supramarginal gyrus
temporal lobe
topographical organization
transverse temporal gyri of Heschl
upper motor neurons
vertical branch of lateral fissure
visual association cortex
Wernicke's aphasia
Wernicke's area

VENTRAL SURFACE

abducens nerve
accessory cranial nerve
amygdala
anterior median fissure
brainstem
cerebellar folia
cerebellar hemispheres
cerebellum
cerebral peduncles
collateral sulcus
cranial fossae
cranial nerves I-XII
facial nerve
glossopharyngeal nerve
gyrus rectus
hypoglossal nerve
hypothalamus
inferior temporal gyrus
inferior temporal sulcus
infundibular stalk
interpeduncular fossa
limbic system
mamillary bodies
medulla
mesencephalon
midbrain

occipitotemporal gyri
oculomotor nerves
olfactory bulb
olfactory sulcus
olfactory tract
olives
optic chiasm
optic nerves
optic tracts
orbital gyri
parahippocampal gyrus
pituitary gland
pons
posterior perforated substance
postolivary sulcus
preolivary sulcus
pyramids
trigeminal nerve
trochlear nerve
tuber cinereum
tuberculum cinereum
uncus
vagal nerve
vermis
vestibulocochlear nerve

MEDIAL SURFACE

anterior commissure
area 17
body of corpus callosum
calcarine sulcus
cerebellum
cerebral aqueduct
cerebral peduncles
cerebrospinal fluid (CSF)
choroid plexus
cingulate gyrus
column of the fornix
commissural fibers
corpus callosum
cuneus
diencephalon
folia
foramen of Luschka
foramen of Magendie
fornix
fourth ventricle
genu of corpus callosum
hypothalamus
inferior colliculi
infundibular stalk
interpeduncular fossa
interthalamic adhesion
interventricular foramen (of Munro)
lamina terminalis
lateral ventricle
lingual gyrus

DORSAL SURFACE - BRAINSTEM

central canal
cranial nerve IV
cuneate fasciculus
cuneate nucleus
cuneate tubercle
dorsal column-medial lemniscal system
(DCMLS)
foramen of Luschka

mamillary bodies
mamillary bodies
mesencephalon
midbrain
middle cerebellar peduncle
occipital pole
oculomotor complex
oculomotor nerve
optic chiasm
parieto-occipital sulcus
pineal gland
primary visual cortex
rostrum of corpus callosum
septum pellucidum
splenium of corpus callosum
split-brain patients
striate cortex
superior colliculi
tectum
tegmentum
telencephalon
thalamus
third ventricle
trigeminal nerve
tuber cinereum
V1

gracile fasciculus
gracile nucleus
gracile tubercle
inferior colliculi
obex
posterior intermediate sulcus
posterior median sulcus
superior colliculi
trochlear nerve

CORONAL SECTION THROUGH ANTERIOR COMMISSURE

anterior commissure	hypothalamus
anterior limb of the internal capsule	lentiform nucleus
body of the lateral ventricle	optic chiasm
caudate nucleus	putamen
corpus callosum	septum pellucidum
globus pallidus	third ventricle

CORONAL SECTION THROUGH THE INTERTHALAMIC ADHESION

amygdala	interthalamic adhesion
body of the lateral ventricle	lateral fissure
cerebral peduncles	lateral ventricle
corpus callosum	lentiform nucleus
fornix	mamillary bodies
globus pallidus	optic tract
hippocampus	posterior limb of the internal capsule
hypothalamus	putamen
inferior horn of the lateral ventricle	septum pellucidum
insular cortex	thalamus
	third ventricle

HORIZONTAL SECTION THROUGH THE ANTERIOR COMMISSURE

anterior commissure	internal capsule
anterior limb of the internal capsule	lateral ventricles
basal ganglia	lenticular nucleus
caudate nucleus	medial geniculate nucleus
cerebral aqueduct	posterior limb of the internal capsule
colliculi	putamen
globus pallidus	thalamus
hypothalamus	third ventricle
insula	visual (optic) radiations
lateral geniculate nucleus	

HORIZONTAL SECTION THROUGH THE SPLENIUM

Anterior horn of lateral ventricle	posterior horn of lateral ventricle
Anterior limb of the internal capsule	posterior limb of the internal capsule
Columns of the fornix	putamen
corpus callosum	septum pellucidum
head of caudate nucleus	splenium
pineal body	thalamus

BLOOD SUPPLY -ARTERIES

anterior cerebral	posterior cerebral
anterior communicating	posterior communicating
basilar	superior cerebellar
Circle of Willis	vertebra
internal carotid	
middle cerebral	