Medical Neuroscience
Laboratory Guide
2010

Learning Neuroanatomy

Neuroanatomy is easy. Learning neuroanatomy is difficult. Why? First, because it is a new vocabulary. Second, because no matter where you start, you are always referring to parts of the brain you haven't studied yet. Third, because students almost invariably "fail to see the forest for the trees," losing sight of the important relations by focusing on unimportant, trivial details. This laboratory manual emphasizes important facts you should know. Study it carefully. It contains many references to pictures and illustrations in the Haines atlas (*Neuroanatomy: An Atlas of Structures, Sections, and Systems*), which is a *reference book* that contains many things we think you should *not* learn at this time. Therefore, do not use the Haines atlas as a book to be studied and memorized but only as a reference and aid to learning the material **in this manual**.

Examples of important facts include the main sensory and motor pathways and systems, such as the *dorsal column/medial lemniscal pathway*, the *visual pathway*, and the *corticospinal pathway*. Other important topics include understanding the relation of the *cerebellum* and *basal ganglia* to the rest of the motor system. Examples of unimportant facts include the names of the ten or twelve different *raphe nuclei*, the exact location of the spino-olivary fibers in the spinal cord, and the location of the frenulum. If you spend a minute studying these last three items, you have not only wasted your time but have actually seriously hindered your learning of the essentials by filling your mind, which has a finite capacity to absorb new information, with trivia. **Do not do this.** Rather always strive to keep the big picture and the overall pattern before you.

Note About Cases: In almost all chapters you will find one or more clinical case descriptions. You will find some of the cases studied early in this lab manual difficult because they require more knowledge than most of you will have at this time. However, do not be discouraged. One of the reasons the cases are presented is to show you where you are going, what your final destination is, how fundamental knowledge about the brain is actually used clinically. Even if you are not there yet, some sense of your ultimate goal is useful.

Lab 1

Spinal Cord, Brain, Meninges, Cranial Nerves, and Blood Vessels

Familiarity with the gross structure of the human nervous system will provide you with a **framework** to organize what you will learn about its function. In addition, because nerve cells and their processes frequently connect structures far removed from one another, even this early in the course it will help if you have at least a vague idea of where these "distant places" are located. The first two laboratory sessions will also introduce the proper **nomenclature** or **terminology** used for the various parts of the human brain. The sooner you learn this terminology and what it refers to, the easier it will be to understand the lectures and readings.
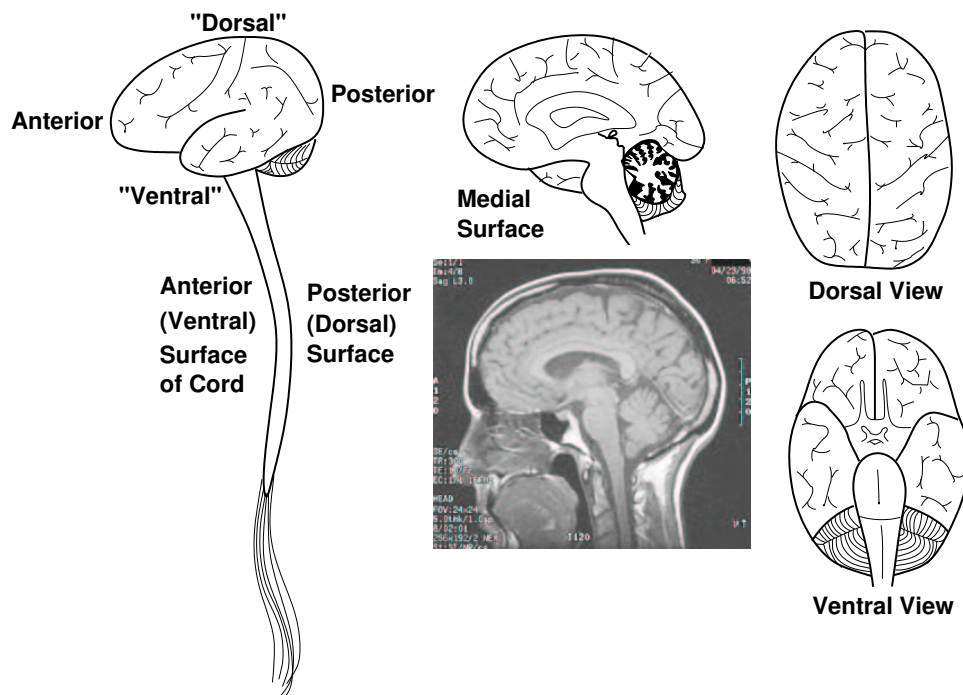

Figure 1.1: Brain orientation nomenclature.

Orientation Nomenclature: As seen in the MRI in the figure above, for a person standing up, the axis of the cerebral hemispheres is roughly horizontal (parallel to ground), that through the brainstem oblique, and that of the spinal cord approximately vertical. Thus, for the spinal cord the term **anterior** refers to the part closest to the front of the neck, chest or abdomen, while for the cerebral hemispheres it means the part closest to the forehead. Obviously, for the spinal cord **posterior** means the part closest tos the back of the neck, chest, or abdomen

Likewise, the base of the brain as it sits in the skull is sometimes referred to as **"ventral,"** while the superior portion of the brain just beneath the top of the head is **"dorsal."** (If, however, you are trying to refer to progression along the neuraxis from the "higher level" of the cerebral hemispheres to the "lower level" of the spinal cord, calling the cerebral hemispheres "anterior" to the spinal cord can be confusing, since they are both anterior. The term **"rostral"** is commonly used to indicate this evolutionary or developmental relationship; thus the cerebral hemispheres are considered "rostral" to the spinal cord.)

1.1   Spinal Cord

1.1.1   External Anatomy of Spinal Cord (Haines 2–1 to 2–4)

Vertebral Column:

The *vertebral column* consists of seven *cervical*, twelve *thoracic*, five *lumbar*, five fused *sacral*, as well as four (usually) *coccygeal* vertebrae. The relationships of these vertebrae with the spinal cord and roots were studied in the Structure of the Human Body course and can be appreciated in the sagittal MRI in Figure 1.2 below.

Figure 1.2: Sagittal MRI showing relation of vertebral column and spinal cord. Can you find the herniated disc?

Spinal Cord:

The *spinal cord* measures about 42-45 centimeters in length. However, the specimens available for study are somewhat shorter, since all of them are lacking the first few upper cervical segments. The spinal cord itself lies within the vertebral canal and extends from the *foramen magnum* to the lower border of the first lumbar vertebra. The cord is cylindrical in shape and somewhat flattened anteroposteriorly. Two spindle-shaped swellings, the *cervical* and *lumbar enlargements*, comprise those portions of the cord which innervate the upper and lower extremities. Below the lumbar enlargement the cord rapidly narrows to a cone-shaped termination, the *conus medullaris*. From the conus a slender non-nervous filament, the *filum terminale*, extends downward to the fundus of the dural sac at the level of the second sacral vertebra. It penetrates the dura and, invested by the dura, forms the *coccygeal ligament*. The bundle of descending nerve dorsal and ventral roots below the conus medullaris is known as the *cauda equina* ("horse tail") and is illustrated in Figure 1.3. They

are located in the *lumbar cistern* from which samples of *cerebrospinal fluid* are commonly taken. **See Haines 2–4**.

Figure 1.3: Cauda equina and conus medullaris of spinal cord.

Meninges:

Examine the outer aspects of the *dura mater*, which is the outermost of the *meninges*. Notice the *spinal ganglia* and nerve roots coming out of the dural sheath along the lateral margins. Most cords will have spinal ganglia, particularly at the lower end of the specimen. With the spinal cord and its dural covering lying flat, use a pair of forceps and scissors to open the dura from the transected upper cervical end, along the midline to the lower end. Turn to the opposite surface and repeat the procedure. **Do not cut the dura along the lateral margins where the nerve roots are located.**

When the dura is opened, find the *denticulate ligaments*, which are extensions of the *pia*, the innermost of the *meninges* that is applied directly to the lateral aspect of the cord, to the *arachnoid*, the intermediate layer of the *meninges* that lies just beneath the *dura*. The *denticulate ligaments* "tether" the cord in place inside the dural sac. **See Haines 2–1.**

Blood Supply to Cord:

The blood supply to the spinal cord is provided by (1) the *anterior* and *posterior spinal arteries*, which are branches of the *vertebral arteries*, and (2) by multiple *radicular arteries*, which are derived from segmental vessels. Roughly speaking, the *anterior spinal artery* supplies the anterior 2/3 of the cord, while the *posterior spinal artery* supplies the posterior 1/3, including the dorsal or posterior columns. **See Haines 2–3.**

Observe the more continuous course of the anterior spinal artery on the anterior aspect of the cord compared to the plexiform arrangement of vessels on the posterior aspect of the cord (see Figure 1.4). The spinal and radicular arteries form a more or less continuous anastomosis for the entire length of the spinal cord.

Holding the dural coverings open, note that the spinal cord has a several longitudinal furrows or grooves (often hard to see unless the pia is stripped off). On the anterior surface is a fairly deep *anterior median fissure* just beneath the anterior spinal artery. On the posterior surface is the
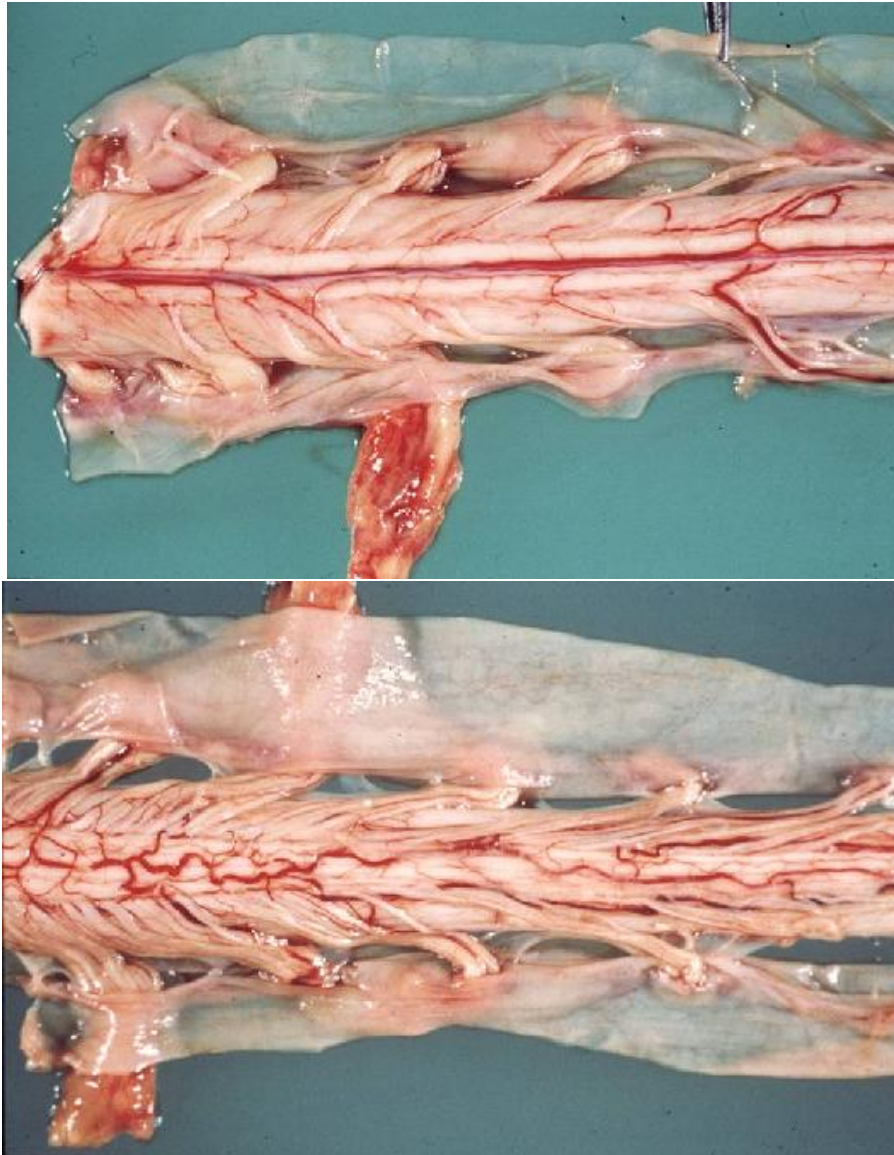
Figure 1.4: Top: anterior (ventral) view of spinal cord; bottom: posterior (dorsal) view of spinal cord. ID the blood vessels and roots on each picture.

shallow *posterior median sulcus* and, more laterally, the *posterolateral sulcus*, which is a fairly distinct furrow marking the entrance of the filaments of the dorsal roots. Above the level of T6 there is a *posterior intermediate sulcus* in between the two sulci just identified. This marks the border between the two bundles of fibers on each side that form the "dorsal columns": the medial *fasciculus gracilis* and the lateral *fasciculus cuneatus*. Anteriorly, the *anterolateral sulcus* marks the exit of the ventral root fibers and is hard to see. **See Haines 2–2.** If you have trouble finding these structures on the spinal cord, use the rubber brain stem model.

Study Questions

Identify the following structures and answer the questions:

- *cervical* and *lumbar enlargements*: Why do these develop?

- *conus medullaris*: Which interspinous space is used for lumbar puncture in order to prevent damage to the conus?

- *cauda equina*: Explain the formation of this structure.

- *filum terminale*: Does this structure contain nerve fibers?

- *ventral nerve roots* (motor): Where do these fibers emerge from the cord? How many segments and how many nerve roots are there in the spinal cord?

- *dorsal nerve roots* (sensory): Which sulcus marks the entrance of these fibers into the cord? Where are the cell bodies of the dorsal root nerve fibers? Where are the dorsal root ganglia located with respect to the vertebrae?

- *anterior median fissure* and the *posterior median sulcus*: Which of these contains a blood vessel? What is the vessel's name?

- *posterior intermediate sulcus*: Does this extend throughout the length of the cord?

- *fasciculus gracilis* and *fasciculus cuneatus*: Where are the cell bodies of these fibers?

1.1.2 Internal Anatomy of Spinal Cord (Haines 5–1 to 5–5)

If not done already, With a scalpel, and being careful **NOT** to cut the dura, transect the spinal cord through the centers of the cervical and lumbar enlargements and at a mid-thoracic level. Examine the various levels of the spinal cord and note the presence of a central gray zone having an "H"-shaped configuration. In addition, Figure 1.5 displays myelin-stained cross sections of the major levels of the spinal cord and should also be referred to as you proceed with this laboratory exercise.

Gray Matter: The *gray matter* will vary in its mass depending on the level studied. The gray matter consists of nerve cells, glial cells, and myelinated and unmyelinated fibers. The *central canal* in the center of the spinal cord is almost impossible to see with the naked eye but is visible under a microscope. Surrounding the spinal gray matter is *white matter*, consisting of ascending and descending myelinated and unmyelinated fibers. Those fibers traveling together and serving a similar function are referred to as *tracts* or *fasciculi*. The spinal gray matter is divided into a *posterior* or *dorsal horn*, an *intermediate gray*, and an *anterior* or *ventral horn*.

C2

C8
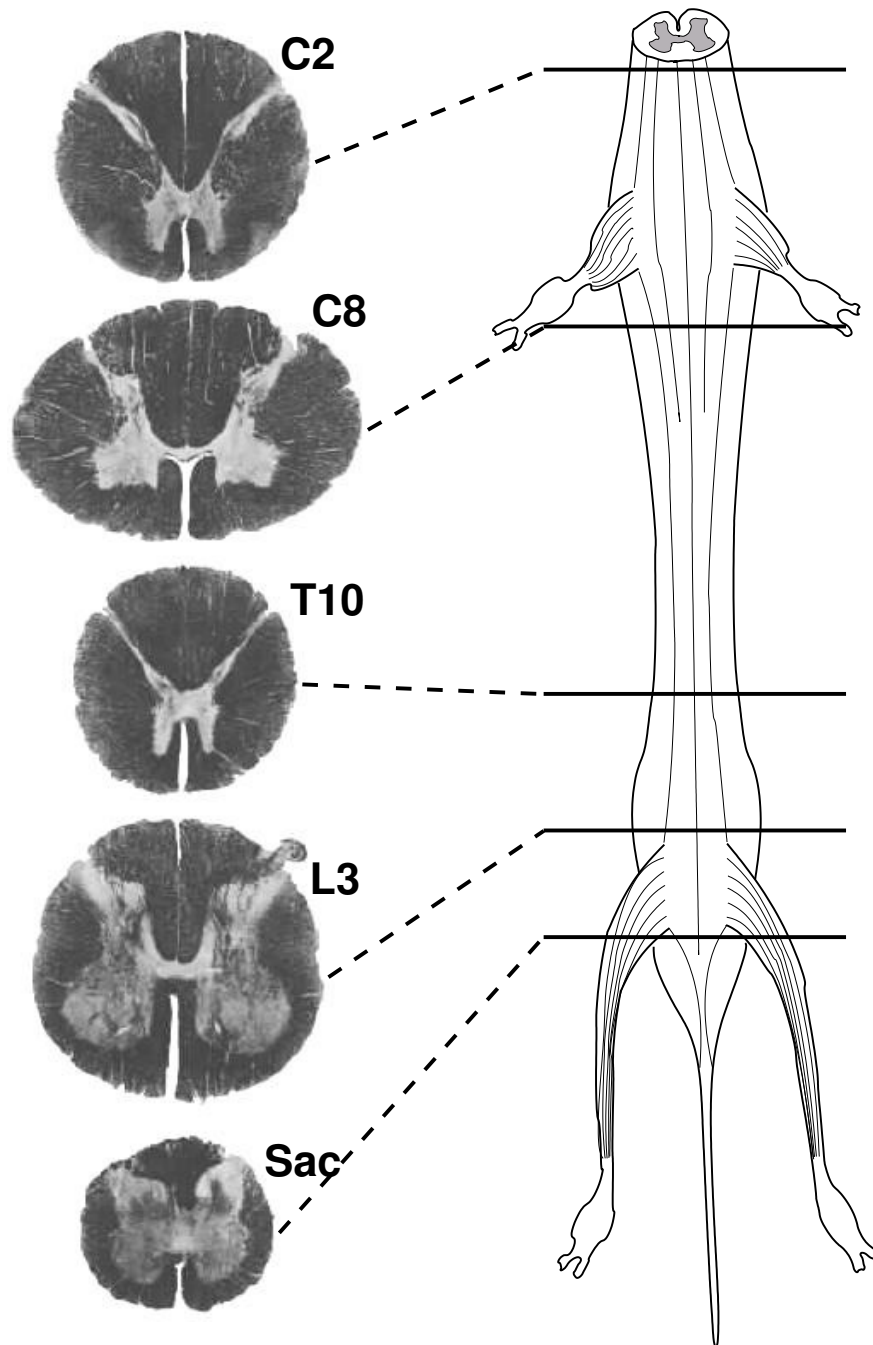
T10

L3

Sac

Figure 1.5: Dorsal (posterior) view of spinal cord and cord cross sections from *Atlas Anatomicum Cerebri Humani* by G. Jelgersma, Scheltema & Holkema Boekhandel en Uitgeversmaatschappij N.V., Amsterdam.)

White Matter: The white matter is conventionally subdivided into *posterior* (dorsal), *lateral*, and *anterior* (ventral) *columns* or *funiculi*.

The ratio of gray to white matter varies depending on the level studied. The gray matter is larger at levels providing innervation to the extremities (cervical or lumbosacral enlargements). The cervical segments contain a greater total amount of white matter than lower levels because the ascending and descending pathways have more fibers in them at these levels than at lower levels. Compare a cervical and lumbar segment. With reference to your textbook or atlas study the following details.

Cervical Cord (Haines 5–4): This is somewhat oval in outline, with an increase in its transverse diameter at lower cervical levels that are part of the cervical enlargement. Note that the *anterior* and *posterior horns* of the gray matter are large. There is no lateral horn as found at thoracic levels. The white matter forms a greater proportion of the transverse cross-sectional area here than at lower levels. The *posterior* or *dorsal columns* of the white matter are larger than elsewhere and are clearly subdivided into the medial *fasciculus gracilis* and the lateral *fasciculus cuneatus*, with the *posterior intermediate sulcus* separating them.

Thoracic Cord: (Haines 5–3) This is smaller and more nearly circular than the cervical cord. The gray matter is reduced to slender *posterior horns* and a small rounded *anterior horn*. The *lateral horn* containing the sympathetic preganglionic neurons is now visible. This is characteristic of the thoracic region.

Lumbar Cord: (Haines 5–2) This is more or less circular in outline and is larger in diameter than the thoracic cord but smaller than the cervical cord. There is much less white matter surrounding the gray, and the *posterior columns* show no subdivision into the medial *fasciculus gracilis* and lateral *fasciculus cuneatus* since only the *fasciculus gracilis* is present at lumbar levels. The gray matter is greatly swollen in both the *dorsal* and *ventral horns*.

Sacral and Coccygeal Cord: (Haines 5–1) At these levels the cord contains only a thin rim of white matter surrounding a shrunken core of gray matter that exhibits little subdivision into dorsal and ventral horns.

Review Exercise

Label the structures listed below on Figure 1.5. Review again on the spinal cord.

- *cervical enlargement*
- *lumbar enlargement*
- *conus medullaris*
- *filum terminale*
- *cauda equina*
- *spinal ganglia*
- *nerve roots*
- *anterior median fissure*

- *posterior median fissure*
- *posterior lateral sulcus*
- *posterior intermediate sulcus*
- *posterior horn*
- *anterior horn*
- *posterior funiculus*
- *anterior funiculus*
- *lateral funiculus*

Study Questions

1. What is the *lumbar cistern* and why is it important diagnostically?
2. What tracts comprise the *posterior columns*?
3. What is the *motor horn*?
4. Where do you find a *lateral horn* and what is its significance?
5. What are the major criteria for determining cord levels in cross-sections?

Cases (Ponder and then discuss with lab faculty)

Aorta Surgery

A 65 year old man with heart disease undergoes surgery on his thoracic aorta. Afterward he notes paralysis of both lower limbs. On examination there is loss of pinprick and temperature sensation from his umbilicus on down but preserved vibration and proprioception. Both lower limbs are flaccid (hypotonic), paralyzed, and areflexic. No Babinski signs are present.

1. What part of the spinal cord is involved and at what level?

2. Why are some sensory modalities preserved?

3. A lesion in which tract has caused the paralysis?

4. Why are there no upper motor neuron signs in the lower limbs?

5. What blood vessel could be involved and why?

Breast Carcinoma

A 50 year old woman has been diagnosed with breast carcinoma, which has spread to her axillary lymph nodes. For 2 weeks now, she has noticed sharp, shooting pain from the interscapular (upper back) area, radiating around her thorax into the the right nipple anteriorly. This increases with coughing or straining. Yesterday she awakened with numbness over the left leg and dragging of her right leg. Examination shows reduced temperature and pinprick sensation over the lower left thorax and entire left lower limb, reduced proprioception at the right toes and ankle, and reduced vibration throughout the right lower limb. The right lower limb is mildly weak with increased right knee and ankle reflexes, and a right Babinski sign is present.

1. What localizing significance is there to her chest pain?

2. Why does it increase with coughing or straining?

3. What structure(s) are involved to produce this pain?

4. Explain her sensory and motor signs and symptoms.

5. What type of lesion do you most likely suspect?

1.2   Brain, Meninges, and Sinuses (Haines 2–9, 2–15, 2–26)

Use the whole brain or a brain model for the study of the dorsal (Figure 1.6), lateral (Figure 1.7), and ventral (Figure 1.9) surfaces, and the half brain for the study of the medial surface (Figure 1.8). Dissect away the meninges as necessary to visualize underlying structures, **taking care not to destroy blood vessels that will be studied later.**

1.2.1 Cerebrum (Haines 2–9, 2–15)

The *cerebrum* is composed of *two hemispheres*, which display prominent round convolutions or *gyri* separated by *sulci* or *fissures*. The *brain stem* is a midline structure attached rostrally to the deep structures of the hemispheres, and its caudal end is continuous with the spinal cord. The *cerebellum* is attached directly to the brain stem.

The *cerebral hemispheres* consist of a superficial covering of *cortex* only a few millimeters thick (called *gray matter* because that is its color in poorly fixed specimens), while the underlying nerve fibers wrapped with myelin appear white, hence *white matter*. Embedded deeply in the white matter of each hemisphere (and hence not visible in the gross brain) are large aggregates of gray matter known collectively as the *basal ganglia*. Likewise, within each hemisphere a large cavity is also found, the *lateral ventricle*.

Using the whole brain or a brain model, note that the two hemispheres are separated from one another by the *longitudinal fissure* and from the brain stem and cerebellum by a *transverse fissure*. Much of the transverse fissure is hidden, including the portion that lies superior (dorsal) to the *colliculi* of the midbrain and the portion that lies between the diencephalon inferiorly and the *fornix* and *corpus callosum* superiorly. **See Haines 2–27 and 2–28.**

Figure 1.6: Dorsal view of brain. Arrow indicates arachnoid granulations.

Figure 1.7: Lateral view of brain. Arrow indicates lateral (Sylvian) fissure.

On the lateral aspects of each hemisphere observe that the *lateral (Sylvian) fissure* separates the *temporal lobe* below it from the *frontal* and *parietal* lobes above. The *central (Rolandic) sulcus* forms the posterior boundary of the *frontal lobe*, marking its border with the *parietal lobe*. **See Haines 2–9.**

Using the rubber brain stem model, note that the brain stem is attached to the cerebral hemispheres by the *crus cerebri*, large bundles of fibers running on the ventral surface of the midbrain. From rostral to caudal, the brain stem is divided into four important regions: the *diencephalon*, the *midbrain* or *mesencephalon*, the *pons*, and the *medulla*. Overriding the brain stem at the level of the pons is the cerebellum, which is attached to the brain stem by three pairs of large fiber bundles, the *cerebellar peduncles*.

On the ventral surface of the whole brain or a brain model, locate the *optic nerves*, *optic chiasm*, and the *mammillary bodies*. Lateral to the *optic chiasm* there is a bulge in the medial border of the temporal lobe called the *uncus*. **See Haines 2–18.** (**Important clinical question:** What cranial nerve courses just medial to the uncus and could be compressed if the uncus herniated?)

Using both the half brain or a midsaggital MRI (see MRIs on lightboxes or Figure 1.8 below), locate on the medial surface the *corpus callosum*, *septum pellucidum*, *fornix*, *anterior commissure*, *third ventricle*, *interventricular foramen (of Monro)*, *mammillary body*, *pineal body*, *thalamus*, *hypothalamus*, *pituitary*, *optic chiasm*, *midbrain*, *pineal gland*, *cerebral aqueduct*, *superior colliculus*, *inferior colliculus*, *tentorium cerebelli*, *pons*, *fourth ventricle*, *medulla*, *cerebellum*, and *spinal cord*. Where would midline dural structures such as the *falx cerebri*, *superior sagittal sinus* be found? **You must learn to identify these structures on the midsagittal view of the brain MRI—they will be tested!**
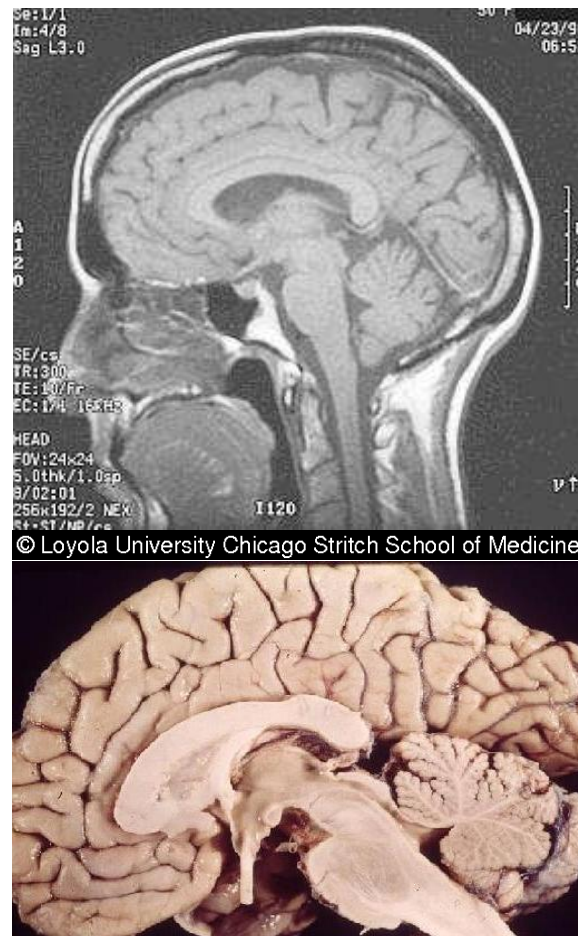

Figure 1.8: Midsagittal views of brain.

1.2.2 Brain Stem and Cerebellum (Haines 2–18, 2–30, 3–10)

Use the brain specimens, figures, and the rubber brain stem model to help you find and identify the structures in this part of the lab exercise.

Figure 1.9: Top: ventral view of brain stem; bottom: dorsal view of brain stem with cerebellum removed to display floor of fourth ventricle, cerebellar peduncles, etc.

The undersurface of the *midbrain* presents paired fiber bundles called *crus cerebri* (also called *cerebral peduncles*). The space between these obliquely placed peduncles is called the *interpeduncular fossa*, where the *oculomotor nerves* (III) emerge. **See Haines 2–18 and 2–21.** The posterior surface of the midbrain consists of paired *superior* and *inferior colliculi* (all four together are referred to as the *tectum* or roof of the midbrain). **See Haines 2–28 and 2–32.**

Caudal to the *midbrain* is the *pons*. Laterally and posteriorly (dorsally) the *pons* is connected with the *cerebellum* by three pairs of peduncles: the *superior cerebellar peduncle* (or *brachium conjunctivum*), the *middle cerebellar peduncle* (or *brachium pontis*), and the *inferior cerebellar peduncle* (or *restiform body*). These can be most easily found on the rubber brain stem model. On a real brain, slight elevation of the rostral portion of the *cerebellum* off the brain stem will bring the superior peduncle into view. The middle peduncle is the large fiber bundle that passes posteriorly and caudal from the region of the attachment of the trigeminal nerve. The inferior peduncle is difficult to see. **See Haines 2–32 and 2–33.**

The *pons* is continuous caudally with the *medulla oblongata*. Anteriorly, the *medulla* presents a *median fissure*, bounded on each side by a fiber bundle called the *pyramid*. Near the caudal end of the *medulla* most of the fibers of the *pyramids* decussate or cross. Verify this by gently spreading the edges of the fissure apart. Each *pyramid* is defined laterally by an *anterolateral fissure*, which contains root filaments of the *hypoglossal nerve* (XII). Just behind these hypoglossal rootlets in the rostral half of the medulla an oval bulge, the *olive*, is evident. Rootlets of the *glossopharyngeal* (IX), *vagus* (X) and *accessory* (XI) nerves emerge from the dorsal or *post-olivary sulcus*, which is slightly posterior to the *olive*. The *medulla oblongata* becomes the spinal cord at the level of the most rostral anterior (ventral) root filament of the first cervical nerve (C1); this is the approximate level of the *foramen magnum*. **See Haines 2–18, 2–28, 2–32, and 2–33.**

1.2.3   Meninges (Haines 2-41)

The brain, consisting of the *cerebrum*, *cerebellum* and *brain stem*, is covered with an outer dense fibrous sheath, the *dura mater*, and an inner membrane, the *pia-arachnoid* membrane, which is sometimes termed the *leptomeniges* (lepto = light or delicate). The latter actually consists of two distinct membranes, the *pia mater* and the *arachnoid*. Between the pia and the arachnoid lie the major blood vessels, and the cerebrospinal fluid is found in the *subarachnoid space*. Because the meninges may have been removed from your brain specimen, you should refer to your textbooks and examine other specimens when possible. **See Haines 2–41.**

The *dura* has an outer, *periosteal* or *endosteal layer* that is adherent to the inner surface of the cranium and an inner, *meningeal layer*. These two layers are usually tightly fused but separate at certain sites to form the *venous sinuses* (see below). In several places the inner dural layer forms septa which divide the cranial cavity into compartments. The most prominent of these septa are the mid-sagittal *falx cerebri*, located between the two cerebral hemispheres; the horizontally positioned *tentorium cerebelli*, located between the cerebral hemispheres and the cerebellum; and the *diaphragma sella*, covering the pituitary fossa and perforated by the pituitary stalk. (The *tentorium cerebelli* has an opening or notch in it through which the midbrain passes; increased supratentorial (above the tentorium) intracranial pressure from a hemorrhage or other cause can herniate or push the *uncus* and adjacent portions of the medial part of the temporal lobe through this opening, thereby compressing the third nerve and midbrain and possibly causing coma and other problems. What reflex would be affected by such third nerve compression?)

The *middle meningeal artery*, a branch of the maxillary artery, provides the major blood supply to the dura. Branches of this vessel may be lacerated by skull fractures, producing a space-occupying *epidural hemorrhage* between the skull and the dura.

On the dorsal surface of the hemisphere notice the gray-white granular (cauliflower-like) structures known as the *arachnoid villi*, most obvious in the parasagittal region. On specimens where a portion of the dura remains attached, note the relationship of these arachnoid villi to the *superior sagittal sinus* as well as to the adjacent dural membrane. Arachnoid villi, which are also called *arachnoid granulations* or *pacchionian bodies*, act as one-way valves that allow cerebrospinal fluid to enter the venous circulation. The *arachnoid*, which represents the outer membrane of the leptomeninges, "bridges over" the sulci between gyri and is fixed to the pia by fine connective tissue
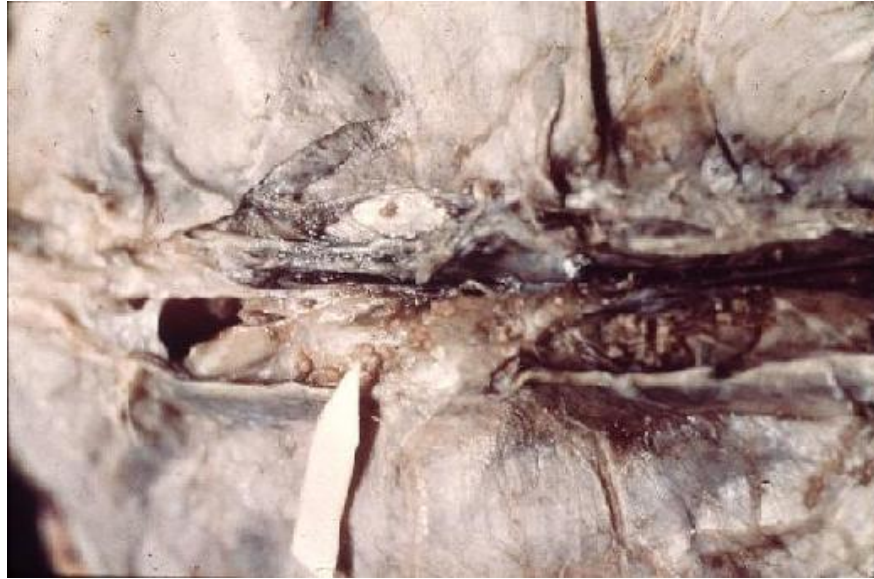
Figure 1.10: Dura with superior sagittal sinus opened to show arachnoid villi.

filaments known as as *arachnoid trabeculae*. **See Haines 2–41.**

The *pia*, in contrast to the arachnoid, adheres closely to the brain's surface and extends into the depths of the sulci and fissures, carrying the blood vessels with it. A subarachnoid space exists between the arachnoid and pia mater, and in life this space is filled with the *cerebrospinal fluid* or CSF, which thus separates the two membranes. In the postmortem specimen, this space usually collapses due to the loss of fluid.

In certain areas at the base of the brain and around the brainstem, the pia and arachnoid are widely separated, thus creating *subarachnoid cisterns*. Identify the *cisterna magna* (cerebello-medullary cistern), the *interpeduncular cistern* (between the cerebral peduncles), the *pontine cistern* (ventrally at the ponto-medullary junction), the *chiasmatic cistern* (around the optic chiasm), and the *superior cistern* (above the midbrain). Also identify these cisterns on the midsagittal pictures in Figure 1.8.

1.2.4   Venous Sinuses (Haines 2–8, 2–11, 2–14, 2–17, 8–2, 8–4, 8–5, 8–9)

Locate the *superior* and *inferior sagittal sinuses* in the upper and lower margins of the the *falx cerebri*, the *right* and *left transverse sinuses* along the attachment of the tentorium to the occipital bone, and the *straight sinus* in the attachment of the falx cerebri to the tentorium. The superior sagittal, straight, and transverse sinuses converge at the *confluence of sinuses*. Draining the confluence, the transverse sinuses continue as the S-shaped *sigmoid sinuses* that are in turn drained by the *internal jugular veins*. The *cavernous sinus*, which is located on the side of the sphenoid bone lateral to the *sella turcica*, is drained partly by the *superior and inferior petrosal sinuses*, which empty into the *sigmoid sinus* that drains into the jugular vein.

Study Questions

1. What is the *tentorial notch* (or incisure)?

2. Where are the anterior, middle and posterior *cranial fossas*?

3. What is the function of the *arachnoid villi*?

4. What is the clinical significance of the *cisterna magna*?

5. Where is the *CSF* produced?

6. What artery supplies the cranial dura? What is its clinical significance in cases of skull fracture?

7. What are the *venous sinuses*? How are they related to the dura?

8. What are the major *subarachnoid cisterns*?

9. What are the major subdivisions of the brain stem?

10. Where is the *central sulcus*? What border does it mark?

11. Where is the *lateral sulcus*? What border does it mark?

12. Where is the *tectum*?

1.3   Blood Vessels

1.3.1   Review of Major Blood Vessels (Haines 2–16, 2–19)

On the LUMEN web site there is a *Neurovascular Anatomy* section. Visit it at
`www.meddean.luc.edu/lumen/MedEd/Neuro/neurovasc/navigation/nvhome.htm`

As you learned in the Structure course, Three major arteries arising from the aortic arch form the major vascular supply to the brain. These include the *brachiocephalic* on the right and the *left common carotid* and the *left subclavian arteries*. The brachiocephalic gives rise to the *right common carotid* and the *right subclavian* arteries. The *common carotid arteries* divide to form the *external carotid arteries*, which supply the face, and the *internal carotid arteries*, which supply the brain. The *internal carotid artery* enters the skull through the carotid canal in the petrous portion of the temporal bone and then makes an acute, hairpin turn back upon itself within the *cavernous sinus*. Once inside the cranial cavity it gives off its first branch, the *ophthalmic artery*, which supplies the eye. Shortly thereafter it divides to form the *anterior* and *middle cerebral arteries*.

The two subclavian arteries give rise to *vertebral arteries* that pass through the formina in the transverse processes of the upper six cervical vertebrae and enter the skull through the *foramen magnum*. After running on the anterior surfaces of the medulla, the two vertebral arteries fuse at the lower border of the *pons* to form the *basilar artery*, which ultimately bifurcates at the level of the midbrain to form the two *posterior cerebral arteries*.

In summary, the vascular supply to the brain originates from two sources: the *anterior circulation* (carotid system) and the *posterior circulation* (vertebral system), as seen in the figures on the following page. These two circulations are connected by means of the *posterior communicating arteries*.

1.3.2   Blood Supply of the Brain (Haines 2–19, 2–22, 2–33)

Internal Carotid Artery (Anterior Circulation) (Haines 2–21)

The major branches of the *internal carotid artery* include the *ophthalmic artery*, which enters the orbit through the optic foramen and supplies the eye; the *posterior communicating artery*, which joins the posterior cerebral artery; and the *anterior choroidal artery*, which passes backward across the optic tract and then laterally into the temporal lobe. The *internal carotid artery* has two terminal branches: the smaller *anterior cerebral artery* and the larger *middle cerebral artery*, which can be considered the direct continuation of the *internal carotid*.

Vertebral Artery (Posterior Circulation) (Haines 2–21, 2–22, 2–33)

The paired *vertebral arteries* fuse at the medullary-pontine junction to form the midline *basilar artery*. Branches of the *vertebral arteries* include 1) paired *posterior spinal arteries*, which descend as a longitudinal plexus on posterior surface of the spinal cord; 2) paired *anterior spinal arteries*, which immediately unite to descend as a single vessel (*anterior spinal artery*) along the *anterior median fissure* of the spinal cord; and 3) the *posterior inferior cerebellar artery*. Branches of the *basilar artery* include the *anterior inferior cerebellar artery*, the *superior cerebellar artery*, and several small *pontine arteries*, one of which is identified as the *internal auditory (labyrinthine) artery*.

Circle of Willis (Haines 2–21)

The connection of the *posterior* and *middle cerebral arteries* by the *posterior communicating artery* and the connection of the two *anterior cerebral arteries* by the *anterior communicating artery* form an arterial loop known as the *circle of Willis*.
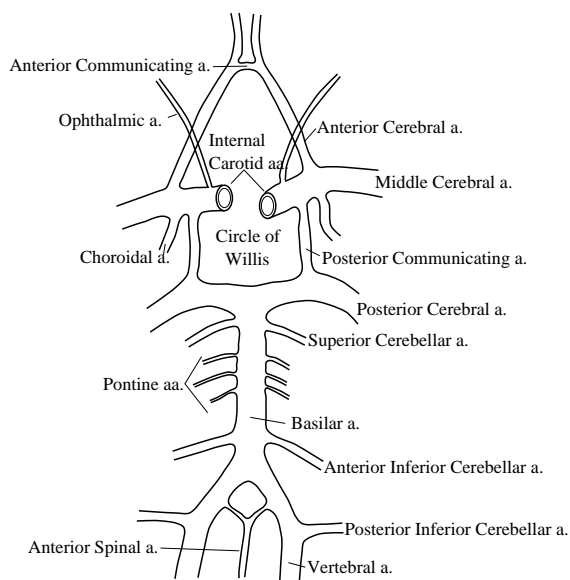

Figure 1.11: Brain circulation.

Figure 1.12: On this carotid angiogram identify the internal carotid artery, the middle cerebral artery, and the anterior cerebral artery.

1.4   Cranial Nerves (Haines 2–15, 2–18, 2–19, 2–20)

Figure 1.13: Identify all of the cranial nerves. **See Haines 2–18.**

I. Olfactory Nerve Locate the *olfactory bulb* and *tract* on the orbital (ventral) surface of the frontal lobe and note how the tract divides into *lateral* and *medial olfactory striae*. The triangular zone created between these two striae is the region where many small blood vessels penetrate into the brain substance and hence is known as the *anterior perforated substance*.

II. Optic Nerve Locate the two *optic nerves*, the *optic chiasm*, and the *optic tract*, which proceeds centrally to the *lateral geniculate body*.

III. Oculomotor Nerve The root fibers of the third nerve emerge from the ventral aspect of the mesencephalon medial to the *cerebral peduncles* in the *interpeduncular fossa*. This nerve innervates most of the extraocular muscles and also is part of the pupillary light reflex circuit.

IV. Trochlear Nerve This is the only cranial nerve leaving the brain stem dorsally (see Haines 2–19). The fibers emerge immediately below the *inferior colliculi* after crossing the midline in the *anterior medullary velum*. The nerve then curves around the *cerebral peduncles* rostral to the *pons* and ultimately enters the orbit to innervate the superior oblique extraocular muscle.

V. Trigeminal Nerve The fifth nerve leaves the brain stem from the ventrolateral aspect of the pons about halfway between the rostral and caudal borders of the *middle cerebellar peduncle*. It is made up of two bundles, a larger one that is sensory and a smaller one that is motor. It passes below the *tentorial notch* and courses through the *cavernous sinus* along with the third, fourth and sixth nerves. It provides sensory innervation of the face and motor innervation to the muscles of mastication.

VI. Abducens Nerve The fibers of the sixth cranial nerve leave the brain stem near the midline within the *pontomedullary sulcus*, coursing through the pyramids. It enters orbit and innervates the lateral rectus extraocular muscle.

VII. Facial Nerve The *facial nerve*, along with the *nervus intermedius*, emerges at the caudal border of the pons lateral to the sixth nerve and rostral to the *flocculus*, a part of the cerebellum. It innervates the muscles of facial expression and innervates taste receptors on the anterior two-thirds of the tongue, among other functions.

VIII. Vestibulo-Cochlear Nerve The eighth nerve also emerges caudal to the pons and immediately lateral to the facial-intermediate nerve. As its name implies, it innervates both the cochlea (hearing) and the semicircular canals (balance). The region where the seventh, eighth and ninth cranial nerves are found, along with the flocculus, is called the *cerebellopontine* or *cerebellomedullary angle*. Tumors sometimes develop in this region producing symptoms in one or all of the nerves surrounding the angle. See Haines 2–20 for a closeup picture of this region.

IX and X. Glossopharyngeal and Vagus Nerves These two nerves emerge from the brain stem as a series of rootlets beginning at the cerebellopontine angle and extending in a linear fashion caudally immediately posterior to the *inferior olive*. The most rostral fibers belong to the ninth nerve, whereas the rest are those of the larger tenth nerve. These nerves have a number of complex functions, with the vagus serving as the main parasympathetic nerve to the heart, lungs, and abdominal viscera.

XI. Accessory Nerve The *cranial division* of this nerve emerges from the lateral surface of the medulla caudal to the lowest roots of the vagus nerve where it joins the *spinal division*, which has ascended to this level after its exit from the lateral aspect of the upper cervical spinal cord in between the dorsal and ventral roots (Haines 2–18). It innervates the sternocleidomastoid and trapezius muscles.

XII. Hypoglossal Nerve The twelfth cranial nerve rootlets emerge in the *anteromedial sulcus*, between the *pyramid* and the *inferior olive* on the ventral aspect of the medulla. It innervates the intrinsic muscles of the tongue.

1.4.1 Cases (Ponder and then discuss with lab faculty)

> **Window Washer Fall**
>
> A window-washer falls two stories after his scaffolding breaks, and is found unconscious on the sidewalk below. Upon evaluation in the emergency room, a right parietal skull fracture is noted, with underlying cerebral hemorrhage. One hour later, his right pupil becomes fixed (unresponsive to light directly and consensually) and dilated (3 mm larger than the left pupil).
>
> 1. What cranial nerve is involved?
>
> A CT scan shows massive herniation of the temporal lobe across the (sagittal) midline of the cranium, secondary to the cerebral hemorrhage and its edema.
>
> 2. What portion of the temporal lobe is compressing the nerve?
>
> The parietal lobe is likewise swollen, but has not herniated over to the other side.
>
> 3. What structure prevents its herniation?
>
> Unfortunately, the man remains in coma, breathes rapidly for a time, and later, after breathing irregularly, becomes apneic and dies.
>
> 4. What vital structures in which part of the CNS were compressed and led to a fatal outcome?
>
> 5. Where was the compression?
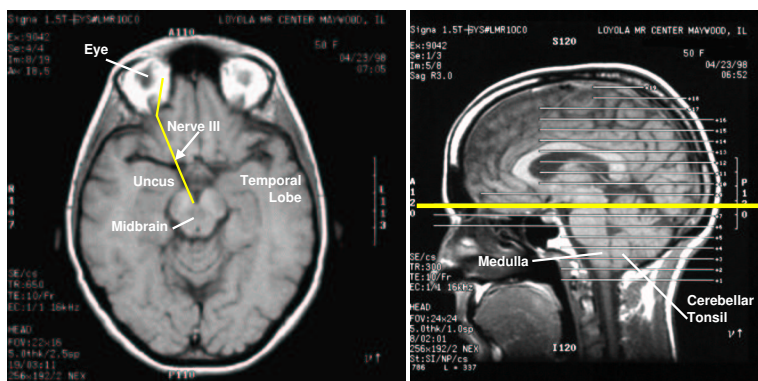
In reference to the case just described, in the axial (horizontal) MRI on the left note the relation of the uncus in the medial part of the temporal lobe to the course of the oculomotor nerve (III) from the midbrain to the eye and extraocular muscles. This should help you understand how increased intracranial pressure and subsequent medial uncal herniation can compress the nerve and impair or abolish the pupillary light reflex. The sagittal MRI on the right shows the approximate level of the axial MRI at left. On the sagittal MRI note the relation of the medulla and cerebellar tonsil to the foramen magnum, since tonsillar herniation also occurs, compressing the medulla's respiratory center and thereby stopping breathing. Try to find these levels on the MRI films on the light boxes in the lab.

Head-On Crash

A 35 year old woman driving to work is struck head-on by a drunk driver crossing into her lane. She broke the windshield with her head and was unconscious for 36 hours. In the hospital, she was found to have a fracture of the petrous portion of the left temporal bone. There was paralysis of her entire left face, and she became deaf on the left side. Days later, the patient complained of being unable to smell and had diplopia (images side-by-side) when looking to the right.

1. What cranial nerves are involved and why?

In addition to the above findings, a CT scan of the brain showed contusions (superficial hemorrhages) on the orbital surfaces of both frontal lobes and on the anterior tip of the left temporal lobe.

2. Why did this occur?

Examine the characteristics of the roof of the orbital bones inside a skull.

3. What effect could this have on the orbital frontal cortex in this patient?

Secretary Headache

A healthy secretary suddenly develops a severe headache and loses consciousness briefly at work. In the emergency room, her neck is stiff, she is sleepy but arousable, and she cannot raise her left eyelid. When you open her left eye, you find the eye can only move in abduction, and the left pupil is enlarged and barely reacts to light.

1. What cranial nerve is involved?

A CT scan of the brain shows no tumor or obvious parenchymal hemorrhage, and the cerebral hemispheres are not swollen or herniating.

2. An abnormality of which blood vessel would most likely compress this cranial nerve?

3. Why did she develop a headache and lose consciousness?

The ER physician decides to perform a lumbar puncture to retrieve CSF for analysis. She performs the LP under sterile conditions, inserting a needle between the spinous processes of the L3 and L4 vertebrae.

4. Why here? Why not higher (e.g., between L1 and L2)?

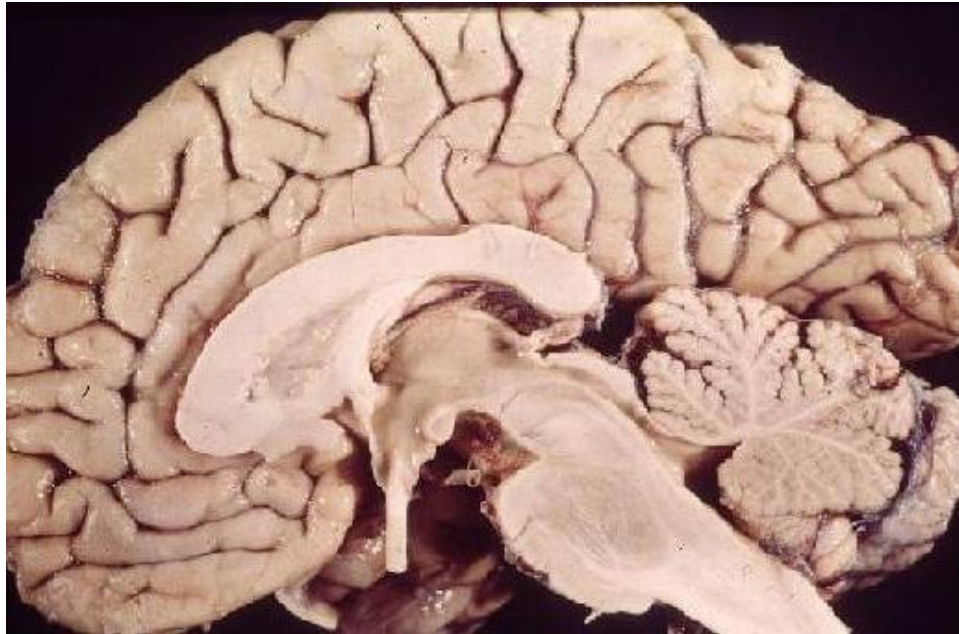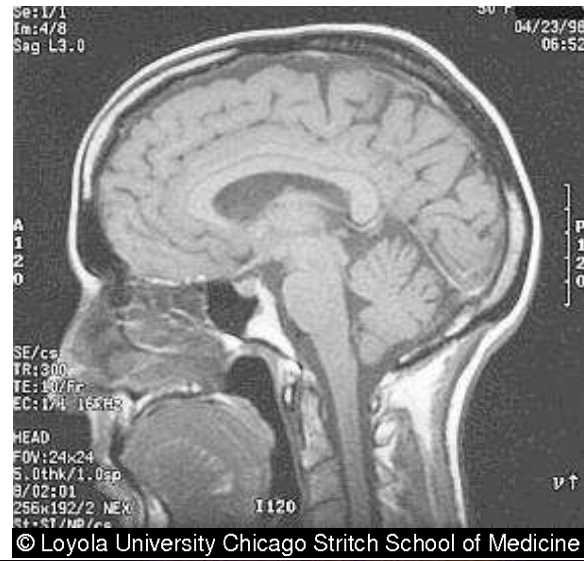5. What should be looked for in the CSF?

Figure 1.14: Midsagittal views of brain. Label as many structures as you can.

Review Exercises

1. Label as many structures listed below on the diagram above (sagittal view of brain stem) as you can. Review their position on your specimens.

- *anterior commissure*
- *anterior medullary velum*
- *cerebral aqueduct*
- *central canal of spinal cord*
- *cerebellar hemispheres*
- *cerebral peduncle*
- *choroid plexuses of 3rd and 4th ventricles*
- *superior and inferior colliculi*
- *corpus callosum*
- *fornix*
- *fourth ventricle*
- *hypophysis (if present)*
- *hypothalamus*
- *infundibulum*
- *interventricular foramen*
- *lamina terminalis*

- *mammillary bodies*
- *massa intermedia (if present)*
- *medulla oblongata*
- *oculomotor nerve*
- *optic chiasm*
- *pineal gland*
- *pons*
- *posterior commissure*
- *septum pellucidum*
- *spinal cord*
- *tectum*
- *tegmentum of midbrain and pons*
- *thalamus*
- *third ventricle*
- *vermis of cerebellum*
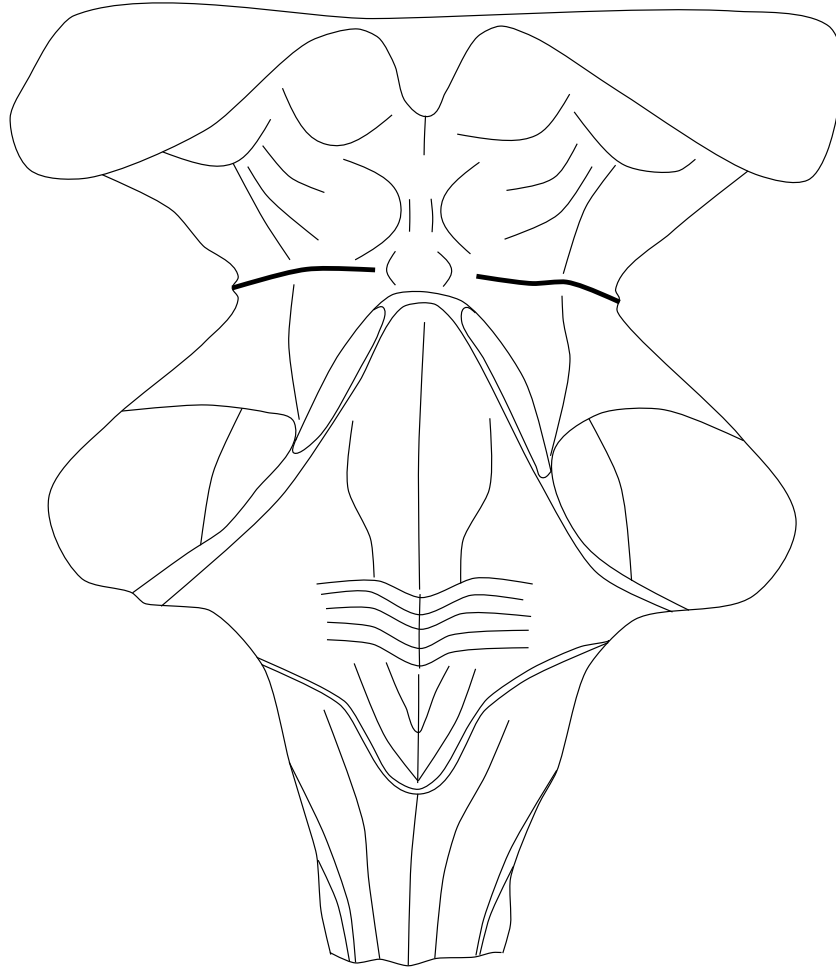
2. Label as many structures listed below on the following diagram (dorsal view of the brain stem) as you can. Review again on gross brain stem specimen.

- *anterior medullary velum*
- *aqueduct*
- *superior cerebellar peduncle (brachium conjunctivum)*
- *middle cerebellar peduncle (brachium pontis)*
- *cerebral peduncle*
- *superior and inferior colliculi*
- *facial colliculus*
- *fourth ventricle - lateral recesses*
- *fasciculus and tuberculum gracilis*
- *fasciculus and tuberculum cuneatus*
- *hypoglossal triangle*
- *lateral geniculate body*

- *medial geniculate body*
- *median eminence*
- *obex*
- *pineal gland*
- *posteromedian and posterointermediate sulci*
- *inferior cerebellar peduncle (restiform body)*
- *striae medullares*
- *sulcus limitans*
- *thalamus (pulvinar)*
- *trochlear nerve (IV)*
- *vagal triangle*
- *vestibular area*