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BIOL 244L HUMAN ANATOMY AND PHYSIOLOGY LABORATORY
NERVOUS SYSTEM II

The central nervous system (CNS) is one of the more difficult systems of the body to understand, partially because of its fundamental complexity and partially because good dissections are difficult to make. Fresh CNS tissue has the consistency of jello and the preserved tissue we will work with today has the consistency of string cheese. Using the cat, the sheep brain, demonstration cow brains, models, and prepared microscope slides, identify the following features of the peripheral and central nervous system.

I. SPINAL CORD AND MAJOR PERIPHERAL NERVES IN THE CAT

1. SPINAL CORD: The **spinal cord** lies within the vertebral canal of the vertebral column. The spinal cord and brain are the two components of the central nervous system, and the nerves outside of the skull and vertebral column are the peripheral nervous system. The spinal cord is nearly cylindrical, although it tapers from the foramen magnum to the pelvic region but with enlargements at the cervical and lumbosacral regions at the level of the forelimbs and hind limbs. Can you explain why? We will study only a section of the spinal cord as it is well protected within the vertebral column. From the dorsal side of the cat, work in the posterior (caudal) thoracic region, and expose a few centimeters of the vertebral column by removing the dorsal muscles overlying it. Using bone scissors, which look like diagonal pliers, available at the front of class, cut the pedicles of the vertebrae and remove the tops of the vertebral arches to expose the spinal cord. This is not easy to do without damaging the cord, and if you work too delicately, it takes too much time. Ask the instructor for guidance if the approach seems uncertain. Remove more bone and fat from the upper region of the spinal cord until you can see several roots of **spinal nerves** along with the spinal cord. The spinal cord is covered with **dura mater**, a tough connective tissue layer that resembles stiff cellophane and is the outermost layer of the **meninges**. The meninges have a protective and nutritive role. The **pia mater**, which we observed histologically last week adheres to the brain and spinal cord tissue. In certain places which we will study in microscopic section, pia mater is invaginated into the ventricles of the central nervous system to form the **choroid plexuses** which are responsible for secreting the cerebrospinal fluid. Follow a **dorsal root** and a **ventral root** laterally (recall the diagram in the previous laboratory exercise and see diagrams in the text Chapter 13). The best approach for this view is to make a cross (transverse) section of the vertebral column and spinal cord using a bone saw (in our tool box, this will be a hack saw). The roots pass through the intervertebral foramen and then come together to form a **spinal nerve**. As we learned last session, the dorsal root contains sensory nerves and the ventral root contains motor nerves. Before the dorsal root unites with the ventral root, there is an enlarged region, the **dorsal root ganglion** containing sensory nerve cell bodies. A ganglion is a concentration of neuron cell bodies in the peripheral nervous system, while collections of cell bodies in the central nervous system are called nuclei. Technically, the dorsal root ganglion should be called the posterior root ganglion in the upright human, but it is usually still called "dorsal" in both cat and human. Cut out a segment of the spinal cord and carefully remove the meninges with fine forceps to observe how the dorsal and ventral roots connect to the spinal cord, and look at the preparation under the dissecting microscope at the front of class. In last week's laboratory exercise, these connections may not have been particularly clear in the microscope slide section of the spinal cord, because some tissue sections for the slides miss the root connections to the ganglia, and the ganglia can get pushed out of position

when the section is cut. In the transverse section of the spinal cord, you may be able to distinguish the **white matter** and **grey matter**, but the clarity of this distinction depends on preservation conditions of the cat.

2. SYMPATHETIC CHAIN GANGLIA: Return the cat to lie on its back. In the thorax, push the lungs and heart to one side (if they are still there). Examine the area along the center of the rear wall of the thorax where the mediastinum intersects the thorax wall. You will be able to see the position of the vertebral column, even though it is not actually visible behind the thoracic wall. On each side of the center line, there is a thin nerve trunk. This is the **sympathetic chain ganglia** (also known as sympathetic trunk). It is shown both very diagrammatically and more realistically in two figures of Chapter 16. You may need to gently scrape the parietal pleura and underlying thin fat away from the thorax wall to expose this nerve trunk. You should be able to see the **sympathetic chain ganglia** along their length like little beads on a fine string. As the name implies, the sympathetic chain ganglia contain cell bodies of the sympathetic division of the autonomic nervous system.

3. NERVES OF THE FRONT LIMB: (The illustrations in Chapter 13 are helpful). In the region of the axilla ("armpit"), where the subclavian artery leaves the neck-thorax region, there is a branching network of nerves, the **brachial plexus**. This plexus is formed by the merging of branches of several spinal nerves that subsequently diverge into new branches to form the nerves for the front limb. In the limb itself, examine the area where the brachial artery (red) and vein (blue) extend along the medial (inner) surface of the upper limb, parallel to, but between the major muscle masses. Near these two blood vessels are two nerves. The more anterior nerve is the **median nerve**, and the more posterior one is the **ulnar nerve**. The ulnar nerve is the famous "funny bone" that gives you a jolt when you pinch it against the ulna at your elbow.

4. NERVES OF THE HIND LIMB: (Again, see Chapter 13 for illustrations of the human). On the medial (inner) side of the thigh, the femoral artery & vein extend parallel with the **saphenous nerve**. This nerve is usually a bit smaller than the nearby blood vessels, and will look rather pearly white by comparison. The saphenous nerve is the main branch of the femoral nerve and can be seen in the text diagram as the major branch continuing down below the end of the femoral nerve. The **sciatic nerve** is located on the lateral (outer) side of the thigh. It is covered by the biceps femoris muscle. The biceps femoris was probably sectioned across its belly last semester. Reflect its ends with a probe, and look beneath them, although sometimes the sciatic nerve gets caught in the sectioning of the muscle. The sciatic nerve is large, and has a flattened ribbon-like shape.

5. VAGUS NERVE (CRANIAL NERVE NUMBER X): The **vagus nerve** can be seen easily in the neck region, extending alongside the common carotid artery. The text illustration in the crainal nerve section toward the end of Chapter 14 shows its path and connections in the human. It is the major supplier of parasympathetic fibers to the thoracic and abdominal viscera, and parasympathetic activity here acts in an opposing balance to sympathetic activity in fibers from the sympathetic chain ganglia. As the vagus nerve enters the thorax, it no longer contains purely parasympathetic fibers; it picks up some sympathetic fibers from the **sympathetic chain ganglia** here where they run close together. The sympathetic chain ganglia as a unit is smaller and can usually be seen running parallel to the vagus nerve.

II. CRANIAL NERVES:

Cranial nerves are peripheral nervous system nerves that connect directly to the brain (as opposed to other peripheral nerves connecting to the spinal cord); therefore they emerge from the skull. There are 12 designated by roman numerals as well as names. All are paired bilateral. Some cranial nerves are entirely sensory, some are entirely motor, and some are mixed sensory and motor. Use the illustrations in Chapter 14, the illustration in this laboratory guide, and the model human brain to learn the cranial nerves. Some of these emerge from the brain close to one another and can be difficult to identify, particularly on the brain models where they are present as stubs and one cannot see the route they take to their peripheral destinations. Thus the illustrations in the text may be a better guide for some of these nerves.

Nerve	Mode	Major Function
I. Olfactory	sensory	Sense of smell
II. Optic Nerve	sensory	Sense of vision
III. Oculomotor	motor	Extrinsic and intrinsic movements of the eye and lens
IV. Trochlear	motor	Extrinsic movements of the eye.
V. Trigeminal	sensory and motor	Sensory and motor (including mastication) over the face.
VI. Abducens	motor	Extrinsic movements of the eye.
VII. Facial	sensory and motor	Sensory (including taste) and motor (including salivary glands).
VIII Vestibulocochler	sensory	Sense of balance (vestibular) and hearing (cochlear)
IX. Glossopharyngeal	sensory and motor	Sensory (including tongue) and motor (including swallowing)
X. Vagus	sensory and motor	Sensory and motor of pharynx and thorax and abdominal viscera (parasympathetic innervation of respiratory, cardiac and digestive organs).
XI. Accessory	motor	Motor to muscles of neck and upper back.
XII Hypoglossal	motor	Movement of tongue during speech and swallowing

III. BRAIN OF THE SHEEP AND THE CAT

The sheep brain as you receive it will still be surrounded by the **dura mater**. On its under side, the brain will have some heavy tissue and perhaps some attached bone that will surround the optic nerves. At very nearly the center of the underside of the brain, the **pituitary gland (hypophysis)** should show as a somewhat rounded object, even though covered by the dura mater and attached pieces of bone. If all the cranial bone has been pulled off the brain, the hypophysis, which is suspended in the sella turcica by a thin stalk, may have been torn away in preparation of the specimen. With careful use of scissors, cut through the dura mater. Keep the lower blade of the scissors parallel with the surface of the brain, so you don't dig into the brain while cutting. Bearing in mind the gel-like consistency of brain tissue, it is not for nothing that they say the easier things in life are "not brain surgery". Peel off the dura mater, taking care that you do not tear off any brain structures with it. If it is still present, the hypophysis, attached to the brain by a thin stalk, will inevitably break free. The optic nerves will also usually tear at their cross-over attachment (the **optic chiasm**) to the brain. Look at the illustrations (and especially the photographs) in Chapter 14, so you will know what to expect. The **pia mater** with its blood vessels will still be closely attached to the surface of the brain.

To see the cat's brain, we need to make a sagittal section (i.e. of the head) - ask the instructor for help with the hack saw. Rinse the section under the tap at the back of the room to see the structures clearly. After viewing the sagittal section of the brain in the head, and after doing the dissection of the sheep brain below, come back to the cat, and use a blunt probe to gently pry one of the hemispheres and cerebellum out of the skull.

<u>1. SHEEP BRAIN, CAT BRAIN, AND HUMAN BRAIN MODEL</u>: Learn the following structures for the sheep brain, cat brain (where specifically referenced), and for the model of the human brain. Also see the demonstration cow brains at the front of the class. Your text in Chapter 14 has an illustration of the bottom surface of the human brain. Find on the lower surface the **olfactory bulb, olfactory tract, optic nerve, pons, medulla, cerebellum,** and **spinal cord**. The latter may be missing from the sheep brain depending on where it was cut during removal. Almost all of the dorsal surface of the brain is the largest brain region, the **cerebrum**. The outer layer of the cerebrum visible here is the **cerebral cortex**, and together with the underlying cerebral nuclei performs the "higher" level processing of sensory and motor information. Olfactory nerve fibers connect to the olfactory bulb through the cribriform plate of the skull. The olfactory bulb was once thought to be cranial nerve number I, but the bulb is actually part of the cerebrum. Cranial nerve I is actually the collection of olfactory nerves that leave the braincase through the cribriform plate. The olfactory tract brings olfactory sensations to the cerebral cortex. The optic nerve (cranial nerve II) is similarly sensory for vision. The medulla oblongata is much like the spinal cord in organization, but it also contains connections for many of the cranial nerves and special control centers for regulation of heartbeat, respiration, swallowing, and vomiting. The pons also contains centers for generation of the respiratory rhythm that interact with the medulla to control respiration. The cerebellum is another of the larger portions of the brain. Its function is to compare intended movement initiated as signals from the cerebral cortex with current positions and movements of skeletal muscles - in short, it is a major center for co-ordination of body movements.

Pull the two **hemispheres** of the sheep cerebrum gently away from each other while looking down between them. You will be able to see a whitish solid tissue which interconnects the right and left hemispheres. This connecting tissue is known as the **corpus callosum**. Its function is to co-ordinate activities in the right and left halves of the brain. Section of the corpus callosum leads to such bizarre behavior as the inability to recognize things learned by the right side of the body when examined by the left side of the body.

Using a <u>long knife</u> (ask the instructor), now split the sheep brain sagittally into right and left halves. The cut surface of one of the halves will look somewhat like the human brain on p 465 in your textbook. The other illustrations on p 462-475 are also very useful for learning the spatial relationships of brain structures. Identify and learn for the sheep brain, cat brain, and the model of human brain: **thalamus, corpus callosum** (in sagittal section now above the thalamus), **hypothalamus**, and **third ventricle**. The thalamus is the main relay center for sensory information reaching the cerebral cortex from the spinal cord, cerebellum, and cranial nerves. It contains many nuclei. A nucleus in the central nervous system is a region containing neuron cell bodies and synapses; just like a ganglion does in the peripheral nervous system. Thalamic nuclei have relay switching function and the thalamus also contains centers for controlling sleep and wakefulness. The hypothalamus contains numerous nuclei associated with control of homeostatic functions (hunger, thirst, osmoregulation, thermoregulation, endocrine system control, and control of the autonomic nervous system). The CNS ventricles are spaces filled with cerebrospinal fluid that circulates and nourishes the CNS tissue. They are interconnected and the fluid circulation provides nutrients and carries away metabolic waste products much like the blood stream. The cerebrospinal fluid exchanges compounds with the blood stream in the choroid plexuses (see below) but is isolated by a cellular barrier from the blood. This is the "blood-brain barrier" that gives the CNS an additional level of protection from chemical imbalances in the fluid compartments, like the blood stream, in the rest of the body. This third ventricle cavity is usually narrowed by swollen brain tissue, so that it may be difficult to identify in the preserved brain of the sheep and especially in the smaller cat. The **cerebral aqueduct** (not readily seen here in the tissues but visible on the model described below) leads from the **third ventricle** to the **fourth ventricle**. Finally, identify the **pons, medulla oblongata, cerebellum,** and **pituitary gland (hypophysis)**. The pituitary gland is sometimes called the "master gland", because it contains a great variety of cells that, through their endocrine secretions, control the function of many other endocrine glands, particularly those involved in reproduction. That said, the secretions of the pituitary gland are often controlled by the hypothalamus.

Place the two halves of your sheep brain together again, and make a transverse section of the brain at the level of the pituitary. Note that if this were a brain from upright standing humans, it would be a frontal section. The cut surface of the brain will then look somewhat like the illustration of a human brain frontal section in the Chapter 14 section on basal nuclei, although the section illustrated in the text is a little more anterior than yours will likely be. Identify the **lateral ventricles** and the **thalamus**. The thalamus will not look as separate as it does from the other structures in the text diagrams; we will know it only by its location. The **third ventricle** will be just a mere slit between the 2 sides of the thalamus. The **hypothalamus** lies below the thalamus. Like the thalamus, the hypothalamus can be identified only by its location in gross dissection. Identify also in this section the **corpus callosum** and the **cerebral cortex** with its **"grey matter"** and **"white matter"** (not labeled in the human model). Pry out one hemisphere of the cat brain from the skull, and section it similarly to see the **corpus callosum** and **cerebral cortex** in section

2. MODEL OF HUMAN BRAIN VENTRICLES: The model is a copy of a casting made by filling the ventricles of a brain with a liquid casting material that then solidified. On the text illustration early in Chapter 14, the cavities of the human brain are shown in blue gray shading. Using the model of the ventricles, identify the **2 lateral ventricles**, the **third ventricle**, **mesencephalic aqueduct**, and **fourth ventricle**. The pink areas on the model indicate the locations of **choroid plexuses**. A choroid plexus secretes the cerebrospinal fluid into the ventricles, and these structures will be studied in microscopic section below.

WHEN FINISHED WITH DISSECTIONS:

***Place larger sections of your sheep brain and the cat brains you pried out of the skulls in the plastic bag at the front of the lab**

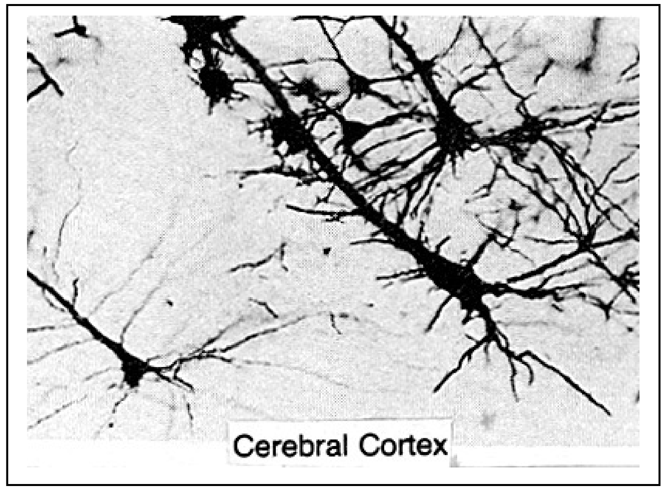
***Throw small tissue scraps (such as pieces of dura mater) in the scraps can at the back of the lab.**

***Wash out the dissecting trays and return the cats to the bins at the back of the lab**

***Clean your dissecting tools, blot them dry, return them in their boxes to the instructor.**

IV. SOME BRAIN HISTOLOGY:

1. CEREBRUM: On the slide ("cerebral cortex") a portion of cerebrum from a mammal has been stained, using silver compounds to produce black stained neurons. With the 10X objective lens, look along what appears as the top edge of the tissue through the microscope. Some of the slides are better than others, but on all of them there are thousands of black neurons. They should resemble those in the photo at the right. Look all along the "upper" edge for the best neurons on most of the slides. These large neurons in the **cerebral cortex** are known as **pyramidal cells**, and they are typical of the cortex. They are motor neurons that initiate distinct motor movements of some part of the body. In the interior of the tissue, note that there are none of these neurons. There may be large black blobs that appeared during the process of staining the tissue, but these are NOT neurons. Look back at the surface of the cortex again, and note that almost all of the pyramidal cells have a process (fiber) that passes toward the surface. Those processes are **dendrites**; axons are NOT visible. Find what appears to be a typical pyramidal cell, and sketch it to show its **cell body** and **dendrite**. You may use high power. Look at more than one slide, because some are better than others.



2. CEREBELLUM: Hold the **cerebellum** slide up to the light, and notice the overall appearance of the tissue slice. Note its resemblance to the cut surface of the sheep brain cerebellum (or Chapter 14 for the human cerebellum). The cerebellum has a prominent role in co-ordination. It integrates motor commands coming from the cerebrum with sensory information on body position and movements. Some of our slides are pink and purple from hematoxylin and eosin stain, while others are brownish from a silver compound stain. With the 4X and then the 10X objective lenses, find an outer layer of the cerebellum. It will be pink (or yellow) and fairly smooth. Just toward the interior from that layer is a grainy-looking layer that is more purple (or brown). The outer, smoother layer is called the **molecular layer**, while the grainy layer is called the **granular layer**. Both layers are "**grey matter**". The molecular layer looks smooth because it is composed of unmyelinated fibers and only a few cell bodies. The granular layer is composed of great numbers of cell bodies and fewer fibers. Where the molecular and granular layers meet, note the occasional conspicuous, large cell bodies (purple or brown stain). These are **Purkinje cells**, and they are typical of the cerebellar cortex. They receive inputs from the spinal cord and cerebrum (via the thalamus) and, integrating the sensory information from the body and motor commands from the cerebrum, their co-ordinating outputs are directed to nuclei in the base of the cerebellum. You may observe them with high power.

In the interior of the tissue, there are areas made of hundreds of parallel purple (or black) lines. These are neuron processes (fibers) that compose the white matter of the cerebellum. They form the branches of the tree-like pattern that is visible on the cut surface of the cerebellum, as on the diagram in Chapter 14 in your textbook.

3. CHOROID PLEXUS: Use the slide of human choroid plexus. Most of what is on the slide is other brain tissue, but look for very lacy objects which seem to be suspended above the ordinary brain tissue (at the top of the field as seen through the microscope). The lacy material is the **choroid plexus**. This tissue secretes the cerebrospinal fluid and is a specialized part of the pia matter. Choroid plexuses are also, as discussed above, the site of the "blood-brain barrier" separating the blood stream from the cerebrospinal fluid while permitting a restricted chemical exchange.

Illustrations of peripheral nerves in the thorax, abdomen, pelvis, and cranial nerves from
Martini, F. H. et al. Fundamentals of Human Anatomy and Physiology. 9th ed. 2012. Pearson.
Gilbert, Steven G. Pictorial Anatomy of the Cat. 1975 University of Washington Press.