

Lecture 4 Review

Before discussing the sensory and motor systems it is important for you to have an understanding of the anatomical organization of the brain and spinal. The reason for this is that for the rest of the course I will be building on your understanding of the basic organization of the CNS. In this lecture I focus on the mammalian nervous system. However, with the exception of the cerebral cortex, which is a unique feature of the mammalian brain, the basic structural organization of the CNS is the same in all vertebrates, from fishes to humans.

It is assumed that you have an understanding of basic anatomical terms (dorsal, ventral, rostral, caudal, etc). There are a few anatomical terms that are used in discussions of the anatomy of the nervous system. You should know these terms and their definitions. **Ipsilateral** is a term that refers to two structures that are on the same side of the body. The term **contralateral** is used in describing two structures that are on opposite sides of the body. **Decussate** means to cross the midline of the brain. There are many places in the CNS where axons decussate (i.e. cross to the other side of the brain), and the place where axons decussate is called a **decussation**.

As I discussed in the introductory lecture for the course, the nervous system can be divided into two major anatomical parts: the **central nervous system (CNS)**, and the **peripheral nervous system (PNS)**. The CNS consists of the brain and spinal cord. And the PNS consists of ganglia, nerves, and sensory structures and receptors (eyes, tastebuds, etc.). **Ganglia** are aggregations of neurons that lie outside the CNS. **Nerves** are bundles of axons that originate from neurons either in the ganglia or the CNS. A **nucleus** is an aggregation of cells in the CNS that have common connections and carry out a common function. A bundle of axons in the CNS is called a **tract**.

It is easiest to understand the organization of the adult brain by first understanding how the brain develops. The formation of the nervous system in mammals begins about 3-4 weeks after fertilization. Nervous system formation begins as a process called **neurulation** and is summarized in Figure 7.8. At the beginning of neurulation the embryo consists of three layers of cells, the **ectoderm**, the **mesoderm**, and the **endoderm**. As I discussed in lecture, each of these layers develop into the various organs and organ systems of the body. You should know the organs that each layer gives rise to in the adult. The ectoderm gives rise to the nervous system. During neurulation the central part of the ectoderm thickens into what is called neuroectoderm. The neuroectoderm forms a flat plate of cells called the **neural plate**. As development continues the edges of the neural plate form folds, which are called the neural folds. The peak of these two folds consists of special cells that will differentiate into what is called the **neural crest**. As process of neurulation continues the neural folds come together and fuse along the midline of the embryo to form a tube called the **neural tube**. The parts of the CNS develop out of the neural tube. The rostral portion of the neural tube develops into the brain, and the caudal portion into the spinal cord. As the neural tube forms, the cells of the neural crest separate from the neuroectoderm. The neural crest cells give rise to the ganglia, nerves and glial cells of the PNS. Because the brain and spinal cord develop out of a tube, they have a central space that is hollow. In the brain these central spaces are maintained in the adult and are called **ventricles**. In the spinal cord, the central hollow

space is called the **spinal canal**. The nuclei of the CNS develop out of the walls of the neural tube.

The anatomical organization of the spinal cord is fairly straightforward. The central region, called the **gray matter**, is composed of the neurons of the spinal cord and the outer region, called the **white matter** is composed of myelinated axons that originate from cells in the spinal cord or brain. You should know the divisions of the gray and white matter of the spinal cord as I presented them in lecture. The spinal cord can be divided into 31 segments. Each segment is associated with and identified by the vertebrae that compose the vertebral column. Each spinal segment has a pair of **dorsal root ganglia** that contain the cell bodies of neurons that convey sensory information from the periphery into the **dorsal horn** of the spinal segment. In addition, each segment has a pair of **ventral roots** that are composed of axons from motor neurons in the **ventral horn** of the spinal segment. Each spinal segment receives sensory information from a specific region of the body and provides motor innervation to the muscles in that region. The spinal cord does not extend the full length of the vertebral column, but stops at the level of the 2nd lumbar vertebra. You should know the reason for that this occurs. The end of the spinal cord, the **conus medullaris**, contains spinal segments L4-S5, and the dorsal and ventral roots that come off of this part of the spinal cord compose the **cauda equina**.

The brain develops out of the rostral portion of the neural tube. After the initial stages of neural tube formation, the portion of the tube that will give rise to the brain forms three expansions called **primary brain vesicles**. From rostral to caudal the three primary brain vesicles are the **prosencephalon**, **mesencephalon**, and **rhombencephalon**. As brain development continues, four **Secondary vesicles** develop on the prosencephalon. Two of these secondary vesicles form the **optic vesicles** that will develop into the retinae of the eyes, and the optic tracts and nerves. The other two vesicles, called **telencephalic vesicles**, form expanded bulb-like structures on each side of the prosencephalon. These bulb-like expansions develop into the **cerebral hemispheres**. Another set of vesicles expands off of the rostro-ventral portion of the telencephalic vesicles. These expansions develop into the olfactory bulbs of the adult brain. A portion of the prosencephalon is not involved in formation of the telencephalic vesicles. This portion of the prosencephalon is called the **diencephalon**. The diencephalon gives rise to the **thalamus** and **hypothalamus** of the adult brain. As the telencephalic vesicles expand, the medial wall of each vesicle comes to lie alongside and fuse with the diencephalon. The portion of the telencephalic vesicles that fuse with the diencephalon is called the **basal telencephalon**, and in the adult brain it forms the **basal ganglia**. Throughout the process of brain development the central hollow space, the ventricles are maintained. The ventricles of the telencephalic hemispheres are called the **lateral ventricles** and these are connected with the ventricle of the diencephalon is called the **third ventricle**.

During the developmental process of the prosencephalon, the neurons in this part of the CNS are forming synapses with one another. The connection pathways that the axons form can be divided into **three major systems of white matter**. You should know each of these systems and the parts of the brain that each connects.

The neurons of the cerebral hemispheres form out of the walls of the telencephalic vesicles. In this part of the CNS, the gray matter (neuron cell soma) lies on the surface, and the white matter (myelinated axons) lies at the center around the ventricles. In the

brain, structures in which the neurons are arranged in layers are called cortex. Based on the number of neuronal layers the cerebral hemispheres can be divided into three cortical divisions: The **isocortex** (a.k.a. **neocortex**) has six layers. The **hippocampal cortex** is composed of a single layer of neurons. The **olfactory cortex** has two layers. Each of these divisions carries out different functions. You should know each of those functions.

Functionally, the thalamus can be thought of as the gatekeeper to the isocortex. All inputs to the isocortex are relayed through the thalamus. The thalamus is composed of various nuclei, which are associated with different sensory modalities. You will learn the names each of these nuclei as we cover the various sensory systems.

The hypothalamus functions primarily in the coordination of autonomic functions (involuntary functions) like body temperature, the osmolarity of the body fluids, etc. It is also responsible for behavioral drives, like hunger, thirst, reproduction, etc. The hypothalamus is also the site where the nervous system and endocrine systems interface.

The mesencephalon gives rise to the division of the adult brain called the **midbrain**. The ventricle of the midbrain is called the **cerebral aqueduct** and it is continuous with the third ventricle. The area above the cerebral aqueduct is called the roof or **tectum**, and the region ventral to the cerebral aqueduct is called the floor or **tegmentum**. The tectum differentiates into two pairs of bumps. The rostral pair of bumps (one on each side of the tectum) are called the **superior colliculi**. The caudal pair of bumps are called the **inferior colliculi**. You should know the function of each of the colliculi. The tegmentum is composed of groups of neurons that have make widely distributed connections in the brain. These nuclei (called the midbrain reticular formation) are responsible for regulation of consciousness. Damage to this part of the brain will result in a decreased state of awareness called a coma.

The ventricle of the rhombencephalon is called the **fourth ventricle** and it is continuous rostrally with the cerebral aqueduct and caudally with the spinal canal. The rhombencephalon differentiates into three parts: the **cerebellum**, **pons**, and **medulla oblongata**. The cerebellum and pons develop out of the rostral rhombencephalon and the medulla oblongata develops from the caudal portion. The cerebellum forms from the roof of the rostral rhombencephalon, which is called the **rhombic lip**, and the pons out of the floor. You should know the functions of each of these divisions of the rhombencephalon.

There are **twelve cranial nerves** that are associated with the brain and provide sensory and/or motor innervation to head and visceral organs. Six of these twelve have neural centers, either motor or sensory, in the medulla oblongata. The remaining five nerves have neural centers in more rostral parts of the brain. The names and details of these cranial nerves are summarized on a handout that was provided in class.

Three layers of connective tissue called **meninges** cover the brain and spinal cord. The meninges serve to protect the neural tissue from mechanical damage. The name of each of these layers and their anatomical arrangement was reviewed in class, and you should know this information for the exam.