NBL 355-655 Module 1 Study Guide Review Q&A

1. *What are the three main functions of the nervous system (please be specific and complete)? What are the main anatomical components of the nervous system and what is the function of each of these components?*

The nervous system a) receives/detects sensory input, b) processes, integrates and stores information, and c) produces responses and behavior. The nervous system can be divided into two main divisions, the CNS and PNS. The CNS is itself divided into the brain and spinal cord. The PNS is divided into the somatic, autonomic/visceral and enteric nervous systems. The somatic NS is divided into afferent (sensory) and efferent (motor) components – it controls voluntary movement via skeletal muscles and mediates conscious sensation. The autonomic/visceral NS is also divided into afferent (sensory) and efferent (motor) components. It produces involuntary control of smooth muscles, cardiac muscles, and secretion from glands, and mediates unconscious sensation from the viscera/organs and tissue. The efferent/motor branch of the autonomic nervous system is divided into parasympathetic (rest and digest) and sympathetic (fight or flight). The enteric nervous system is a part of the PNS located within the GI tract. (In some texts, the enteric nervous system is part of the autonomic nervous system, but the current view is that it is a separate system in the PNS.)

1. *What do gray matter and white matter contain? What are the two main types of gray matter in the brain? Where are the various types of gray matter found? What is a distinctive feature of the neocortex?*

Gray matter contains neuronal cell bodies, dendrites, synapses, and gray matter astrocytes (a type of glia). It also contains blood vessels. White matter contains myelinated axons (the myelin membrane wraps around the axons), oligodendrocytes and white matter astrocytes (glia). It also contains blood vessels. The two types of gray matter are cortex/cortical and nucleus/nuclear gray matter. Cortical gray matter is found in the cerebral cortex and cerebellar cortex. The great majority of the cerebral cortex is neocortex. The distinctive feature of the neocortex is that it contains six layers; the neocortex is thought to have evolved in mammalian evolution. Nuclei are found in the subcortical cerebral white matter, and many other brain regions including the basal nuclei/ganglia, amygdala, thalamus, hypothalamus, brain stem and spinal cord.

1. *What are bundles of axons (which are usually myelinated) in the CNS called (there are three different names for these)? What are the three main types?*

Bundles of axons (which are usually myelinated) in the CNS are called tracts. Two examples are the large descending motor tract called the corticospinal tract; and an ascending sensory tract called the spinothalamic tract. (The only exceptions to this nomenclature are the olfactory nerve (cranial nerve I) and optic nerve (cranial nerve II), which are bundles of axons that are part of the CNS.) Tracts are also called “fibers” or a “fasciculus.” The three main types of tracts are projection tracts (which connect one brain region to a different brain region, for example the motor cortex with the spinal cord), commissural tracts (which connect regions in the left and right cerebral hemispheres, with the largest of these being the corpus callosum and the smaller anterior commissure and posterior commissure), and association tracts (which connect two different areas of the cerebral cortex; many of which are called a specific named fasciculus).

1. *What is the large fissure that separates the cerebral hemispheres into right and left halves? What is the large white matter tract under this fissure and what does it do? What type of white matter tract is it?*

The longitudinal fissure separates the right and left cerebral hemispheres. Underneath the longitudinal fissure is the corpus callosum, one of the commissural tracts that connects the right and left hemispheres. (It connects the same region of the cerebral cortex on either side.)

1. *What are the six main lobes of the brain? (Four are visible from an outside view and two are located deeper inside the brain.) What are the three sulci that divide the brain into the four outside visible lobes?*

The four lobes of the brain visible from an outside (lateral) view are the frontal, parietal, temporal and occipital lobes, named for the cranial bones that overlie them. The central sulcus separates the frontal lobe from the parietal lobe. The lateral sulcus (aka Sylvian Fissure) separates the temporal lobe from the frontal and parietal lobes. The parieto-occipital sulcus separates the parietal and occipital lobes. The other two lobes, which lie deep inside the cerebral cortex, are the insular lobe and the limbic lobe.

1. *What are Brodmann’s areas?*

From Wikipedia: A Brodmann area is a numbered region of the cerebral cortex, in the human or other primate brain, defined by its cytoarchitecture, or histological structure and organization of cells. These numerical designations provided neuroscientists and clinician with a map, so we would know exactly which part of the cerebral cortex was being identified or discussed (or even operated on), even before we knew the function of that particular region. This nomenclature is still used today and provides a standardized nomenclature and map, which is superimposed on the somewhat variable gyral and sulcal anatomy. Note that when Brodmann identified the different areas by their differences in tissue/cellular organization by microscopy, it was not widely known and accepted that there are different functional regions of the cerebral cortex and brain, though it was long suspected by scientists and clinicians including Vasalius, Broca and Wernicke.

1. *What are the five major functions of the brain?*

The five major functions of the brain are a) sensation, sensory processing and perception, b) motor control, c) survival and homeostatic functions, d) emotion, and e) cognitive functions. For most of these functions, numerous interconnected regions of the brain are involved. However, some brain regions have more dedicated roles in each function. The primary and secondary sensory cortices for each sense are involved in sensation and sensory processing. The motor cortex is involved in motor control. The brainstem and hypothalamus are involved in survival and homeostasis. The amygdala in involved in emotion. The prefrontal cortex is involved in cognitive functions. But neurons in each of those regions receive many inputs from other brain regions and project outputs to numerous brain regions in generating these functions. Moreover, some functions such as emotion involve not only the amygdala but also the basal ganglia, prefrontal cortex, anterior cingulate cortex, and insular cortex. Many cognitive functions involve not only the prefrontal cortex but also other regions in the frontal, temporal and parietal lobes.

1. *What are the functions of the different lobes and regions of the brain?*

The frontal lobe contains a) the motor cortex, which is involved in conscious control of voluntary muscle contraction and movement. It also contains b) Broca’s area, which is involved in speech production. The frontal lobe also contains c) the prefrontal cortex, which is involved in executive functions (such as attention, planning, reasoning, problem solving, decision making and working memory), and behavioral and emotional control.

The parietal lobe contains the somatosensory cortex, which is involved in somatosensation (touch). It is also involved in attention and combining sensory information from different senses.

The occipital lobe contains the visual cortex, which is involved in vision.

The temporal lobe contains the auditory cortex, which involved in hearing, and the olfactory cortex, which is involved in smell. It contains part of Wernicke’s area, which is involved in language comprehension. The temporal lobe also contains the entorhinal cortex and hippocampus, which is involved in encoding of spatial and declarative memory.

The limbic lobe contains the cortical structures involved in the limbic system, which are involved in motivation, emotion, learning and memory, and behavior.

The insular lobe is involved in consciousness, emotion (such as empathy), self-awareness and regulation of body homeostasis.

1. *What are the functions of the subcortical regions of the brain?*

The basal ganglia (also called the basal nuclei): Involved in movement (especially initiation), motivation and reward, and procedural (skill and motor) memory

The amygdala: Involved in emotions

The thalamus: Involved in relaying sensory information and also relaying feedback motor information to and from the motor cortex

The hypothalamus: Involved in regulation of homeostatic and autonomic functions, and links the brain to the endocrine system

The brain stem: Involved in survival processes such as breathing and sleeping, consciousness, control of eating/drinking and autonomic control of heart rate and blood pressure

The cerebellum: Involved in balance and motor coordination, motor memory and language and speech

1. *What is the purpose of the skull? Which four major bones fuse to form the cranium? What does the term cranial fossa refer to, and why are cranial fossa important?*

The skull is a bone that protects the brain. The cranium (or neurocranium) and mandible are the two major bones that comprise the skull; the cranium encases the brain while the mandible is the jawbone. The cranium forms from the fusion of the occipital, temporal, parietal and frontal bones (as well as the sphenoid and ethmoid bones). Cranial fossa are indentations on the inner surface of the skull. The brain helps form the cranial fossa by the pressure it exerts on the internal side of the cranium during development. The cranial fossa contain regions where the dura mater attaches to the inside of the skull, and prevents the brain from moving too much inside the skull.

1. *What are the meninges and where are they located? What are the three*

*membranes and what is the function of each of the meninges membranes?*

The meninges are a set of three membranes located underneath the skull and entirely around the brain and spinal cord. The dura mater is the tough protective outer covering/ membrane composed of connective tissue. The arachnoid mater is the middle layer that forms the arachnoid granulations and villi, and subarachnoid space for CSF to flow through and for CSF to be resorbed (transported into the blood vessels). The pia mater is a soft thin membrane that is the innermost of the three and attached to the brain. The pia membrane is impermeable to fluid so it can contain the CSF, and with the other two membranes, the pia mater protects and cushions the brain. The meninges cover both the brain and the spinal cord.

1. *What are the brain ventricles and central canal? What is cerebrospinal fluid (CSF) and where is CSF found?*

The brain ventricles are large fluid filled tubes within the brain that synthesize, contain and circulate CSF. The central canal is a narrow tube in the middle of the spinal cord. CSF is cerebrospinal fluid, a specialized type of fluid that is found in the ventricles, central canal, and around the brain, in the subarachnoid space. CSF is similar to the fluid found around brain cells called the extracellular fluid (ECF). CSF is synthesized by the ependymal cells that line the ventricles and regions within the ventricles called the choroid plexus, which will be described in another module.

1. *Where is and what is the function of the brain lymphatic system?*

The brain lymphatic system is proposed to contribute to the drainage of fluid from brain tissue into the blood and as a key part of the immune system where lymphocytes develop, reside and circulate.

1. *What are the main arteries that supply blood to the anterior and posterior parts of the brain? What is a venous plexus? What major vein do the venous plexuses drain into?*

The two internal carotid arteries supply the anterior and middle part of the brain. The internal carotid arteries arise from the common carotid arteries, and give rise to the anterior and middle cerebral arteries. The two vertebral arteries supply the posterior part of the brain and spinal cord. The vertebral arteries arise from the subclavian artery, and merge to form the basilar artery, which then branches to form the two posterior cerebral arteries. The spinal cord is supplied by the vertebral arteries and medullary arteries. A plexus is a group or congregation of something. A venous plexus is a group of veins that drains into the internal jugular vein. The jugular vein then empties into the superior vena cava. Venous blood does contain some oxygen (just a lot less than arterial blood) so the blood is not blue as often depicted in diagrams, but rather is a dark reddish purple color.

1. *What are bundles of axons in the PNS are called? What are the other components of these structures? What are the functions of the connective tissues?*

Bundles of axons with their associated structures in the PNS are called nerves. Nerves contain mostly myelinated and a few unmyelinated axons (axons are also called fibers or fascicles), Schwann cells (which provide the myelin), blood vessels, and connective tissue (that surrounds the individual axons, bundles of axons and the entire nerve structure). Nerves do not contain neuronal cell bodies. The connective tissue provides compartmentalization of axons, physical protection to prevent shearing of axons, and a barrier to the rest of the tissues and organs surrounding the nerves, to prevent unwanted molecules and cells (both immune cells and toxic cells) from entering into the nerves.

1. *What are groups of neuronal cell bodies in the PNS called, where are they located, and what are the main types?*

Groups of neuronal cell bodies in the PNS are called ganglia. The main types of ganglia are sensory ganglia (which include the dorsal root ganglia-also called spinal ganglia, and cranial ganglia) and autonomic ganglia (with two types called sympathetic and parasympathetic ganglia.) Note that autonomic ganglia contain the cell bodies of the postganglionic autonomic neurons. Also note that a confusing exception to this rule is the “basal ganglia” which is formed by regions containing neurons in the brain (CNS). Neuroanatomists and neurologists are trying to transition to calling this the basal nuclei.

1. *All spinal nerves are mixed nerves. What four types of axons do they contain? Are all cranial nerves mixed nerves? Which cranial nerves are part of the PNS and which are part of the CNS, and what is the basis of this distinction?*

Mixed nerves contain both sensory/afferent and motor/efferent axons. Within each of those categories, there are also both somatic and autonomic/visceral axons. Thus a spinal nerve contains somatic motor axons, autonomic motor axons, somatic sensory axons and visceral sensory axons. Not all cranial nerves are mixed nerves. Some cranial nerves contain only motor axons, some contain only sensory axons, and some contain both. The olfactory nerve (CN I) and optic nerve (CN II) are considered part of CNS since they originate in and travel entirely within the cerebrum, part of the CNS. (Technically they should have been named tracts, but oh well.) CN III – CN XII are part of the PNS since the neuronal cell bodies originate in the brain stem but their axons travel outside of the CNS to innervate their targets in muscles, glands and skin etc., and are part of the PNS. (And for cranial nerves that contain autonomic components, those nerves contain axons from postganglionic parasympathetic neurons and/or axons from visceral sensory neurons.)

1. *What are the three functional categories of neurons, and where are these neuronal types and their axons found (which division) of the nervous system?*

The three functional categories of neurons are motor neurons, sensory neurons and interneurons. The majority of sensory neurons are part of the PNS (their cell bodies are found in ganglia-PNS and their axons are located in nerves-PNS and extend to innervate skin, muscles and joints). Most special sense neurons are considered part of the PNS, except for the photoreceptor cells in the retina, which are part of the CNS.) Interneurons lie are entirely within the CNS (cell bodies and axons are within the CNS). Upper motor neurons lie entirely within the CNS. Lower motor neuron cell bodies lie in the CNS but their axons are part of nerves in the PNS. Postganglionic motor neurons lie entirely within the PNS.

1. *What is the overall function of neurons? What occurs at synapses?*

Neurons are the electrical and chemical signaling cells of the nervous system. The synapse is the region where communication between an axon and its target takes place.

1. *Describe the basic morphology of somatosensory neurons and special sense neurons. What is the role of the thalamus in sensory systems?*

Sensory neurons detect information (light, pressure, chemical or thermal information, called modalities) directly from the external or internal environment, not from synapses, and therefore don’t have dendrites. Somatosensory neurons also do not have one typical axon. Instead, the cell body extends two large axonal branches. One axon branch extends to the tissue it innervates, such as skin, muscles, tendons or joints where the ends of the axon have specialized sensory regions to detect pressure, chemicals or temperature. The other axon branch extends into the spinal cord or brainstem where it sends its sensory information to the CNS. Somatosensory neurons are glutamatergic neurons. They are the only neurons in the PNS that use gluatamate as their neurotransmitter.

Special sensory neurons also do not have typical dendrites. Instead they have a specialized receptive region of the cell to detect light, chemicals or pressure (in the case of auditory hair cells). The majority of special sense neurons (photoreceptors, taste neurons and auditory hair cells) don’t have an axon, but they synapse onto another neuron that extends an axon to form the axonal component of the nerve and relay the sensory information to the CNS. Olfactory neurons are the only special sensory neurons that do have an axon. For the majority of sensory neurons, information is relayed first to the thalamus, which then sends the sensory information to the primary sensory cortex for that modality. The exception is the olfactory system, which relays its information first to the olfactory bulb, which sends olfactory info to the primary olfactory cortex.

1. *The great majority of the 86 billion neurons in the CNS are interneurons. What are the two main functional output types of interneurons and how are they different?*

Two functional output categories are projection (also called principal) interneurons and local interneurons. Projection/principal neurons send their axons to another CNS area and provide input to neurons that are in another area. Local interneurons are also called local circuit neurons, association neurons, relay neurons, or connector neurons. Local interneurons send axons within the same brain region, cortical area, nucleus or spinal cord and control the activity of nearby neurons, locally. In general, local interneurons have shorter unmyelinated axons while projection interneurons have longer myelinated axons. Projection neurons can be either excitatory (glutamatergic), inhibitory (GABAergic) or modulatory (cholinergic or monoaminergic). Likewise, local interneurons can be either excitatory (glutamatergic), inhibitory (GABAergic) or modulatory (cholinergic or monoaminergic).

1. *What are the two specific functional/neurotransmitter types of neurons in the cerebral cortex and cerebellar cortex?*

The two types of neurons in the cerebral cortex are glutamatergic (excitatory) interneurons (they use glutamate as their neurotransmitter) and GABAergic (inhibitory) interneurons (use GABA as their neurotransmitter). The majority of projection/principal neurons in the cerebral cortex are glutamatergic/excitatory though there are some GABAergic projections neurons. The majority of local interneurons in the cerebral cortex are GABAergic/inhibitory though there are some local glutamatergic neurons called stellate neurons. In a similar manner, the neurons in the cerebellar cortex are either glutamatergic or GABAergic. Even though there are only two neurotransmitter types of neurons in the cerebral cortex, cortical neurons can receive synaptic inputs from all different types of neurons, including those that release glutamate, GABA, acetylcholine, and monoamines (dopamine, norepinephrine, and serotonin).

1. *Describe the basic neuronal organization of the somatic and autonomic motor systems.*

There are four types of motor neurons: 1) somatic upper motor neurons (cell bodies and axons found entirely within the CNS), 2) somatic lower motor neurons (cell body in CNS, axons found in nerves-PNS) that innervate skeletal muscle 3) preganglionic autonomic neurons (cell bodies found in CNS, axons found in nerves-PNS), and 4) postganglionic autonomic neurons (cell bodies in ganglia and axons in nerves, so entirely in PNS) that innervate smooth muscles, cardiac muscles and glands.