

# Instructor's Answer Key

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## Chapter 8: The Central Nervous System

### Answers to Test Your Understanding of Concepts and Principles

1. *Decussation* refers to the crossing-over of axon tracts within the CNS from the right to the left side and vice versa. As a result of decussation of motor tracts in elevated triangular structures in the medulla oblongata (the pyramids), the motor cortex of the right cerebral hemisphere primarily controls movements of the left side of the body and vice versa. [Note: This question is also answered in the Student Study Guide.]
2. The cerebral cortex controls movements primarily via direct tracts that descend without synaptic interruption from the motor cortex to the spinal cord. These are the corticospinal tracts that comprise the pyramidal system. The remaining descending tracts including those of the *motor circuit* (caudate nucleus, putamen, globus pallidus, substantia nigra, and thalamus) are extrapyramidal motor tracts. These basal nuclei and the cerebellum control movements indirectly via numerous synaptic interconnections of both stimulatory and inhibitory neural pathways. There are no descending tracts from the cerebellum; the cerebellum can influence motor activity only indirectly by its effect on the various nuclei, including the basal nuclei that send axons to the reticular formation. The reticular formation, in turn, produces a descending motor tract called the reticulospinal tract, which is the primary tract of the extrapyramidal system.
3. The term *ablation* refers to the experimental removal of particular structures in the CNS. Experimental removal of the temporal lobes in monkeys has been shown to produce the condition known as Kluver-Bucy syndrome, where the animal sees objects but lacks the ability to recognize the significance of these objects, and lacks the emotional associations normally present when these objects are seen. This implies that the temporal lobes have some role in this type of visual identification. Experimental ablation of different structures in the limbic system have suggested that these structures are involved in the production of various emotional states; and that the hippocampus and amygdala portions of the brain are required for the consolidation of short-term memory. Finally, as revealed by patients with damage to these areas, the functions of the lateral prefrontal area (lack motivation and sexual desire, for example) can be distinguished from the functions of the orbitofacial prefrontal area (experience severe impulsive behavior, for example).
4. When the corpus callosum is cut the communication between the right and left cerebral hemispheres is abolished; and the unique processing of each hemisphere can be studied separately from the other hemisphere (cerebral lateralization and cerebral dominance). Since most somesthetic sensory fibers project to the contralateral hemisphere, a split-brain patient may be asked to handle a familiar object with one hand and name the object. If the object is handled with the right hand, the information will go to the left hemisphere, and vice versa. One would expect that the left hemisphere would be better at naming the object than the right hemisphere. Alternatively, each hemisphere may be separately presented with a picture of an object, and asked to blindly identify the object from among others by feel, using the contralateral hand. One would predict that the right hemisphere, which controls the left hand, would perform this task better.

5. Damage to Broca's area of the cortex produces speech difficulty without causing impairment in verbal comprehension (Broca's aphasia). This evidence suggests that Broca's area is involved in the motor control of speech. Damage to Wernicke's area impairs language understanding, but not motor ability, so that these patients produce a "word salad" (Wernicke's aphasia). It appears that the understanding of speech, requiring neurons in Wernicke's area, projects to the neurons in Broca's area that control the musculature of speech. This logical assumption is supported by the fact that damage to the arcuate fasciculus, which connects Wernicke's area with Broca's area, produces a conduction aphasia that is similar to Wernicke's aphasia. The observation that damage to the angular gyrus also causes aphasias suggests that this region sends fibers to Wernicke's area. The nature of the aphasias produced by damage to the angular gyrus suggests that this integration area located at the junction of the parietal, temporal, and occipital lobes is required for the association of sensory stimuli (oral or visual) with language.
6. It is believed that there is a difference between short-term memory and long-term memory. Short-term memory may involve the establishment of recurrent or reverberating circuits of neuronal activity. Such circuits may explain the neuronal basis for working memory, the ability to hold a memory (of a grocery list, for example) in mind for a relatively short period of time. People with head trauma, and those treated with electroconvulsive shock (ECS) therapy, lose their memory of recent events but retain their older memories that appear to involve permanent changes. People who have had their hippocampus, amygdala, and associated structures of the medial temporal lobe surgically removed can remember their names and other facts for only a short time; they fail to consolidate this memory into long-term memory. Long-term memory appears to require activation of genes in the cerebral cortex leading to altered protein synthesis and synaptic connections; that is to relatively permanent changes in the chemical structure of neurons and their synapses. An amnesiac patient with bilateral damage to his medial temporal lobes reported details of a neighborhood he left 50 years ago but had no knowledge of his current neighborhood. When the hippocampus on both sides was removed in another patient, the patient could remember things learned before the surgery, but could not form any new stable memories.
7. The hippocampus and associated structures of the medial temporal lobe appear necessary for the acquisition of new information about facts and events, and for the consolidation of short-term memory, which is stored in the cerebral cortex. People with head trauma, and those treated with electroconvulsive shock therapy, lose their memory of recent events but retain their older memories. People who have had their hippocampus surgically removed can remember their names and other facts for only a short time; they fail to consolidate this memory into long-term memory. When the hippocampus on both sides was removed in one patient, the patient could remember things learned before the surgery, but could not form any new stable memories. The nature of the synaptic changes involved in memory storage within the hippocampus appears to involve long-term potentiation (LTP). Here the induction of LTP requires activation of the NMDA receptors for glutamate. The diffusion of  $\text{Ca}^{2+}$  through the opened NMDA receptors of the postsynaptic neuron allows  $\text{Ca}^{2+}$  to activate an enzyme called calcium/calmodulin-dependent protein kinase II (CaMKII) within the dendrites. Subsequently, neuron transmission is strengthened both directly and indirectly by phosphorylation of proteins, including the AMPA receptors. In addition, morphological changes that occur during LTP, such as enlarged dendrite spines and changes in shape, may improve synaptic contact and transmission. Also  $\text{Ca}^{2+}$  activation of nitric oxide synthase and the production of nitric oxide may serve as a retrograde messenger causing further increase in  $\text{Ca}^{2+}$  and increased release of neurotransmitters from the presynaptic axon terminal.

8. It is possible to be aware of a reflex action involving skeletal muscles, but this awareness is not necessary for the response to occur. Stimulation of sensory receptors evokes action potentials in sensory neurons, which are conducted to the spinal cord. Entering the dorsal root of the spinal cord the sensory neuron synapses with an association neuron that in turn synapses with a somatic motor neuron. The somatic motor neuron then conducts impulses out of the ventral root of the spinal cord to the muscle and stimulates a reflex contraction. The conscious awareness of the reflex occurs as ascending fiber tracts from cutaneous receptors, proprioceptors, and visceral receptors relay the sensory nerve impulses up the spinal cord, with decussation mostly in the medulla and spinal cord, to the thalamus and on to the somatosensory cortex of the brain.

### Answers to Test Your Ability to Analyze and Apply Your Knowledge

1. The corpus callosum is a large nerve tract composed of about 200 million fibers connecting the left to the right cerebral hemispheres. In fetal alcohol syndrome, damage to the corpus callosum would mimic split-brain procedures in which each hemisphere is surgically isolated from the other. Although subsequent disability is not obvious, specially designed experiments using sensory images to direct motor responses reveal a deficit in intercerebral communication. The basal nuclei are masses of gray matter composed of neuron cell bodies located deep within the white matter of the cerebrum. The basal nuclei are an integral part of motor circuits that function in the control of voluntary movement. Much of this motor circuit control involves GABA-releasing inhibitory axons from basal nuclei regulating the excitatory neurons emerging from the thalamus and traveling to the cerebral cortex. Damage to the basal nuclei (or basal ganglia) caused by alcohol would mimic various diseases that affect this region such as Huntington's disease and Parkinson's disease. Huntington's disease is hyperkinetic disorder characterized by rapid, uncontrolled, jerky movements (chorea). Parkinson's disease is associated with degeneration of dopaminergic neurons of this area causing muscular rigidity, resting tremor, and difficulty in initiating voluntary movements.
2. Memory storage and retrieval can be divided into two major categories: short-term memory and long-term memory. As previously explained in the answers to questions #6 and #7, head trauma or electroconvulsive shock therapy ablates short-term but not long-term memory. More permanent storage as long-term memory appears to occur in the medial temporal lobe and requires the activation of genes, leading to altered protein synthesis and synaptic connections. Long-term visual memories appear to be stored in the inferior temporal lobes. Memory retrieval is the ability to recall or express memory with verbal or nonverbal recognition patterns. Retrieval may occur at the synapses where high frequency stimulation repetition results in a type of synaptic learning called long-term potentiation (LTP). With continued stimulation, LTP may produce morphological (structural) changes in the post-synaptic neuron, enhancing retrieval. More recently, evidence has revealed that the hippocampus region, which is required for the consolidation of long-term memory and for spatial learning, contains neural stem cells. These stem cells may be involved in the generation of new neurons or neuroglia (neurogenesis) that occurs during learning and memory. Perhaps surgical implantation of neural stem cells in patients with damaged or degenerated hippocampus regions could treat the deficit in these patients and further our understanding of memory storage and retrieval.

3. Perhaps. The study that found a greater number of left-handers among college art students than the number of left-handers in the general population, suggests a correlation between artistic ability and cerebral lateralization, or cerebral dominance. This observation and the fact that Leonardo da Vinci and Michelangelo were both left-handed are intriguing but do not constitute scientific proof of this suggestion. Experiments have shown that the right hemisphere is most adept at visuospatial tasks – such as recognizing faces, arranging blocks, drawing cubes, or reading a map. Furthermore, the right hemisphere better comprehends patterns and part-whole relationships; and enhances the ability to compose music. This visuospatial enhancement appears to be found in 70% of all left-handers whereas the remaining 30% split equally between those flip-flopped with language-analytical ability in the right hemisphere and those with a more equal distribution of skill present in both hemispheres. Perhaps Leonardo da Vinci's visuospatial abilities and cerebral lateralization contributed greatly to his artistic expression, but the input from his language and especially, the analytical ability portion of his left hemisphere will keep this answer forever controversial. It is of personal interest that the gifted and artistic author of this text, Stuart I. Fox, is left-handed.