Chapter 34: Neurology

ACTIVE LEARNING EXERCISES

Concept 34.1 - Nervous Systems Consist of Neurons and Glia

1. Draw two neurons that meet at a synapse.
   Label on your diagram:
   a. Axon
   b. Axon hillock
   c. Axon terminal
   d. Cell body
   e. Dendrite
   f. Nucleus
   g. Presynaptic cell
   h. Postsynaptic cell
   i. Synapse

2. What do axons do?
   a. The major function of an axon is to transmit electrical signals from one location to another.
   b. Axons are the primary location where a neuron receives information from other neurons.
   c. Axons manufacture neurotransmitter.
   d. Axons are the primary location where a neuron releases neurotransmitter.
   e. All of the above

Concept 34.2 – Neurons Generate and Transmit Electrical Signals

3. If calcium channels suddenly open,
   a. there will be a net movement of calcium into the cell.
   b. there will be a net movement of calcium out of the cell.
   c. there will be no net movement of calcium.
   d. the cell will hyperpolarize.
   e. Both a and d
4. Blockage of voltage-gated sodium channels in a neuron will cause which of the following?
   a. The neuron’s resting membrane potential will become more negative.
   b. The neuron’s resting membrane potential will become less negative.
   c. The neuron will be unable to produce action potentials.
   d. Both a and c
   e. Both b and c

5. **How does the pufferfish kill?**

   The Japanese pufferfish produces a highly potent neurotoxin called *tetrodotoxin* (TTX). TTX binds to voltage-gated sodium channels. Ingestion of TTX causes numbness of the lips and tongue, followed rapidly by weakness, loss of coordination, and a sensation of limpness and weakness throughout the body. Relatively small doses of TTX can kill a person.

   Develop a hypothesis to explain the symptoms of TTX poisoning in terms of TTX’s effect on sodium channels. How exactly do you think TTX kills? (see #5 for a clue but expand upon it in your explanation)

   **When TTX binds to voltage-gated sodium channels, it prevents them from opening as they usually would when a graded potential passes threshold.**

   **As a result, neurons and muscles cannot fire action potentials. TTX essentially blocks communication, both from neuron to neuron, and from neuron to muscle. This causes paralysis in the affected muscles. If a fatal dose has been ingested, death occurs by paralysis of the respiratory muscles.**
Concept 34.3 – Neurons Communicate with Other Cells at Synapses

6. Put the following steps in the correct sequence (#1 to 10):
   a. ACh binds to membrane receptors.
   b. Vesicles containing ACh fuse with the cell membrane.
   c. A graded potential spreads through the postsynaptic cell.
   d. Action potential arrives at the axon terminal.
   e. Na+ and K+ enter the postsynaptic cell.
   f. Postsynaptic cell fires an action potential.
   g. Calcium enters the presynaptic cell.
   h. Voltage-gated calcium channels open.
   i. ACh diffuses across the synaptic cleft.
   j. Ligand-gated channels on the postsynaptic cell open.

7. An acetylcholinesterase inhibitor would cause which of the following?
   a. No action potentials in the postsynaptic cell
   b. Too many action potentials in the postsynaptic cell
   c. No change in action potentials in the postsynaptic cell
   d. I don’t know.

8. Biology of a weapon of mass destruction
   In Tokyo, Japan, on a Monday morning in 1995, at rush hour, five terrorists dropped bags containing a chemical compound called sarin into 5 subway cars. The perpetrators punctured the bags with sharpened umbrella tips, and then left the cars. Over 5,000 people were affected. Thirteen people died, several dozen became critically ill, and several hundred more suffered vision impairment (in some cases lasting over a decade). Sarin is classified as a weapon of mass destruction.

   
   Sarin forms a covalent bond with the enzyme acetylcholinesterase.
Research and discuss:

a. How exactly could sarin kill a person? (What is the cause of death?)

*Sarin is an acetylcholinesterase inhibitor.*

*When it forms a covalent bond with acetylcholinesterase, it blocks the enzyme’s active site, and the enzyme can no longer break down ACh. The result is that ACh builds up in neuromuscular junctions and continues to act. Respiration stops - death is caused by suffocation.*

b. What might the symptoms of sarin poisoning be?

*Muscles go into a tetanic seizure and cannot relax. Early symptoms include constriction of pupils, drooling (due to constriction of salivary gland smooth muscle), difficulty breathing (due to constriction of respiratory muscles), and nausea (due to seizures of smooth muscle throughout the entire digestive tract, stopping peristalsis). Victims who die usually die of suffocation during convulsions.*

c. Contrast sarin’s mechanism of action with that of pufferfish toxin.

*Sarin and TTX (pufferfish toxin) both cause death by suffocation, but they stop respiration by opposite means. TTX blocks action potentials, so that respiratory muscles are paralyzed (i.e., become limp). Sarin causes the opposite problem - too many action potentials - causing respiratory muscles to seize up in a tetanic contraction during convulsions. Either way, respiration stops.*
Concept 34.4 – The Vertebrate Nervous System Has Many Interacting Components

9. Using the word bank below, complete this chart showing the relationships of these parts of the nervous system:
   a. Sympathetic nervous system
   b. Parasympathetic nervous system
   c. Central nervous system
   d. Peripheral nervous system
   e. Autonomic nervous system
   f. Spinal cord
   g. Voluntary division
   h. Afferent pathways
   i. Efferent pathways

10. The sympathetic nervous system is a part of the
   a. autonomic nervous system.
   b. peripheral nervous system.
   c. parasympathetic nervous system.
   d. Both a and b
   e. All of the above
11. Where was the damage?
Suppose a woman suffers a stroke (bleeding within the brain) and suffers some brain damage. Her symptoms are as follows:
- Inability to speak
- Inability to move the right side of her body
- Some deficits in sensation on the right side of the body
- Inability to recognize faces
She still retains the following abilities:
- Normal sensation on the left side of her body
- Normal vision in both sides of both eyes
- Unchanged personality
- Normal ability to plan and reason

Which lobes of her cerebrum were most likely affected by the stroke? On what side of the brain? Explain (provide evidence based on observations above).

The damage was most likely on the left side of her cerebrum.

Three lobes were affected: frontal, parietal, and temporal.

- Inability to move the right side of the body indicates damage to the left primary motor cortex (part of the frontal lobe), but luckily most of the rest of the frontal lobe seems to have been spared (as indicated by no change in personality and ability to plan/reason).

- The deficits in sensation on the right side of the body indicate some damage to the left primary somatosensory cortex (part of the parietal lobe).

- Inability to speak or recognize faces indicates damage to the temporal lobe.

- The occipital lobe appears to have been unaffected since her vision is normal.

12. Which of the following is associated with the parietal lobe?
   a. Control of the voluntary muscles
   b. The sense of vision
   c. The sense of hearing
   d. Ability to make decisions
   e. Perception of three-dimensional space
Concept 34.5 – Specific Brain Areas Underlie the Complex Abilities of Humans

13. Which of the following brain areas is associated with understanding of speech in humans?
   a. Broca’s area
   b. Wernicke’s area
   c. The hippocampus
   d. The insula
   e. The thalamus

14. A new ape
Suppose a previously unknown species of ape is discovered in Africa. To everybody’s astonishment, the new apes turn out to use a fairly complex form of verbal communication - something never before observed in any non-human ape. Tests reveal that the new apes appear capable of highly advanced planning and decision-making, and appear to recognize themselves in a mirror.
   a. What brain areas would you predict might be especially well-developed in these apes, compared to other mammals and compared to other apes (chimpanzee, gorilla)? Why?
   b. Finally, would your answer be the same if the new species were an intelligent bird, rather than an intelligent mammal? Why or why not?

- We could expect speech areas, especially Broca’s and Wernicke’s areas, to be especially well-developed in the new apes - both compared to all other mammals and compared to other apes, since no other apes use complex speech.

- The frontal lobes (decision-making/planning) and the insula (putative site of self-awareness) will also likely be larger in the new apes than in other mammals, though not necessarily larger than in other apes, since other apes also have the capabilities of decision-making/planning and self-awareness.

b. Finally, would your answer be the same if the new species were an intelligent bird, rather than an intelligent mammal? Why or why not?

The cerebral areas described in the text are found only in mammals. Therefore, intelligent non-mammals would not necessarily use the cerebral cortex for advanced cognitive abilities. They might instead use different brain regions entirely. (As it happens, this seems to have happened in birds. The most intelligent birds - parrots and corvids - have brain/body ratios similar to the apes, and similar or even slightly superior cognitive abilities. But these birds appear to use entirely different brain regions for advanced cognition. In general, birds have not elaborated the cerebral cortex as mammals have, and instead have elaborated the underlying neostriatum, a region that is relatively undeveloped in mammals. Additionally, birds in general tend to use a much higher degree of learned vocal communication than do mammals, and birds have evolved a novel set of brain regions for this ability.)