Nervous System Case Studies

Objectives:

- To be able to describe the nervous system structure and function
- To understand how neurons communicate using electrical and chemical signals
- To know how the nervous system controls and responds to body functions and directs our behavior

Place the following steps in the order that they occur in the signaling cascade on the next page. Use the diagrams provided to guide your answers.

A. Voltage-gated Na^+ channels inactivate and slow-opening voltage-gated K^+ channels open. K^+ exits the cell to repolarize the cell membrane, while Na^+ locally diffuses down the axon to depolarize the adjacent region of the membrane.

B. Interneurons communicate with motor (efferent) neurons to send a signal away from the central nervous system.

C. Voltage-gated Ca^{2+} channels open and Ca^{2+} moves across the cell membrane and into the cytosol.

D. The graded electrical potential reaches the axon hillock

E. Intracellular Ca^{2+} binds to vesicles and triggers the release of neurotransmitters into the synaptic cleft via exocytosis.

F. Neurotransmitters are removed from the synaptic cleft. They are either taken up by the presynaptic cell, diffuse away, or are degraded by enzymes.

G. K^+ channels are stimulated to close, but their slow-moving gates allows continued K^+ diffusion, resulting in hyperpolarization of the membrane and a brief refractory period before returning to resting potential. Na^+ channels at the next Node of Ranvier open in order to conduct the action potential.

H. A graded electrical potential travels down the dendrite.

I. Neurotransmitters trigger ligand-gated channels in the postsynaptic nerve cell to open, causing that nerve's membrane to depolarize, and an excitatory postsynaptic potential (EPSP) is produced.

1 A stimulus is detected by a sensory (afferent) neuron

2

3 The cell body processes the signal and produces an outgoing signal

4

5 An action potential is triggered, causing voltage-gated Na^+ channels to open. Na^+ diffuses into the cell and depolarizes the cell membrane

6

7

8 Voltage-gated K^+ channels sequentially close and resting membrane potential is restored

9 The action potential moves quickly down the axon in a saltatory motion until it reaches the axon terminal

10

11

12 Neurotransmitters diffuse across the synaptic cleft and bind to receptors embedded in the postsynaptic cell membrane

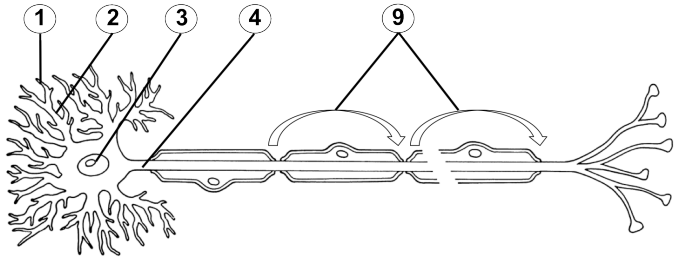
13

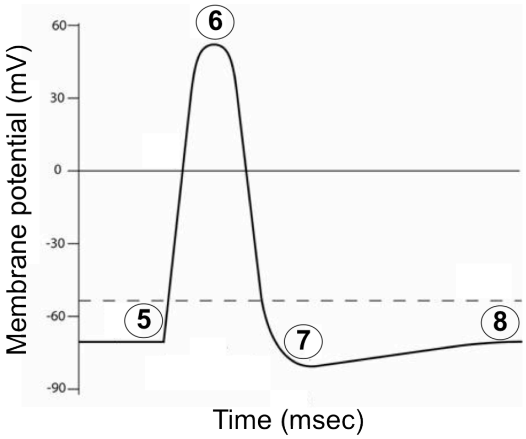
14

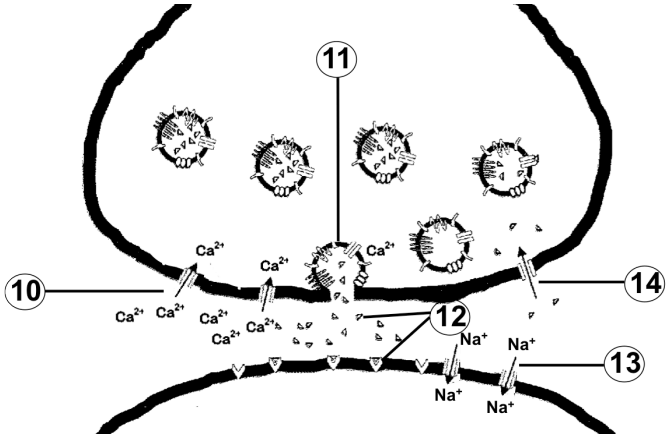
15 The signal reaches interneurons in the central nervous system, which interpret the information

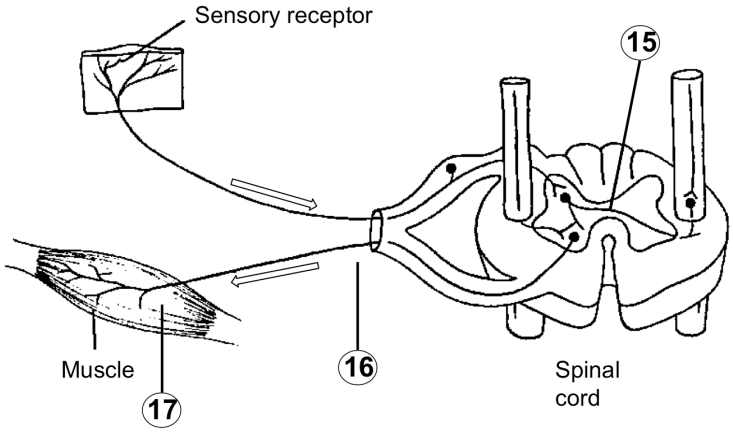
16

17 A response is generated, such as movement or the secretion of hormones from endocrine glands.





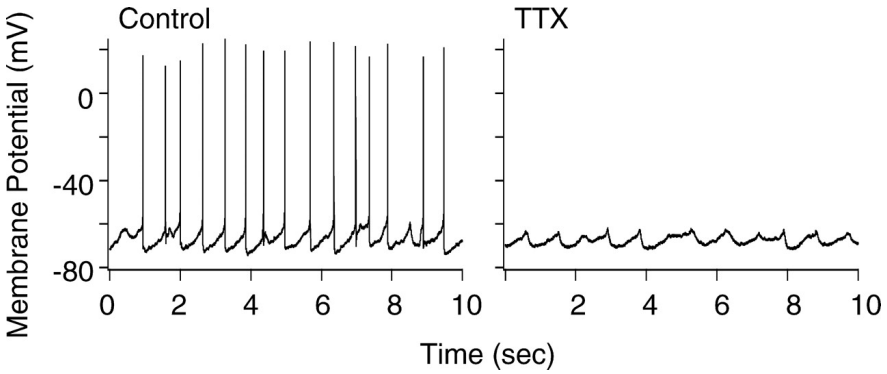




Read the descriptions of the following conditions below. For each condition, determine which step in the signaling cascade is disrupted. Then, use what you know to choose the reason why this step cannot be completed correctly.

Question 1

Tetrodotoxin (abbreviated TTX) is a potent neurotoxin found in a pufferfish that is often served in sushi restaurants as a delicacy. However, when improperly prepared, this dish can result in poisoning. Ingestion of TTX first causes numbness of the lips and tongue, followed by increasing paralysis. When ingested in larger amounts, full loss of movement occurs, followed by death. Below is a diagram of a series of action potentials of a normal person (Control) and a person suffering from TTX poisoning (TTX).



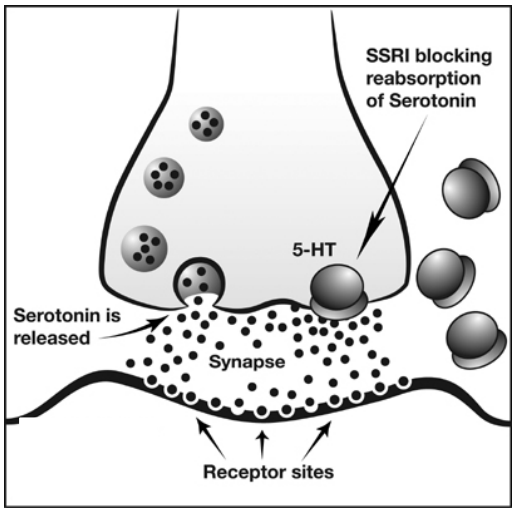
a) Which step of the signaling cascade does TTX disrupt?

b) What evidence do you have that this step cannot be completed properly?

c) This step cannot be competed because TTX:
   a) prevents the action potential from propagating down the axon
   b) blocks Na^+ channels
   c) binds to the neurotransmitter receptors
   d) disables the Na^+/K^+ pump
   e) inhibits the depolarizing stimulus from reaching the membrane

Question 2

Major depressive disorder is a neurological condition that results from abnormal neuronal activity within the area of the brain involved in processing emotion. Drugs can be prescribed to individuals suffering from this disorder. Commonly, selective serotonin reuptake inhibitors (SSRIs) are effective at reducing or removing the symptoms of depression. SSRIs function to increase the extracellular concentration of serotonin by blocking neurotransmitter reabsorption, as seen in the figure below.



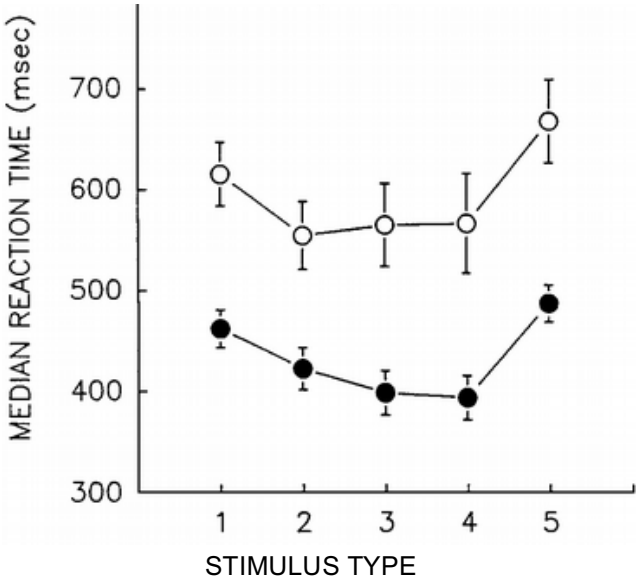
a) Which step of the signaling cascade does major depressive disorder disrupt?

b) What evidence do you have that this step cannot be completed properly?

c) This step cannot be competed because people suffering from major depressive disorder:
   a) have very low levels of cytosolic Ca^{2+}
   b) have mutant neurotransmitter receptors in the post-synaptic cell
   c) have low levels of the neurotransmitter serotonin in the synapse
   d) are incapable of synthesizing any neurotransmitters

Question 3

Multiple sclerosis is a serious autoimmune disease that affects the transduction of nervous signals. Symptoms of this disease often include loss of sensitivity, difficulty moving, problems speaking, and a loss of coordination and balance. Further, people diagnosed with this disease (open circles) take longer to respond five different stimuli than do healthy individuals (closed circles), as diagrammed in the graph below.



a) Which step of the signaling cascade does multiple sclerosis disrupt?

b) What evidence do you have that this step cannot be completed properly?

c) This step cannot be competed because multiple sclerosis:
   a) degrades the myelin sheath surrounding nerve cells
   b) causes in fewer ion channels to open
   c) reduces the number of interneurons that communicate to motor neurons
   d) neurotransmitters cannot bind as tightly to the post-synaptic receptors