Chapter 48: Neurons, Synapses, and Signaling

48.1 Explain how the specialized anatomy of neurons supports their function in information transfer.

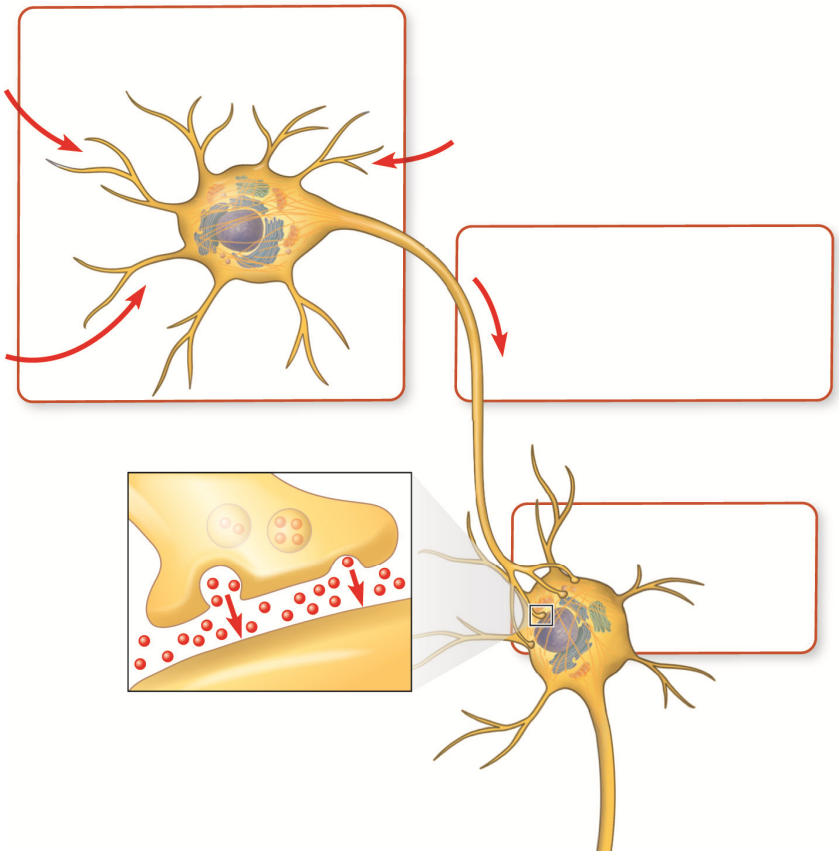
48.2 Compare and contrast the role of ion pumps and ion channels in establishing the resting potential of a neuron.

48.3 Describe the role of action potentials in propagating signals along axons.

48.4 Relate the structure of synapses to their function in communication between neurons.

This chapter introduces you to neurons and how they function. You will review information you learned about the structure of cell membranes and their embedded proteins as well as signaling molecules and their receptors. Devote careful study time to understanding action potentials and nerve impulse transmission across the synapse.

Study Tip: *Neurons* (nerve cells) are specialized cells that can receive and transmit information. Figure 48.1 shows communication between two neurons. Notice that the first neuron receives information and transmits it to a second cell. The second cell may be another neuron or a muscle cell or gland. Label the three boxes to show this transmission pathway.



Concept 48.1 Neuron structure and organization reflect function in information transfer

LO 48.1: Explain how the specialized anatomy of neurons supports their function in information transfer.

1. Return to Figure 48.1 It shows two neurons. Label the following elements of this figure while you provide the function of each:

   cell body

   dendrites

   axon

   synapse

   synaptic terminal

   neurotransmitter

2. Neurons can be placed into three groups, based on their location and function. Complete this chart by providing the function of each type of neuron.

Type of Neuron	Function
Sensory neuron	
Interneuron	
Motor neuron	

3. What structures may comprise the *central nervous system (CNS)*?

4. What do the neurons of the *peripheral nervous system (PNS)* do?

Concept 48.2 Ion pumps and ion channels establish the resting potential of a neuron

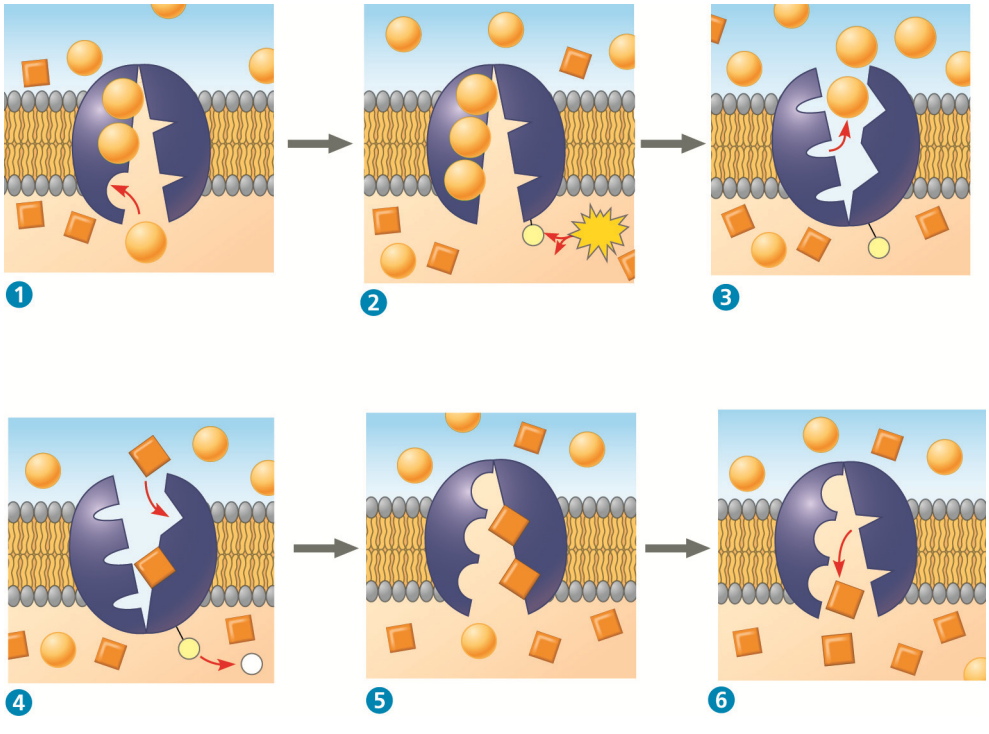
LO 48.2: Compare and contrast the role of ion pumps and ion channels in establishing the resting potential of a neuron.

In this section you will need to recall information about the structure and function of the plasma membrane. Ions are not able to diffuse freely through the membrane because they are charged, and so must pass through protein channels specific for each ion.

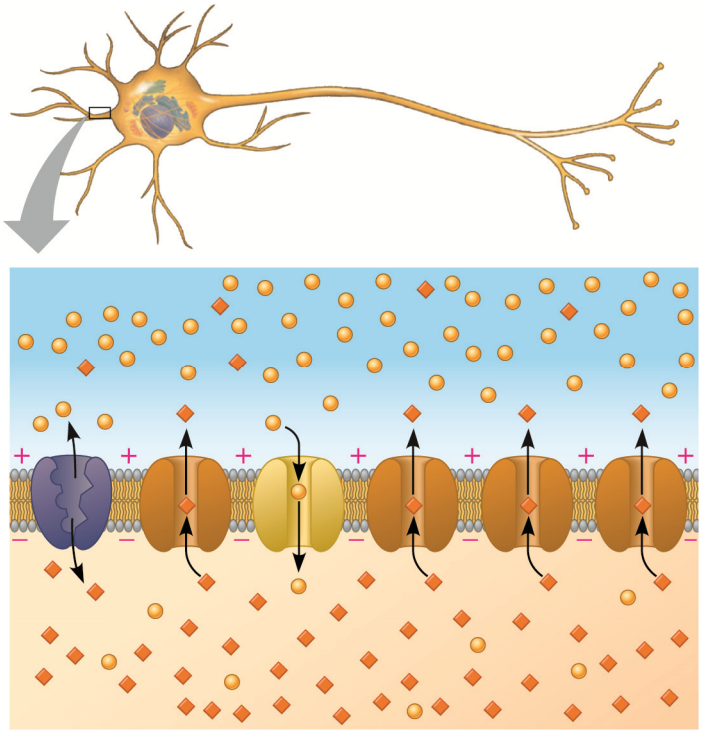
5. All cells have a *membrane potential* across their plasma membrane, measured in mV (millivolts). What is the typical *resting potential* of a neuron?

6. The resting potential of the membrane requires the *active transport* of Na^+ and K^+ across the plasma membrane by the *sodium-potassium pump.* Because it is so important that you understand this process, which was first discussed in Chapter 7, refer back to Figure 7.16 on p. 137. Use these terms to label the figures, and briefly summarize what is occurring in each step: *extracellular fluid*, *cytoplasm*, *Na^+*, *K^+*, *ATP*, *ADP*, *P*, and *transport protein*.

SUMMARY: SODIUM-POTASSIUM PUMP



7. On this sketch, label the following: *outside cell, inside cell*, Na^+ and K^+ *ions*. Show where the concentrations of Na^+ and K^+ are highest and label the three proteins imbedded in the membrane.



8. How are the concentration gradients of Na^+ and K^+ maintained?

Concept 48.3 Action potentials are the signals conducted by axons

LO 48.3: Describe the role of action potentials in propagating signals along axons.

9. *Gated ion channels* open or close in response to stimuli. This may allow ions to flow across the membrane, changing the membrane potential. Describe the change in membrane potential that occurs if Na^+ channels open. What is this decrease in the magnitude of the membrane potential called?

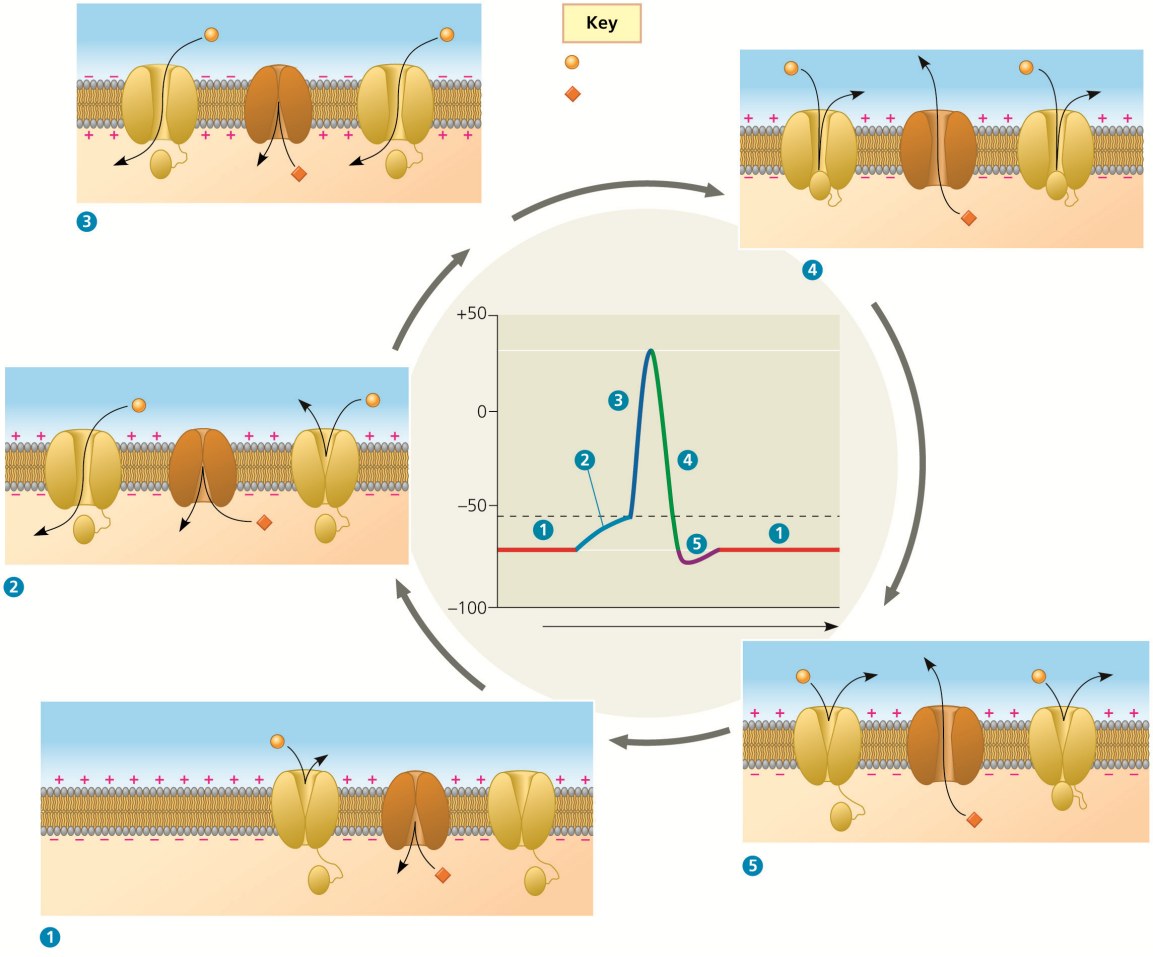
10. As you see in the previous figure (Figure 48.7), in a resting neuron the outside of the membrane is positively charged relative to the inside of the membrane. If positively charged K^+ flow out of the cell, the difference in charge between the two sides of the membrane becomes greater. What is the increase in the magnitude of the membrane potential called?

11. When a *stimulus* is applied, ion channels will open. If positively charged ions flow in, the membrane is said to *depolarize*. If depolarization causes the membrane potential to drop to a critical value, a wave of depolarization will follow. What is this critical value called? What is its approximate value in mV?

12. What is the wave of depolarization called?

13. Just like toppling dominoes in a row, either the *threshold* of depolarization will be reached and an *action potential* will be generated, or the threshold will not be reached and no wave will occur. Therefore, an action potential either occurs fully or does not occur at all. What term is used to describe this response?

14. Figure 48.12 in your text contains almost all you need to know about nerve impulse transmission, so it is worth some careful study time. Let's approach it in steps. You will find instructions for this exercise on the next page.



a. Label Na^+, K^+, and their respective *ion channels*.

b. Label the *resting state* figure. Are the Na^+ and K^+ channels open or closed?

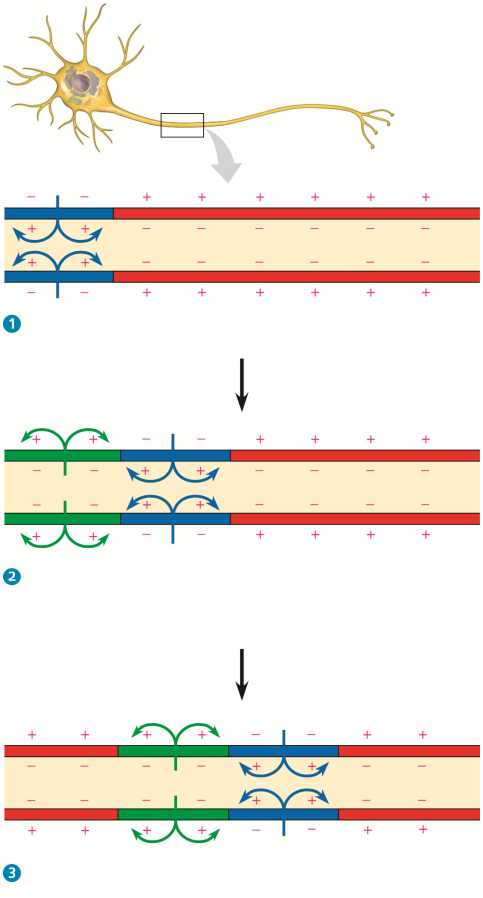
c. Label *depolarization*. What triggers depolarization? What channels open? What occurs if the depolarization threshold is reached?

d. Label Stage 4 in the figure *repolarization*. How is the charge on the membrane reestablished?

e. Label these regions of the graph: x- and y-*axes, membrane potential*, *time*, *threshold, resting potential, action potential*, and *repolarization*.

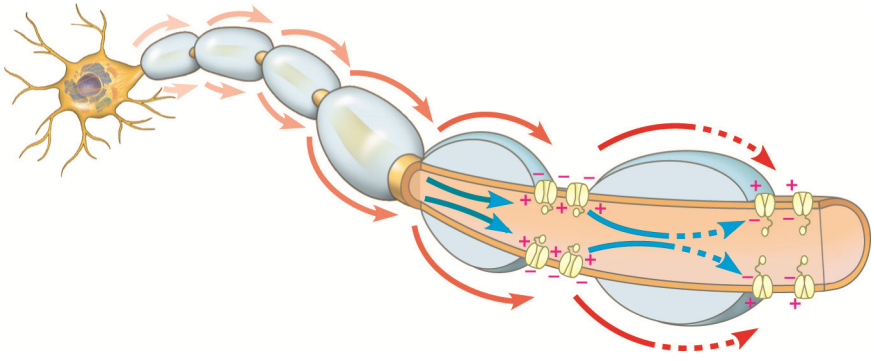
f. Let's see if you really understand this concept. Draw another line on the graph to show what the change in membrane potential would look like if a stimulus were applied that did *not* reach the depolarization threshold.

15. Here is a closer look at what is happening along the membrane as a wave of depolarization (an action potential) travels along the length of the axon. Label the key elements of the figure and, to the side, explain how the action potential is conducted.



16. Within the nervous system there are specialized supportive cells known as *glial cells*. What are the *glial cells* that produce *myelin sheath* in the PNS?

17. Label *Schwann cells*, *axon*, *myelin sheath*, *node of Ranvier*, and *ion channel* on the following figure. How does a *myelin sheath* speed impulse transmission? Include a discussion of *saltatory conduction* and *nodes of Ranvier* in your response.



18. In the disease multiple sclerosis, the myelin sheaths harden and deteriorate. How would this affect nervous system function?

Concept 48.4 Neurons communicate with other cells at synapses

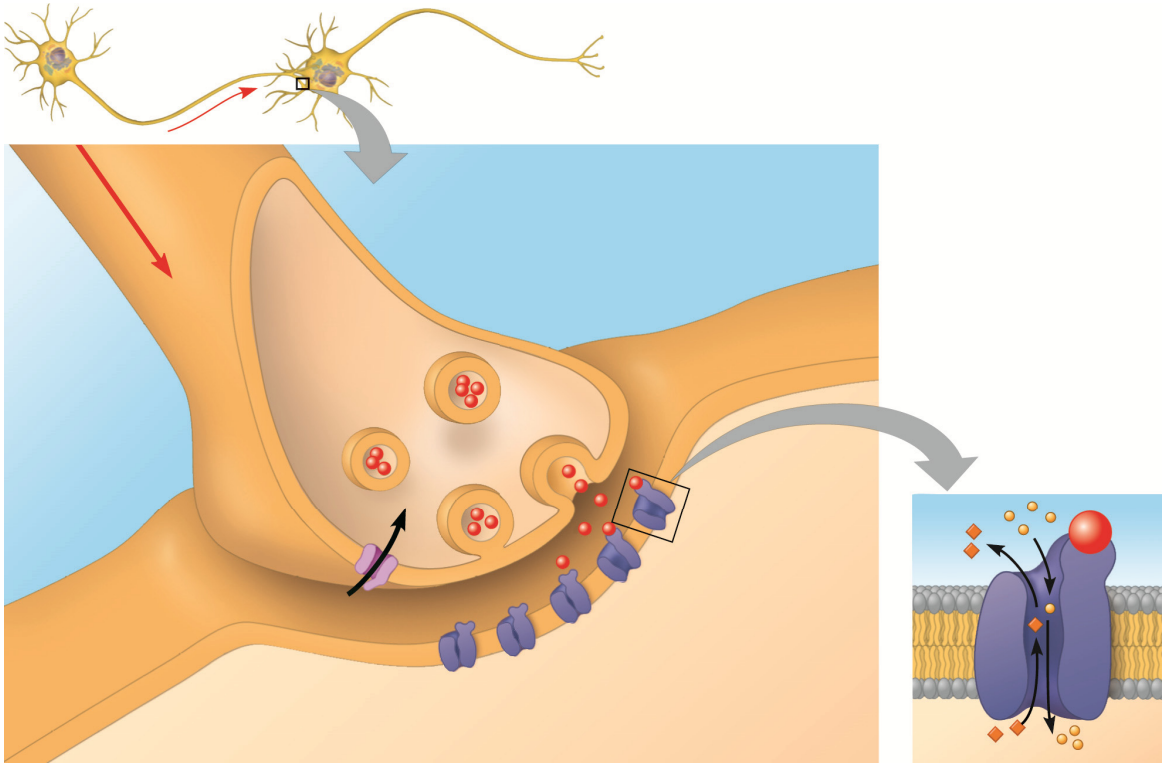
LO 48.4: Relate the structure of synapses to their function in communication between neurons.

As you haven seen, neurons transmit information to other neurons or cells. We will describe the first neuron in the path as the *presynaptic neuron,* and the muscle/gland/nerve cell that is second in the pathway as the *postsynaptic cell.*

19. When the wave of depolarization arrives at the synaptic terminal, calcium ion channels open. What occurs to the *synaptic vesicles* as the Ca^{2+} level increases?

20. What is contained within the *synaptic vesicles*?

21. Label the following on the figure: *synaptic vesicle*, *neurotransmitter*, *calcium ion channel*, *presynaptic membrane*, *postsynaptic membrane*, and *synapse*. Explain what is occurring in the inset box of this figure.



22. Explain how an action potential is transmitted from one cell to another across a synapse by summarizing what is shown above in four steps.

1.

2.

3.

4.

23. There are many different types of neurotransmitters. Each neuron secretes only *one* type of neurotransmitter. Some neurotransmitters *hyperpolarize* the postsynaptic membrane. Are these *excitatory* or *inhibitory* neurotransmitters?

24. Define and explain *summation*. Distinguish between *temporal summation* and *spatial summation.*

25. A single postsynaptic neuron can be affected by neurotransmitter molecules released by many other neurons, some releasing *excitatory* and some releasing *inhibitory* neurotransmitters. What type of summation is this? What will determine whether an action potential is generated in the postsynaptic neuron?

26. Table 48.2 in your text lists several of the major neurotransmitters. If your instructor expects you to know their actions and secretion sites create a table to help learn this. Otherwise, you *should* recognize that they are neurotransmitters! Go through the list that follows and say each term aloud. Put a checkmark by any that you have heard mentioned before: *acetylcholine*, *epinephrine*, *norepinephrine*, *dopamine*, *serotonin*, *GABA*, *glutamate*, *glycine*, *substance P*, *endorphins*, and *nitric oxide*.

27. What is the most common neurotransmitter in both vertebrates and invertebrates? It is released by the neurons that synapse with muscle cells at the *neuromuscular junction*.

28. The toxin that results in botulism prevents release of acetylcholine. Predict how this would affect muscle contraction. Explain how this mechanism makes Botox effective at keeping the forehead from wrinkling.

29. At the neuromuscular synapse, the signal molecule is acetylcholine. Acetylcholine is removed from the synapse by an enzyme, *acetylcholinesterase*. The deadly nerve gas sarin prevents the function of acetylcholinesterase. Explain how this results in paralysis.

Test Your Understanding, p. 1084.

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____