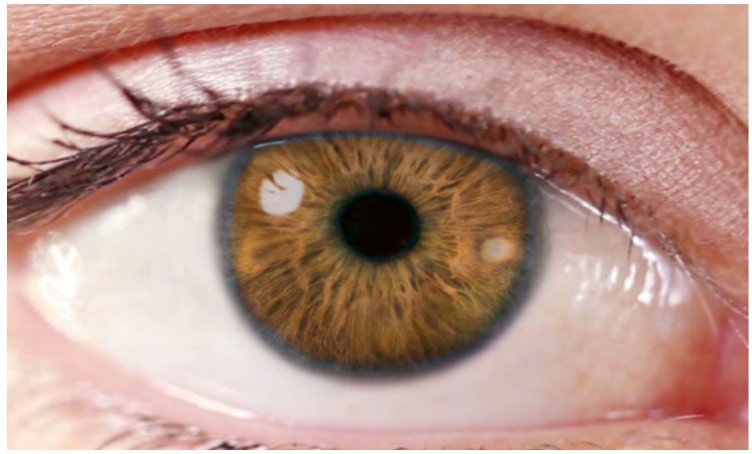
Chapter 12

The Nervous System



12.5 How Neurons Fire

Is the human body like a toaster? Well, it is in one small way. Like a toaster or a computer, your body relies on electrical signals to do its work.

The Action Potential

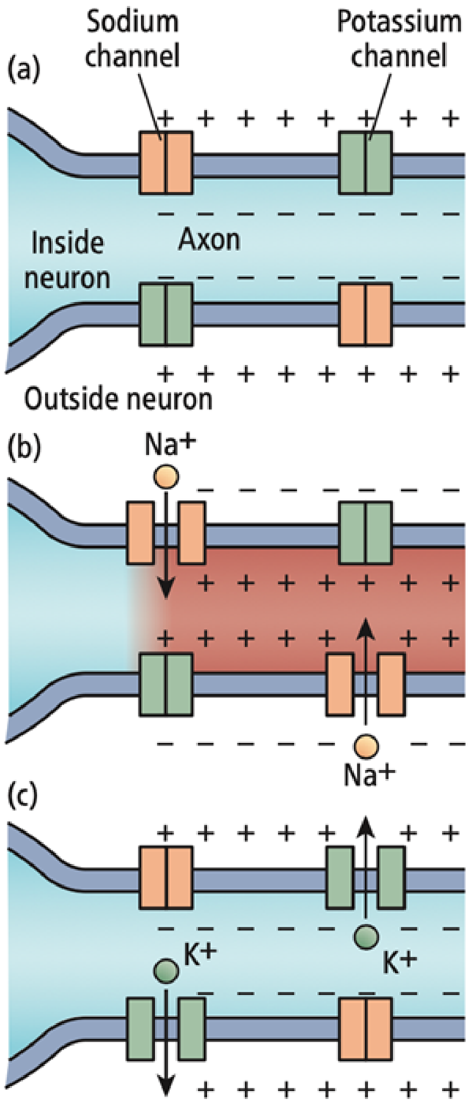
In neurons, the electrical signals are changes in the voltage, also known as electric potential, across the cell membrane. A neuron has an electric potential across its cell membrane because the electric charge inside a neuron is different from the electric charge outside. This electric potential is called a *membrane potential* because it is the cell membrane that keeps the charged particles separate.

When a neuron is not signaling, it is at its *resting potential*. The resting potential of a neuron is negative. Why? First, like other cells, neurons have more potassium ions inside the cell than outside and more sodium ions outside the cell than inside. The overall effect of these concentration gradients is to help establish a negative resting potential. (You may remember that the sodium-potassium pump maintains these concentration gradients by using active transport to move sodium ions out of cells and potassium ions into cells.) Second, neurons contain many negatively charged ions, including proteins and other organic molecules. As a result, the inside of a neuron is normally negatively charged and the outside of a neuron is normally positively charged, creating a resting potential of about -70 millivolts (mV) across the cell membrane.

A neuron sends information by signaling, or "firing." How does this happen? A neuron is stimulated when its membrane potential is increased. If a neuron's membrane potential reaches a certain *threshold* value—about -55 mV—sodium channels in the neuron's cell membrane suddenly open, allowing positively charged sodium ions to move into the neuron. (Sodium ions move into the neuron because there are more sodium ions outside the cell than inside.) This influx of positively charged ions causes the membrane potential to spike and become positive. This spike is called an **action potential**. The action potential is the neuron's way of signaling, or "firing." Once the spike occurs, the sodium channels quickly close and the potassium channels open. Positively charged potassium ions flow out of the neuron (they flow out because there are more potassium ions inside the cell than outside), causing the membrane potential to return to resting potential. The sequence of events in an action potential is shown in Figure 12.9.

FIGURE 12.9

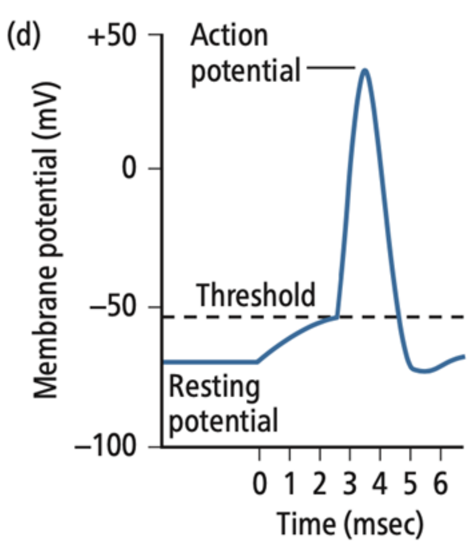
The action potential is the neuron’s way of signaling.



(a) The inside of the neuron is negatively charged, and the outside is positively charged.

(b) During an action potential, sodium channels in the neuron’s cell membrane open. Sodium ions move into the neuron.

(c) Sodium channels close, and potassium channels open. Potassium ions move out of the neuron, causing the membrane potential to return to resting potential.



(d) This graph shows how the membrane potential changes during an action potential. Resting potential is negative. When the neuron is stimulated, the membrane potential increases slowly until it reaches threshold. Then the action potential happens—sodium channels open, causing the membrane potential to spike. The membrane potential decreases when potassium channels open. It returns to resting potential.

An action potential is an all-or-nothing event—a neuron either fires or it doesn't. A neuron cannot fire "harder" when a stimulus is more intense. However, it does fire more often. For example, touch sensors in your skin fire slowly when they feel a little pressure (tick ... tick ... tick ...) and quickly when they feel lots of pressure (tick-tick-tick-tick-tick).

How an Action Potential Is Propagated

An action potential doesn't spike everywhere on a neuron's cell membrane at once. It begins at one end of the axon, near the neuron's cell body, and then travels down the axon. How does this happen?

When an action potential begins, sodium ions enter the end of the axon that is closest to the cell body. These ions diffuse into adjacent areas along the axon. Because the sodium ions are positively charged, they cause the local membrane potential to increase. When the local membrane potential reaches threshold, a new action potential, farther along the axon, begins. The process is similar to the way a row of dominoes falls: The first domino knocks down the next one, which knocks down the next one, and so forth. Similarly, an action potential sets off an action potential farther down the axon, and the action potential travels down the entire axon (Figure 12.10).

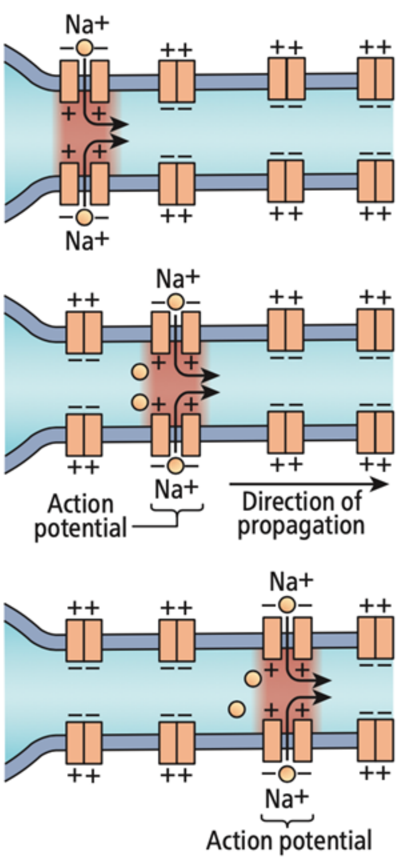


FIGURE 12.10

Action potentials are propagated down an axon. The action potential starts near the cell body. Sodium ions that enter the neuron diffuse down the axon, initiating an action potential farther along the axon. The action potential continues to move down the axon until it reaches the end of the axon.

Some axons, like the one shown in Figure 12.11, are surrounded by a *myelin sheath* that allows the neuron's signal to be transmitted more quickly. The sheath consists of glial cells wrapped around and around the axon, insulating it with multiple layers of cell membrane. There are periodic gaps in the sheath, and the action potential jumps down the axon from one gap to the next.

In the disease *multiple sclerosis*, the body's immune system destroys myelin in the central nervous system. The symptoms of multiple sclerosis vary depending on the parts of the brain and spinal cord that are affected. Symptoms can include problems with fatigue, dizziness, bladder and bowel control, vision, muscle control, and balance.

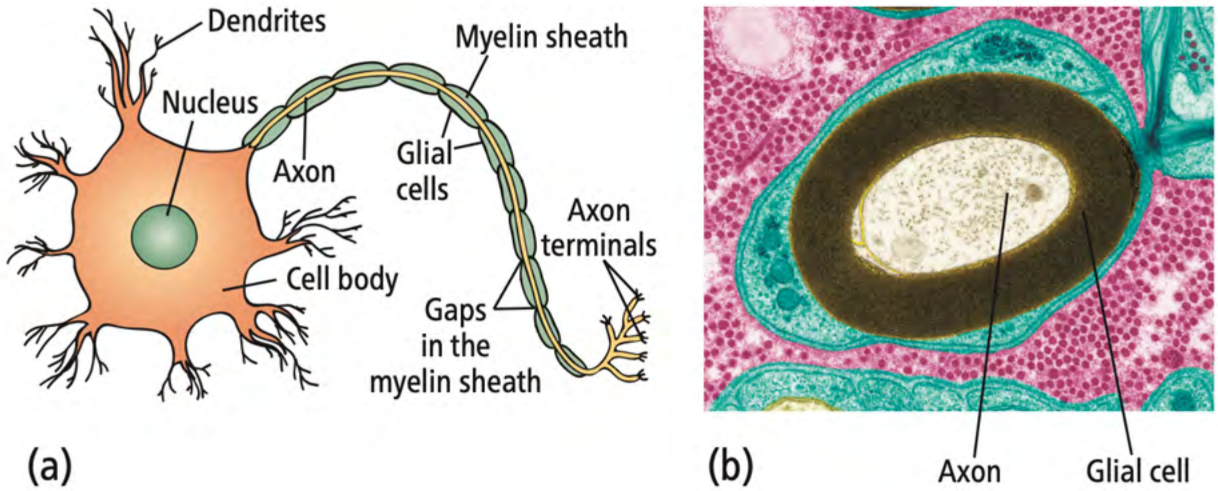


FIGURE 12.11

(a) A myelin sheath surrounds some axons, enabling the signals they transmit to travel faster.
(b) The myelin sheath consists of glial cells wrapped around and around an axon, as shown in this cross-section. The brown ring is the myelin. (The green is the cytoplasm of the glial cell.)

READING CHECK

1. **What causes sodium channels to open, initiating an action potential?**
2. **What causes an action potential to end?**

CHECK YOUR ANSWERS

1. A stimulus that increases the membrane potential to its threshold value.
2. The opening of potassium channels, which returns the membrane potential to its resting potential.

For more on the action potential, you can check out this website:

https://faculty.washington.edu/chudler/ap.html