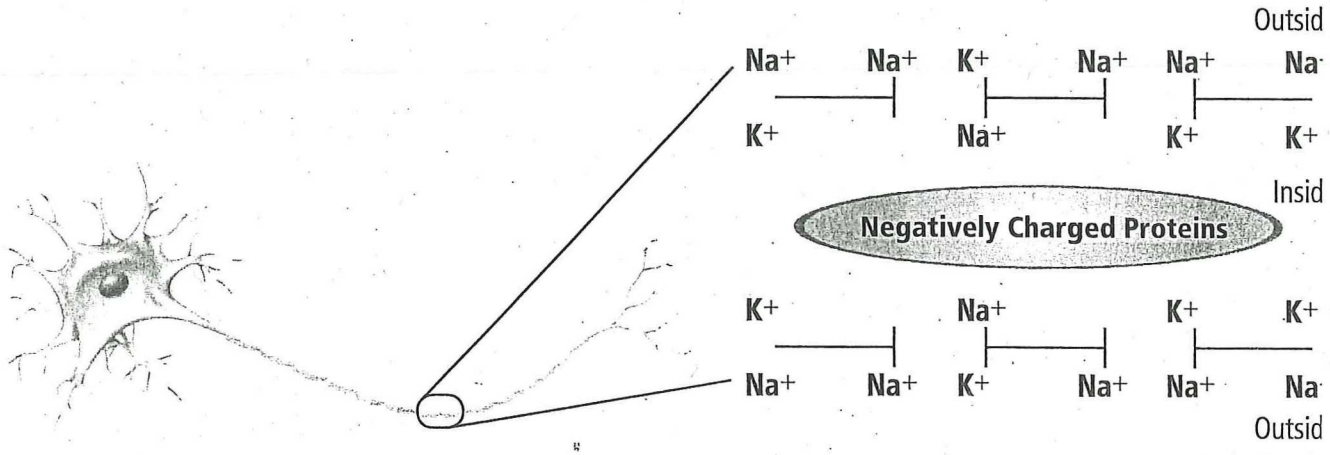
A Nerve Impulse

Connection to Physics A nerve impulse is an electrical charge traveling the length of a neuron. An impulse results from a stimulus, such as a touch or perhaps a loud bang, which causes a person to jump.

A neuron at rest When a neuron is at rest, as shown in **Figure 3,** it is not conducting an impulse. Notice that there are more sodium ions (Na^+) outside the cell than inside the cell. The reverse is true for potassium ions (K^+)—there are more potassium ions inside the cell than outside the cell.

Figure 3 The distribution of Na^+ and K^+ ions, and the presence of negatively charged protein molecules in the cytoplasm, keep the inside of the cell more negatively charged tha the outside when a neuron is at rest.



Recall that ions tend to diffuse across the plasma membrane from an area of high concentration of ions to an area of low concentration of ions. Proteins found in the plasma membrane work to counteract the diffusion of the sodium ions and potassium ions. These proteins, called the sodium-potassium pump, actively transport sodium ions out of the cell and potassium ions into the cell.

For every two potassium ions pumped into a neuron, three sodium ions are pumped out. This maintains an unequal distribution of positively charged ions, resulting in a positive charge outside the neuron and a negatively charged cytoplasm inside the neuron.

An action potential Another name for a nerve impulse is an **action potential.** The minimum stimulus to cause an action potential to be produced is a **threshold.** However, a stronger stimulus does not generate a stronger action potential. Action potentials are described as being "all or nothing," meaning that a nerve impulse is either strong enough to travel along the neuron or it is not strong enough.

When a stimulus reaches the threshold, channels in the plasma membrane open. Sodium ions rapidly move into the cytoplasm of the neuron through these channels, causing a temporary reversal in electrical charges. The inside of the cell then has a positive charge, which causes other channels to open. Potassium ions leave the cell through these channels, restoring a positive charge outside the cell.

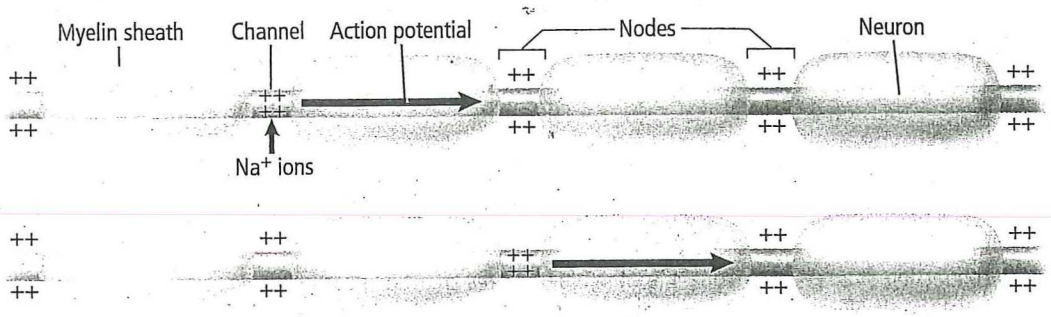


Figure 5 A nerve impulse moves from node to node along myelinated axons.

Speed of an action potential The speed of an action potential varies. Many axons have a covering of a lipid called myelin, which forms an insulating layer, called a sheath, around the axon. The myelin sheath has many gaps, called **nodes,** along the length of the axon, as shown in **Figure 5.** Sodium ions and potassium ions cannot diffuse through myelin, but they can reach the plasma membrane at these nodes. This allows the action potential to jump from node to node, greatly increasing the speed of the impulse as it travels the length of the axon.

In the human body, there are neurons that have myelin, and neurons that do not have myelin. Neurons with myelin carry impulses that are associated with sharp pain; neurons that lack myelin carry impulses associated with dull, throbbing pain. The action potentials in these neurons travel much more slowly than they do in neurons with myelin. When you stub your toe, which kind of neurons are involved?

Figure 7 A single neuron can have multiple connections with other neurons.

The synapse A small gap exists between the axon of one neuron and the dendrite of another neuron. This gap is called a **synapse** (SIH naps). When an action potential reaches the end of an axon, small sacs called vesicles carrying neurotransmitters fuse with the plasma membrane and release a neurotransmitter by exocytosis. When a motor neuron synapses with a muscle cell, as illustrated in **Figure 6,** the released neurotransmitter crosses the synapse and causes a muscle to contract.

Connection to Chemistry A **neurotransmitter** is a chemical that diffuses across a synapse and binds to receptors on the dendrite of a neighboring neuron. This causes channels to open on the neighboring cell and creates a new action potential.

There are more than 25 known neurotransmitters. Once a neurotransmitter has been released into a synapse, it does not remain there for long. Depending on the neurotransmitter, it might simply diffuse away from the synapse, or enzymes might break it down. Some neurotransmitters are recycled and used again. **Figure 7** shows that a single neuron can communicate with many other neurons.