Before You Read

On the lines below, describe how you reacted the last time you touched a hot object such as a pan heating on the stove. Read about the structures that help you react quickly to your environment.

Neurons

A neuron (NOOR ahn) is a specialized cell that helps you gather information about your environment, interpret the information, and react to it. Neurons make up the nervous system. The nervous system is a huge communication network that runs throughout your body. As you can see in the figure below, a neuron has three regions: the dendrites, a cell body, and an axon. Dendrites receive signals called impulses. They send the signals to the cell body. The nucleus and other organelles of the neuron are found in the cell body. The axon carries the impulse from the cell body to other neurons and muscles.

MAIN Idea

Neurons conduct electrical impulses that allow cells, tissues, and organs to detect and respond to stimuli.

What You’ll Learn

- the major parts of a neuron and their functions
- how a nerve impulse is similar to an electrical signal

Read to Learn

Make Flash Cards Write an underlined term on one side of a flash card. Write the definition for the term on the other side of the card. Use the flash cards to quiz yourself on the terms and their definitions.

Picture This

1. Label Add a title that describes the figure.
What are the three types of neurons?

There are sensory neurons, interneurons, and motor neurons. All neurons have the same three regions. However, each type of neuron performs a specific function. Sensory neurons send signals from receptors in your skin and sense organs to your brain and spinal cord. Interneurons are located in the brain and spinal cord. They receive the signals sent by the sensory neurons. Interneurons also send signals to the motor neurons. The motor neurons are located in your glands and muscles and cause movement.

When you stub your toe, sensory neurons in your foot send impulses to the interneurons. The interneurons signal the motor neurons to move your foot. The nerve pathway that consists of a sensory neuron, an interneuron, and a motor neuron is called a reflex arc. A reflex arc is the basic structure and function of the nervous system.

A Nerve Impulse

A nerve impulse is an electrical charge traveling the length of a neuron. Any stimulus, such as a touch or a loud noise, can cause an impulse.

What is a sodium-potassium pump?

When a neuron is not conducting an impulse, it is at rest. When a neuron is at rest, there are more sodium ions outside the cell than inside the cell. In addition, there are more potassium ions inside the cell than outside the cell.

Ions diffuse from an area of high concentration to an area of low concentration. Proteins in the neuron’s plasma membrane work against diffusion of sodium ions and potassium ions. These proteins are called the sodium-potassium pump. They work against the normal flow of ions by actively transporting sodium ions out of the cell and potassium ions into the cell.

The sodium-potassium pump moves two potassium ions into a neuron for every three sodium ions it pumps out. The uneven number of ions results in a positive charge outside the cell and a negative charge in the cytoplasm of the neuron.

What is an action potential?

Another name for a nerve impulse is an action potential. If an action potential is strong enough, it travels along a neuron. If it is not strong enough, nothing happens. The minimum stimulus needed to produce an action potential is a threshold.
What happens when threshold is reached?

When a stimulus reaches threshold, channels in the plasma membrane open. A channel is a path along which an electrical signal passes. As the channels open, sodium ions rapidly move into the neuron’s cytoplasm. The inside of the cell now has a positive charge.

The positive charge causes other channels in the membrane to open. Potassium ions leave the cell through these channels, and the cytoplasm returns to a negative charge. This change in charge, shown below, moves like a wave down the length of the axon. In the figure, sodium ions are labeled \(\text{Na}^+\) and potassium ions are \(\text{K}^+\). The + and − signs indicate positive and negative charges inside and outside the cell.

4. Define What is a channel?

5. Explain Use the figure to explain to a partner what happens when a stimulus reaches threshold.
What is the speed of an action potential?

The speed of an action potential varies. Many axons are covered in a myelin sheath, which is a lipid layer that protects the axon. Sodium and potassium cannot diffuse through the myelin sheath. The myelin sheath, however, has many gaps called nodes. The ions reach the cell’s plasma membrane at the nodes. The action potential jumps from node to node, increasing speed as it moves along the axon.

Some neurons in the human body have a myelin sheath, and other neurons are not protected by myelin. Neurons with myelin carry impulses that signal sharp pain, such as the pain felt when you stub your toe. Neurons that do not have myelin are associated with dull, throbbing pain.

How do impulses move from one neuron to another neuron?

Neurons do not touch each other. There is a small gap between them. The gap between the axon of one neuron and the dendrite of another neuron is called a synapse (SIH naps). When an action potential reaches the end of one axon, channels open. Vesicles carrying neurotransmitters are released from the axon. A neurotransmitter is a chemical that diffuses across the synapse and binds to receptors in the dendrite of the neighboring neuron.

What is the job of neurotransmitters?

Neurotransmitters have one job: to send the action potential to the next neuron. The human body has more than 25 neurotransmitters. Once a neurotransmitter has been released into the synapse, it does not remain there for long. Some neurotransmitters diffuse away from the synapse. Enzymes break down other neurotransmitters. Some neurotransmitters are recycled and used again. As shown in the figure below, neurotransmitters allow one neuron to communicate with many other neurons.

![Diagram of a synapse showing axon, synapse, receptors, and surface of next neuron.](image-url)
Before You Read

Electrical impulses travel throughout your body, sending information from place to place. On the lines below, list three examples of information that can be sent from place to place in your body. Read the section to learn about how the brain controls the flow of information in your body.

Main Idea

The nervous system is divided into the central nervous system and the peripheral nervous system.

What You’ll Learn

■ the major divisions of the nervous system
■ the somatic nervous system and the autonomic nervous system

Read to Learn

The Central Nervous System

The two major divisions of the nervous system are the central nervous system (CNS) and the peripheral nervous system (PNS). The brain and the spinal cord make up the central nervous system. The CNS coordinates all of the body’s activities and mostly consists of interneurons. Functions of the CNS include sending messages, processing information, storing information, and analyzing responses.

What makes up the peripheral nervous system?

The peripheral nervous system consists of sensory neurons and motor neurons. The neurons of the PNS send information to and receive information from the CNS.

Sensory neurons send information about the environment to the interneurons in the spinal cord. The interneurons relay that information to the brain. The brain responds by sending a message to the interneurons. The interneurons send the message to the motor neurons. Your body responds appropriately to the messages received by the motor neurons. The brain also stores some of the information received from sensory neurons for later use.

Create a Quiz

After you have read the section, create a quiz based on what you learned. After writing the quiz questions, be sure to answer them.

1. Summarize Complete the flowchart to show how information about the environment travels in the body.
What is the largest part of the brain?

More than 100 billion neurons are found in the brain. The brain is involved in most of the body’s activities and serves as the body’s control center as it works to maintain homeostasis.

The largest part of the brain is the **cerebrum** (suh REE brum). The two halves of the cerebrum are called hemispheres. The hemispheres are connected by a bundle of nerves. The cerebrum controls most of the body’s voluntary activities, memory, language, speech, and the senses. Most higher thought processes occur on the surface of the cerebrum. The many folds and grooves of the cerebrum increase the surface area. This large surface area enables more complex thinking.

What does the cerebellum control?

The cerebellum (ser uh BE lum) is at the back of the brain, as shown below. It controls balance, posture, and coordination. When you are playing a musical instrument or riding a bike, your cerebellum is hard at work.

The brain stem connects the brain to the spinal cord. The two regions of the brain stem are the medulla oblongata (muh DEW luh • ahb long GAH tuh) and the pons. The **medulla oblongata** controls breathing, heart rate, and blood pressure. The **pons** also helps control the rate of breathing.

A small structure called the hypothalamus (hi poh THA luh mus) is located between the brain stem and the cerebrum. The **hypothalamus** helps the body maintain homeostasis by regulating body temperature, thirst, appetite, and water balance. The hypothalamus is also important in controlling blood pressure, sleep, aggression, fear, and sexual behavior.

---

**Picture This**

3. Circle the names of the parts of the brain that control breathing.
Where is the spinal cord located?
The spinal cord extends from the brain to the lower back. It is a column of nerves protected by vertebrae. Many pairs of spinal nerves reach out from the spinal cord to all parts of the body. This nerve network connects the body to the CNS.

The Peripheral Nervous System
A nerve is a bundle of axons. Many nerves contain both sensory neurons and motor neurons. The 12 cranial nerves, the 31 spinal nerves, and their branches are part of the CNS. All of the neurons that are not part of the CNS make up the PNS. The neurons of the PNS are either part of the somatic nervous system or part of the autonomic nervous system.

What does the somatic nervous system do?
Nerves in the somatic nervous system send information from sensory receptors in the skin to the CNS, and motor nerves relay information from the CNS to skeletal muscles. This pathway of information is voluntary.

Sometimes a stimulus results in an automatic, unconscious response within the somatic system. When you touch something hot, you automatically jerk your hand away. Such an action is a reflex, an automatic response to a stimulus. A reflex impulse travels only to the spinal cord or brain stem, and an impulse is sent directly back to a muscle.

What is the autonomic nervous system?
Have you ever heard scary sounds in the middle of the night? Maybe your heart began to pound and your palms became sweaty. This type of reaction is involuntary—you do not think about it, it just happens. The autonomic nervous system is responsible for this reaction. The autonomic nervous system carries impulses from the CNS to the heart and other internal organs and glands. The body responds involuntarily. This response is often called a fight-or-flight response.

There are two branches of the autonomic nervous system that act together. The sympathetic nervous system controls internal body reactions in times of stress. The parasympathetic nervous system controls many of the body’s internal functions when the body is at rest. After a stressful experience, the parasympathetic nervous system helps restore the body to its resting state. Both systems send impulses to the same organs. The resulting activity of the organ depends on the strength of the opposing signals.
Before You Read

Think of the last time you had a bad cold. On the lines below, describe how your appetite was affected by your cold. Read the section to learn how your senses of taste and smell work together.

Taste and Smell

Specialized neurons in your body allow you to taste, smell, hear, see, and touch. You also use specialized neurons to sense motion and temperature. Specialized neurons that allow you to detect your surroundings are known as sensory receptors.

**Taste buds** are sensory receptors on the tongue that identify the taste of sweet, sour, salty, and bitter. Taste buds work by sensing chemical combinations in food. They send this information to the brain.

Sensory receptors designed for taste and smell are located in your mouth and nasal cavity. These receptors work together. If you hold your nose while you eat, the food will seem to have less flavor.

Sight

Light first enters your eyes through the cornea. The cornea helps focus the light through an opening called the pupil. The size of the pupil changes to let in more or less light. Muscles in the iris, the colored part of your eye, control the size of the pupil.
Where are the eye’s sensory receptors located?

Behind the iris is the **lens**, which inverts the image and projects it onto the retina. Between the lens and the retina is a gelatinlike liquid called the vitreous humor. The eye’s sensory receptors—rods and cones—are located in the **retina**. **Rods** are sensory receptors that respond to low levels of light. **Cones** provide information about color to the brain. The structures of the eye are shown in the figure below. Action potentials travel from rods and cones to neurons in the optic nerve and finally to the brain. The brain interprets the signals and forms a visual image.

Hearing and Balance

Hearing and balance are the two major functions of the ear. Sensory receptors in the ear detect the volume of sounds and the pitch of sounds. The pitch is the highness or lowness of sounds in your environment. The inner ear controls your sense of balance.

What structures in the ear detect sound waves?

Particles in the air vibrate as a result of sound waves. Sound waves enter the auditory canal of the ear. The waves cause the tympanic membrane (eardrum) at the end of the canal to vibrate. These vibrations travel through three bones in the middle ear, the malleus (hammer), the incus (anvil), and the stapes (stirrup). As the stapes vibrates, it causes a membrane separating the middle ear from the inner ear to move back and forth.

The **cochlea** (KOH klee uh) in the inner ear is filled with fluid and lined with tiny hair cells. When the vibrations reach the inner ear, the fluid in the cochlea moves like waves against the hair cells. The hair cells produce nerve impulses in the auditory nerve and send the impulses to the brain.

Picture This

2. **Explain** Add the label **rods and cones** beside the structure where rods and cones are located.

3. **Identify** The sensory receptors for sound are located in what structure?
How do structures in the ear monitor balance?

There are three semicircular canals in the inner ear, as shown in the figure below. Semicircular canals send information about body position and balance to the brain. The canals are positioned at right angles to each other. Like the cochlea, the semicircular canals are filled with fluid and lined with hair cells. As you move your head, fluid moves through the canals. The fluid movement causes the hair cells to bend, sending nerve impulses to the brain. The brain uses this information to determine your body position. The brain can also tell whether or not your body is in motion.

Touch

The epidermis and dermis layers of the skin contain many sensory receptors. These sensory receptors respond to temperature, pressure, and pain.

Where are sensory receptors located?

Sensory receptors are not distributed evenly throughout your body. The tips of your fingers have many sensory receptors to detect light touch. The soles of your feet have sensory receptors that respond to heavy pressure. However, the soles of your feet have few sensory receptors to respond to a light touch. Consider how this difference helps you respond to your environment.

What is the purpose of pain receptors?

Pain receptors are found in all body tissues except the brain. Pain receptors are free nerve endings. They send pain signals to the brain, and the brain responds to help ease the pain.
Before You Read

On the lines below, list some reasons that you might take legal drugs. Read the section to learn about the helpful and harmful effects of drugs on the body.

What You’ll Learn

• ways drugs can harm the body or cause death
• how a person can become addicted to a drug

How Drugs Work

A drug is a substance that alters the function of the body. Some drugs come from natural sources. Other drugs are made from artificial products. Legal and illegal drugs affect the body in many ways. Some drugs, such as pain killers, affect the nervous system. Other drugs have no effect on the nervous system. The drugs that cause changes in the nervous system work in one of four ways.

1. A drug can cause an increase in the amount of a neurotransmitter that is released into a synapse.
2. A drug can block a receptor site on a dendrite. This prevents the neurotransmitter from binding.
3. A drug can stop a neurotransmitter from leaving a synapse.
4. A drug can act like a neurotransmitter.

What does dopamine control?

Dopamine is a neurotransmitter found in the brain that helps control body movements. Many drugs that affect the nervous system influence the amount of dopamine released by a neuron. The normal action of dopamine is shown in the figure on the next page.
Classes of Commonly Abused Drugs

Both legal and illegal drugs can be abused. Drug abuse is using a drug for any reason other than a valid medical purpose.

What are stimulants?

**Stimulants** are drugs that increase alertness and physical activity. Common stimulants include nicotine and caffeine.

Nicotine in cigarette smoke increases the amount of dopamine released into a synapse. Nicotine also narrows blood vessels, raises blood pressure, and causes the heart to work harder. Cigarette smoking contributes to about 90 percent of all lung cancer cases.

Caffeine is found in coffee, tea, some soft drinks, and even some foods such as chocolate. It is a widely used and often abused stimulant. Caffeine binds to adenosine receptors on nerve cells in the brain. Adenosine slows down nerve cell activity and causes drowsiness. When caffeine binds to the adenosine receptors, it causes a feeling of heightened alertness. Caffeine also raises adrenaline levels briefly and gives a quick burst of energy that soon wears off.

---

**Picture This**

2. **Label** Draw an arrow on the portion of the figure labeled A to show the direction that dopamine travels.

**Think it Over**

3. **Generalize** What effect do many people get from drinking coffee when they get up in the morning?

[Diagram of neurotransmission process]
What are depressants?
Drugs that tend to slow down the central nervous system are **depressants**. These drugs can lower blood pressure, affect breathing, and slow the heart rate.

How does alcohol use affect humans?
Alcohol is a depressant that is abused widely. It affects at least four different neurotransmitters. Alcohol use harms a person’s judgment, coordination, and reaction time. Continued abuse of alcohol has long-lasting effects on the body. These effects include a reduction in brain mass, liver damage, ulcers, and high blood pressure. Alcohol use by the mother during pregnancy can harm the fetus. Fetal alcohol syndrome damages a baby’s brain and nervous system.

What effects do inhalants have on the nervous system?
Inhalants are chemical fumes that affect the nervous system. Most inhalants slow down the nervous system. Inhalants might produce a feeling of intoxication and can cause nausea and vomiting. Inhalants can cause death. Long-term effects of inhalants include memory loss, hearing loss, vision problems, and permanent nerve and brain damage.

What illegal drugs affect the nervous system?
Amphetamines and cocaine keep dopamine from being reabsorbed. This leaves dopamine to build up in the synapse. Some amphetamines can also increase the amount of dopamine released from a neuron. As the levels of dopamine in the brain increase, a person can feel pleasure and a sense of well-being.

What are the effects of amphetamines and cocaine?
Amphetamines and cocaine have both short-term and long-term effects on the body. Amphetamines can increase the heart rate, cause an irregular heartbeat, and increase blood pressure. Permanent damage to the small blood vessels in the brain can occur. Amphetamine use can also affect behavior. Abusers can experience periods of violent behavior, anxiety, confusion, paranoia, and insomnia. An amphetamine overdose can cause death. It can take a year or longer for the drug’s effects to cease after a user stops taking the drug. Cocaine abuse can cause heart attacks, irregular heart rhythms, chest pain, respiratory failure, strokes, seizures, headaches, abdominal pain, and nausea.

Take Notes
Make a concept map Foldable, as shown below. As you read, take notes and organize what you learn about commonly abused legal and illegal drugs.

<table>
<thead>
<tr>
<th>Commonly Abused Drugs</th>
<th>Legal</th>
<th>Illegal</th>
</tr>
</thead>
</table>

4. Name both a short-term and long-term physical effect of amphetamine use.

____________________

____________________

____________________

____________________

____________________

____________________
What problems can marijuana cause?

Marijuana is the most-used illegal drug in the United States. Smoking marijuana releases the chemical tetrahydrocannabinol (THC) into the bloodstream. This chemical travels to the brain and binds to receptors in the neurons. The immediate effect is a strong feeling of pleasure. In the short-term, marijuana use can cause problems with memory and learning, poor coordination, increased heart rate, anxiety, paranoia, and panic attacks. Smoking marijuana can lead to lung cancer if used over the long term.

Tolerance and Addiction

Tolerance of a drug occurs when a person needs more and more of the same drug to get the same effect. Tolerance can lead to addiction. Addiction is the physical or psychological dependence on a drug. Physical dependence occurs when a drug affects the normal functions of the body’s systems. Psychological dependence means that a person has a strong emotional desire for a drug. Marijuana and similar drugs cause psychological addiction. The desire to keep taking the drug is strong, making it difficult to quit.

What neurotransmitter is involved in addiction?

A physical dependence occurs when the drug affects normal body functions. Researchers suggest that the neurotransmitter dopamine is involved in most types of addiction. An addicted person gets pleasure from the increased levels of dopamine. A tolerance to the drug builds up and the person takes more of the drug to achieve the same sense of pleasure. When the person tries to quit using the drug, dopamine levels decrease and make it difficult to resist taking the drug.

How is addiction treated?

People who are psychologically or physically dependent on a drug experience serious withdrawal symptoms without it. Many people who are addicted to a drug have trouble quitting on their own. They might quit for short periods of time. However, they find it hard to resist using the drug again. The best way to avoid addiction is not to use drugs. People who do use drugs should seek treatment for drug dependency. Counseling might be needed to break an addiction. Physicians, nurses, counselors, clergy, and social workers are trained to help people deal with additions.