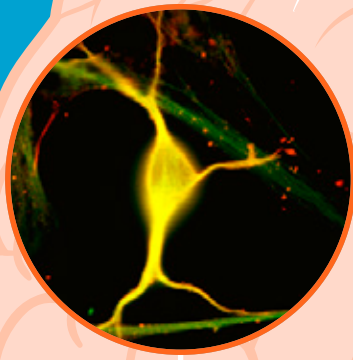


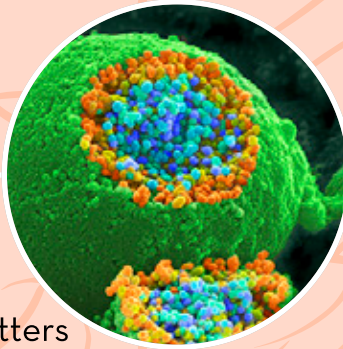
BRAIN CHEMISTRY TEACHER'S GUIDE



Neuron

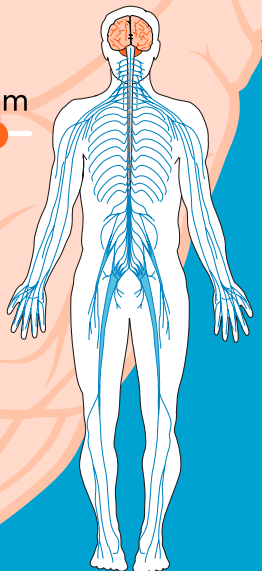


Neuron Network



Neurotransmitters

Nervous System



Nancy P. Moreno, PhD, Barbara Z. Tharp, MS, and Tadzia GrandPré, PhD

BRAIN CHEMISTRY
TEACHER'S GUIDE

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Free, related neuroscience education resources
and online versions of these lessons are
available at www.bioedonline.org/.

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UNIT COMPONENTS

The *Brain Chemistry Teacher's Guide* may be used alone. It also is integrated with the following unit components.

- *Legacy of Lost Canyon: A Curious Cave Conundrum*
- *Brain Chemistry Explorations*
- *The Reading Link*





INTRODUCTION

The *Brain Chemistry Teacher's Guide* may be used as a stand-alone set of science lessons. The guide also is designed to be used together with unit components to introduce and reinforce important concepts for students (see “About The Learning Brain,” right).

To begin teaching with the unit, some teachers prefer to generate students' interest by reading part or all of the student storybook. Others use the cover of the magazine as a way to build student enthusiasm, or begin with the pre-assessment activity in the guide.

You may want to use the “Sample Sequence” (p. iii) to integrate the unit components into your schedule. When teaching the unit for 45 to 60 minutes daily, most teachers will complete an entire unit with their students in two to three weeks. If you use the components every other day or once per week, one unit will take from three to nine weeks to teach, depending on the amount of time you spend on each session.

ABOUT THE LEARNING BRAIN

The Learning Brain's exciting activities, explorations and adventures provide students, teachers and parents with science teaching materials integrated across the curriculum. Prepared by teams of educators, scientists and health specialists, each unit focuses on a different aspect of the brain and the nervous system.

The integrated components of the Brain Chemistry unit enable students to explore chemical communication in the brain and nervous system, while they build understanding of the powerful effects of drugs in the brain and body.

- *Brain Chemistry Teacher's Guide* provides inquiry-based lessons that entice students to discover concepts in science, mathematics and health through hands-on activities.
- *Legacy of Lost Canyon*, the student storybook, features members of the NeuroExplorers Club in an engaging mystery adventure that also teaches science and health concepts.
- *Brain Chemistry Explorations* magazine is full of activities, information and fun things for students and their families to try in class or at home.
- *The Reading Link* provides language arts activities related to the story.

The Learning Brain materials offer flexibility and versatility, and are adaptable to a variety of grade levels and teaching and learning styles. The activity-based, discovery-oriented approach of the unit is aligned with National Science Education Standards and National Health Education Standards.

This teacher's guide provides background information for you, the teacher, at the beginning of each activity. We include a listing of required materials, estimates of time needed to conduct activities, and links to other components of the

unit to aid in planning. Questioning strategies, follow-up activities and appropriate treatments for student-generated data also are provided. The first and final activities will help in assessing student mastery of concepts.

USING COOPERATIVE GROUPS IN THE CLASSROOM

Cooperative learning is a systematic way for students to work together in groups of two to four. It provides an organized setting for group interaction and enables students to share ideas and to learn from one another. Through such interactions, students are more likely to take responsibility for their own learning. The use of cooperative groups provides necessary support for reluctant learners, models community settings where cooperation is necessary, and enables the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. There are materials to be managed, processes to be performed, results to be recorded and clean-up procedures to be followed. When “doing” science, each student must have a specific role, or chaos may follow.

The Teaming Up model* provides an efficient system. Four “jobs” are delineated: Principal Investigator, Materials Manager, Reporter and Maintenance Director. Each job entails specific responsibilities. Students may wear job badges that describe their duties. Tasks are rotated within each group for different activities, so that each student has an opportunity to experience all roles. Teachers even may want to make class charts to coordinate job assignments within groups.

Once a cooperative model for learning has been established in the classroom, students are able to conduct science activities in an organized and effective manner. All students are aware of their responsibilities and are able to contribute to successful group efforts.

* Jones, R. M. 1990. *Teaming Up!* LaPorte, Texas: ITGROUP.



SAMPLE SEQUENCE



The Brain Chemistry unit components can be used together in many ways. The following outline may help you coordinate the activities described in this book with the Brain Chemistry unit's student storybook, *Legacy of Lost Canyon*, and *Brain Chemistry Explorations* magazine. Similar information is provided in the "Unit Links" section of each activity in this guide.

Activity	Concepts	Class Periods to Complete	LINKS TO OTHER COMPONENTS OF UNIT	
			<i>Legacy of Lost Canyon</i>	<i>Brain Chemistry Explorations</i>
1. Pre-assessment: The Brain	Movement, thinking and the senses are governed by the brain and nervous system.	2	Beginnings: The NeuroExplorers, Chapters 1–3; Science box, p. 7	Cover activity "Brain To Body" p. 2–3
2. What Is a Neuron?	Messages are sent and received by a network of living cells called neurons.	1	Chapter 4 Science boxes, p. 11–12	Photo of Neuron, p. 2 "Brain Busters!" p. 7
3. Neural Network Signals	Messages are sent as electrical signals along the length of neurons.	1	Chapters 5–6 Science boxes, p. 13	"Did You Know?" p. 4 "Sending Signals," p. 7
4. Neurotransmitters Contain Chemicals	Neurotransmitters are chemical messengers that fit into specific receptors on receiving neurons.	1	Chapter 7 Science boxes, p. 22–24	"Chemistry Connections," p. 5
5. Crossing the Synaptic Gap	Chemical messengers can either stimulate or inhibit a neuron to fire.	1	Chapter 8 Science boxes, p. 22, 25	"Think About It," p. 8
6. Hormones and Stress	The brain coordinates the release of hormones, affecting many tissues simultaneously.	1	Chapter 9 Science box, p. 12	"Think About It" p. 8.
7. Drugs, Risks and the Nervous System	Health risks associated with drugs of abuse often are underestimated.	1	Chapter 10	"Careers for NeuroExplorers," p. 6, and "How Risky Is It?" p. 8
8. Food for the Brain	The brain and nervous system need many kinds of raw materials from food.	1–2	Chapter 11 Science box, p. 13	"Fueling the Signals" p. 4
9. Post-assessment: Brain Chemistry	Review and post-assessment	1	Review all Science boxes.	





MATERIALS

OPTIONAL MATERIALS

Activity 8

For demonstration purposes, you may wish to obtain the following items (see Setup).

- Cup of raw, chopped carrots
- Deck of cards
- Medium-sized apple or orange
- Slice of sandwich bread
- Teaspoon of margarine

You will need the following materials and consumable supplies to teach this unit with 24 students working in six cooperative groups. See Setup sections within each activity for alternatives or specifics.

Activity 1 (p. 1)

- 7 plain, 11-in.-round balloons
- 6 sheets of drawing or chart paper
- Document projector (or transparency and overhead projector)
- Water

Optional: Human brain model

Activity 2 (p. 7)

- 96 pipe cleaners
- 24 pieces of modeling clay (or small, styrofoam balls)
- 6 bags, resealable plastic, large freezer weight, approx. 12 in. x 15 in. (or gal size)
- 6 rolls of 0.75 in. masking tape
- Document projector (or transparency and overhead projector)

Activity 3 (p. 11)

- 60 mL of sports drink
- 25 clear plastic cups, 9 oz
- 12 clear plastic cups, 2 oz
- 12 coffee stirrers
- 6 batteries, 9 volt
- 5 cups of distilled water
- 3 tsp of sugar
- 3 tsp of table salt
- 8 cm piece of black electrical tape
- Document projector (or transparency and overhead projector)
- Graduated cylinder (100 mL)
- Marker, black
- Roll of #22 gauge insulated wire
- Roll of aluminum foil
- Set of measuring spoons
- String of mini-size holiday lights
- Wire cutter
- Wire stripper

Activity 4 (p. 15)

- 24 sheets of white card stock, 8.5 in. x 11 in.
- 24 pairs of scissors
- 6 resealable plastic bags (approx. 4 in. x 6 in., or gal size)
- Document projector (or transparency and overhead projector)

Optional: Set of dominoes or small wooden blocks

Activity 5 (p. 20)

- 6 square, six-sided, numbered die
- 6 sheets of card stock
- Document projector (or transparency and overhead projector)

Activity 7 (p. 29)

- 24 pairs of scissors
- 24 sheets of paper, 8.5 in. x 11 in.
- 6 rolls of clear tape, 0.5 in.

Activity 8 (p. 34)

- 12 craft sticks
 - 6 slices of prepared and cooled "supreme" pizza
 - Roll of wax paper
- (See "Optional Materials," left sidebar.)

Activities 6 (p. 25), and 9 (p. 41)

Do not require special materials.



OVERVIEW: PRE-ASSESSMENT

This pre-assessment/focus activity introduces students to the brain, the most complex organ of the body, and some of its most important functions (see Answer Key, sidebar, p. 2).

THE BRAIN

Did you ever wonder why you can respond so quickly when you are startled? Wonder why you can “see” a picture in your mind’s eye? Wonder why you can remember facts, events and skills that you learned or experienced a long time ago? Your nervous system makes these and

many more things possible. The brain is the command center of the nervous system; it controls virtually all functions of the body.

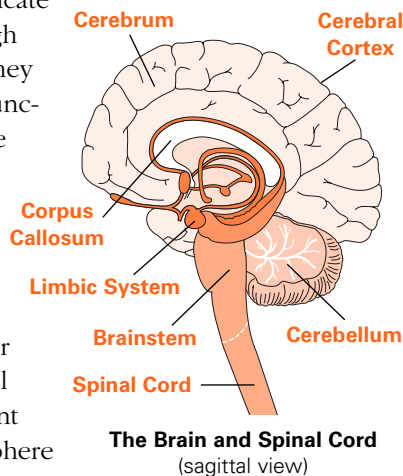
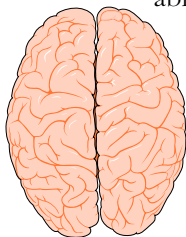
The brain of the average adult weighs about three pounds and fills over half the skull. Even though it is soft (like pudding), the brain can be divided into several regions, each with very specific functions.

The cerebrum, about 85% of the brain’s mass, sits above the brainstem and cerebellum. The surface of the cerebrum, known as the cerebral cortex, has bumps (gyri) and grooves (sulci). The cerebrum enables one to think, learn, reason, remember,

feel sensations and emotions, and move muscles purposefully. It is comprised of two hemispheres (or halves), separated by a deep fissure. The hemispheres are connected by a large bundle of nerve fibers known as the corpus callosum. They communicate with each other constantly. Even though the hemispheres may look the same, they are somewhat specialized for certain functions. For example, in most people, the ability to form words is a

function that seems to be located within the left hemisphere, while the right hemisphere is better at processing spatial information. Different parts of each hemisphere handle specific functions, including hearing, vision, speech, memory, decision making and long-term planning.

Cerebral Hemispheres
(superior view)



The Brain and Spinal Cord
(sagittal view)

CONCEPTS

- The brain is the center of thinking, learning, reasoning, memory, the senses, emotions and movement.
- The brain has unique physical characteristics.
- The brain is specialized into many different areas, each with a different job.
- Brain functions and abilities develop over time.

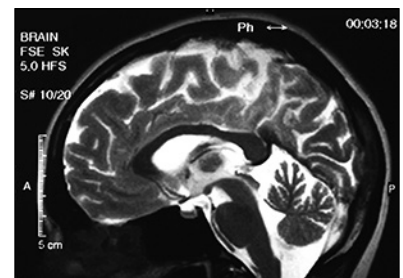
SCIENCE & MATH SKILLS

Observing, measuring, predicting, comparing and drawing conclusions

TIME

Setup: 10 minutes

Activity: 30–45 minutes, in two sessions

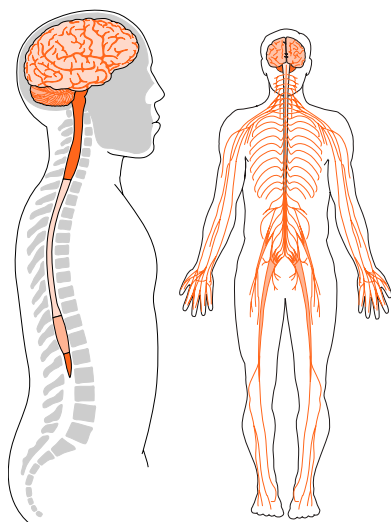


This MRI of a normal brain reveals the different regions of the brain, each of which has specific functions (see illustration, left). Such detailed images allow physicians to visualize diseases, effects of injuries and abnormalities in the brain.

BRAIN DIFFERENCES

Individual talents and skills cannot be predicted based upon the appearance of someone's brain. All humans have brains of about the same size with the same pattern of folding. Differences among individuals are determined by the numbers and kinds of connections among nerve cells within each person's brain.

THE HUMAN NERVOUS SYSTEM



The brain and spinal cord make up the central nervous system. All other nerves in the body form the peripheral nervous system.

ANSWER KEY

The following are answers to the pre-assessment activity.

- **True:** 1, 2, 3, 5, 6, 8, 9, 10, 12, 14, 15, 19, 20, 22
- **False:** 4, 7, 11, 13, 16, 17, 18, 21

of a tennis ball. It helps us maintain balance and posture, and coordinates our movements. The cerebellum also plays an important role in our ability to learn and remember new motor skills, such as riding a bike.

The limbic system is comprised of a number of interconnected brain regions, including areas within and under the cerebral hemispheres. It is involved in many emotions and motivations, especially those related to survival, such as anger, fear, and even the fight-or-flight response. The limbic system also plays an important role in feelings of pleasure, such as those experienced from eating and sex.

The brainstem connects directly with the spinal cord and is responsible for automatic functions of the body, including heartbeat, digestion, breathing, swallowing, coughing and sneezing. Automatic functions are present at birth and happen without thinking about them.

The brain's main communication channel to the rest of the body is the spinal cord. Nerves branch out from the spinal cord and send and receive information.

Functions and abilities develop as the brain grows and matures. The human brain generally reaches close to 80% of its adult weight by the age of two or three, yet it continues to develop throughout adolescence and early adulthood. The region of the cerebral cortex responsible for judgment, organization and reasoning appears to be one of the last brain areas to reach maturity.

MATERIALS

Teacher (See Setup)

- 7 11-in. round, plain balloons
- Document projector (or overhead projector and a transparency of "The Human Brain" page)
- Water

Optional: Human brain model

Per Group of Students

- Balloon filled with water
- Sheet of drawing or chart paper

Per Student

- Copy of the "Know Your Brain?" pre-assessment

SETUP

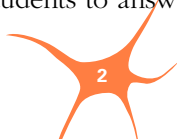
Prior to class, fill one balloon with approximately three pounds (48 oz, or 1,450 mL) of water for each group of students, and one additional balloon for demonstration purposes. Use a scale to weigh the balloons, or compare the balloons to something that weighs approximately three pounds to estimate when you have reached the desired weight.

Photocopy the pre-assessment, "Know Your Brain?" (one per student). Before beginning the activities, have students complete the pre-assessment individually. Have students work in groups of four to discuss functions of the brain (with the balloon), and work individually to create timelines.

PROCEDURE

Pre-assessment and brain basics

1. Distribute copies of the pre-assessment. Without discussion, ask students to answer the questions. Collect the finished sheets and



BRAIN FACTS

- An average brain weighs about three pounds.
- Brain tissue is about 80% water.
- The brain contains over 100 billion neurons (equivalent to the number of stars in the Milky Way galaxy).
- The brain is contained within and protected by the skull.
- The brain is divided into left and right halves.
- The brain has three main parts, each with a special job (cerebrum, where thinking and processing of sensory information take place; cerebellum, which coordinates muscle movements; and brainstem, which governs automatic functions such as breathing and heart beat).
- The brain is pinkish-gray and has the consistency of cooked oatmeal or pudding.

GOOD WRINKLES

The cerebrum is responsible for many aspects of thinking, reasoning, the senses, and movement. Its surface, known as the cerebral cortex, is very wrinkled, with raised parts or bumps known as gyri, and creases or valleys referred to as sulci. These folds allow more cortical cells to fit into the confines of the skull. In fact, if you spread out the cerebral cortex it would take up approximately 2.5 square feet!

keep them for use with the post-assessment at the end of the unit. (*Do not grade the papers.* For Answer Key, see sidebar, p. 2).

2. Begin a class discussion by mentioning that research scientists have learned much about the brain but that there still are many unanswered questions. Discuss students' answers to the assessment and tally the answers for each question on a chart at the front of the room. Moderate the discussion, but do not give answers to the assessment. You may wish to make a separate list of students' questions about the brain.
3. Show the water-filled balloon to the class. Ask, *How is this like a real brain? How is it different?* Give each group one balloon filled with water. Have students within each group share ideas. The Recorder should prepare a chart with two columns labeled "Same" and "Different," and record the students' ideas. Students may use a permanent marker to draw a picture of the brain on their balloons.
Optional: Provide students with access to a brain model.
4. Discuss group answers as a class. Some responses might include the following.
 - **Same:** Balloon is similar size, similar weight, contains water, fragile.
 - **Different:** Balloon is not alive, not made of cells, not wrinkled, without defined parts, not connected to anything.

You also may want to use information listed in Brain Facts (sidebar, upper right).

Functions of different brain areas

1. Project "The Human Brain" page. Discuss the different areas of the brain and the functions that are governed by those areas.
2. Prompt student thinking by asking questions such as, *What part of the brain would be involved in planning your homework?* (cerebrum) *Coordinating your movements when you play soccer?* (cerebellum) *Controlling your rate of breathing?* (brainstem) *Feeling angry?* (limbic system)
3. Then have students consider what parts of the brain are involved in different activities. Reading, for example, involves many areas of the brain (visual information and language is processed in the cerebrum; eye movements are coordinated by the brainstem; triggered emotions might involve the limbic system). Have student groups come up with other common activities or functions and discuss which regions of the brain might be working together during these activities. Have groups present their examples to the class.

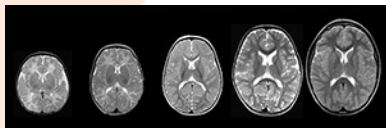
Brain development timeline

1. Begin a class discussion by asking, *Do you have the same capabilities and skills as when you were born? Which capabilities have you always had?* Encourage students to think about automatic functions, such as breathing, or senses, such as hearing. Ask, *Which capabilities or skills*

Continued



NORMAL BRAIN DEVELOPMENT



The MRI images above show normal brain development (left to right) at ages 1 week, 3 months, 1 year, 2 years, and 10 years. Images such as these serve as a baseline for pediatricians when determining problems within the brain.

SENSITIVE TIMING

Early in development, there are windows of time during which the brain is especially changeable and sensitive to experience. Some areas of the brain rely on cues from the external environment to develop normally. For example, the visual system must have visual input to form the connections necessary for sight. If a baby's vision is distorted by cataracts and is not corrected at an early age, the visual area of the brain corresponding to the affected eye will not develop appropriately, which may lead to permanent blindness.

There also is a sensitive developmental window for the acquisition of language. Most people who learn new languages after the age of 10 will speak the new language with the accent of their native tongue. It is important to recognize, however, that these sensitive periods are not the only times at which the brain can be affected by experience. For example, it is possible for adults to learn, and even master, new languages. In fact, the brain is constantly changing, and learning occurs throughout life.

have you developed since then? Responses might include walking, talking and reading.

2. Tell students they will be creating timelines of important events in their development. The timelines will include milestones such as the first time they sat up, walked, ran or spoke a word. Remind students that all of these functions are controlled in some way by the brain.
3. Guide students as they create templates for their timelines. The timelines should include spaces to record at least three important developmental events for each of the first two years of their lifetimes. At least one milestone should be recorded for each subsequent year. Students probably will need to consult their parents or other family members for details about the earliest events. The timelines also should identify whether each milestone was *most* related to movement, communication, senses, thinking, planning or emotions (see "Sample Timeline," right).
4. Have students bring their timelines to class to share in small groups or with the entire class. Ask students if they noticed any similarities in the types of milestones that were most significant in early years of development. In many cases, students will have recorded early events related to basic movements and beginning communication skills. Follow by having students discuss the types of milestones that occurred as they became older. Many of these milestones will be related to thinking, planning, complex movements and types of communication.
5. Conclude by helping students understand that their brains still are changing. For example, brain areas involved in judgement and reasoning (frontal lobes of the cerebrum) continue to develop throughout adolescence and into early adulthood. As the brain continues to mature, adolescents develop increased abilities to plan, reason and exercise self-control.

SAMPLE TIMELINE		
Age	Milestone	Type
1 mo.	Smiled	Emotion
3 mos.	Rolled over	Movement
1 year	Walked	Movement
14 mos.	Ran	Movement
14 mos.	Spoke 1st word	Communication



KNOW YOUR BRAIN?



Name

Read each statement below. Circle **T** if it is true or **F** if it is false.

1. Nerve cells can process many incoming signals from other nerve cells. T F
2. Hormones are chemical messengers that circulate in the bloodstream. T F
3. Our personal desires can affect how we interpret risks to ourselves and to others. T F
4. One special chemical acts as a messenger within the body. T F
5. Many automatic functions of the body, like breathing, are controlled by the brain. T F
6. Stress is a response by the body to help it survive. T F
7. Scientists now understand everything about the brain. T F
8. The pleasure system in the brain can be activated in harmful ways by some drugs of abuse. T F
9. Nerve cells use electricity and chemistry to send signals. T F
10. A person's skills and abilities are related to connections among nerve cells. T F
11. All nerve cells are alike. T F
12. The brains of teenagers still are developing and maturing. T F
13. It is easy to stop being addicted to a drug. T F
14. Our experiences contribute to the development of our brains. T F
15. Signals in the nervous system can travel from the brain all the way to the toe. T F
16. Nicotine, a drug in cigarettes, is not very addictive. T F
17. The part of the brain responsible for judgment and planning is one of the first parts to develop. T F
18. The brainstem is the thinking part of the brain. T F
19. The brain has many specialized areas. T F
20. Some drugs interfere with the sending and receiving of nervous system signals. T F
21. Neurotransmission is part of a car. T F
22. Whole grain breads and cereals provide a steady supply of energy to the brain. T F





THE HUMAN BRAIN

CEREBRUM

(Cerebral Cortex)

- Thinking
- Learning
- Remembering
- Sensing
- Speaking
- Feeling emotions
- Voluntary movement (movements you choose to do)
- Planning
- Decision making
- Reasoning

LIMBIC SYSTEM

- Emotions related to survival, such as fear and anger
- Processing of memories for long-term storage
- Feeling pleasure
- Regulation of body temperature, thirst and appetite or hunger

BRAINSTEM

Automatic body functions, such as:

- Swallowing
- Breathing
- Sneezing
- Heart beat
- Automatic eye movements, such as blinking

SPINAL CORD

- Pathway for nerve signals between the brain and the rest of the body
- Coordination of reflex actions, like jerking your hand away from something hot

CEREBELLUM

- Coordinating balance and movement
- Remembering well-learned tasks and skilled movements
- Processing some types of memory

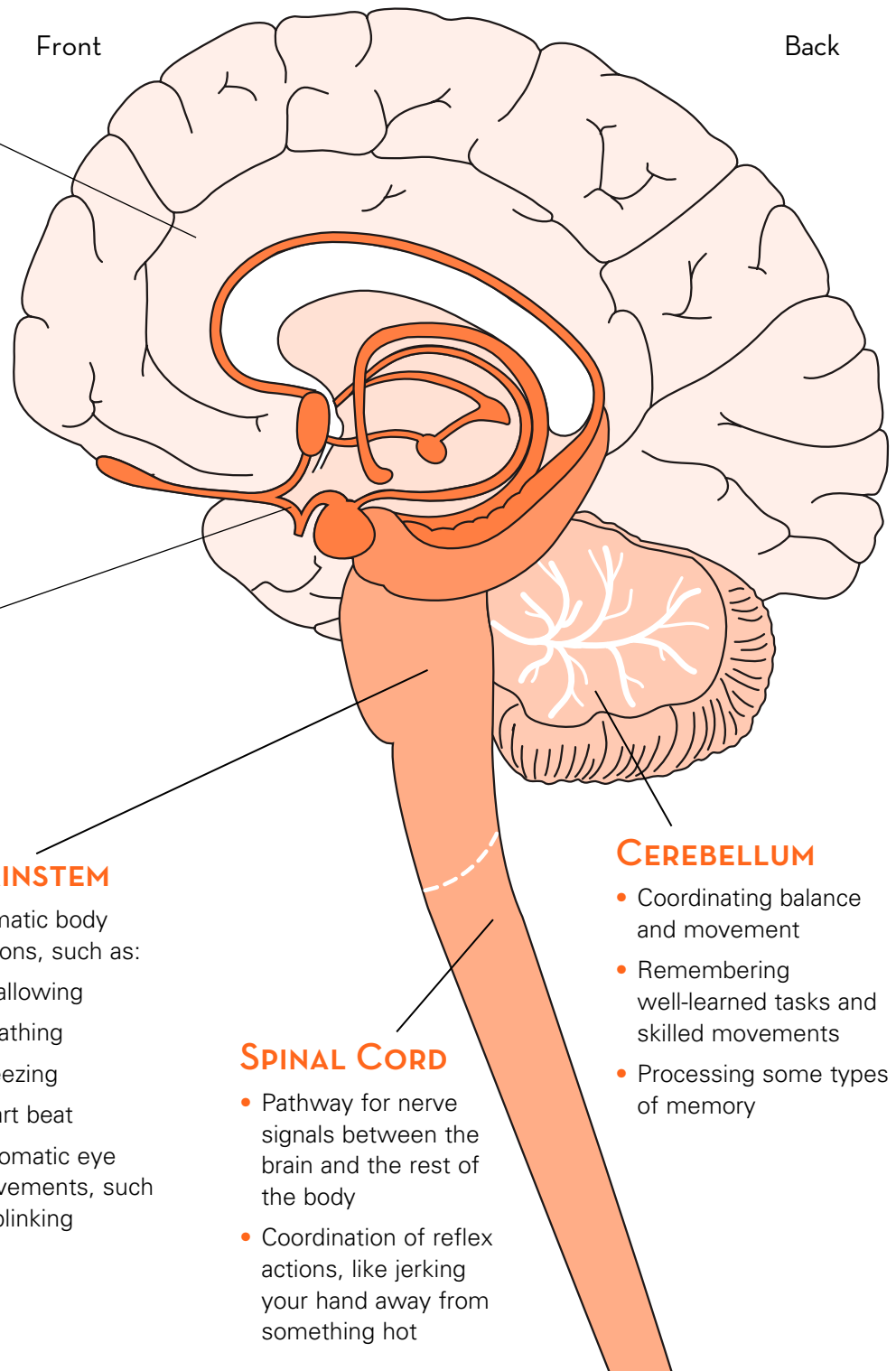
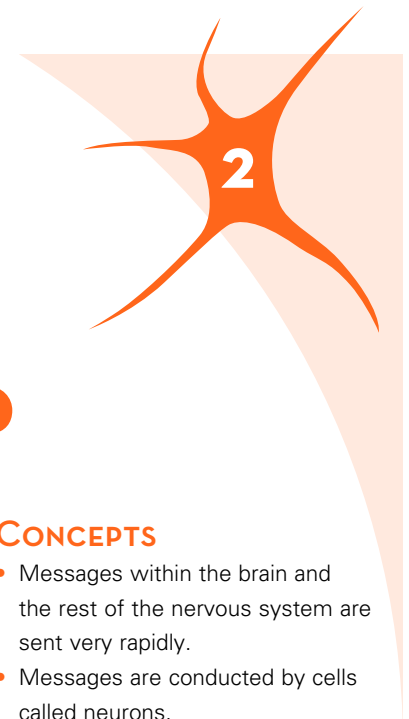


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OVERVIEW

Students are introduced to how messages are sent and received by neurons, and they build a model neuron.



WHAT IS A NEURON?

The human brain is the most complex structure in the known universe. Consisting of close to 100 billion nerve cells (and many times that number of supporting cells), the brain is the center of our thoughts and emotions. It receives and processes information from the world around us, directs our movements and controls automatic functions of our bodies. Amazingly, virtually all functions of the brain and the rest of the nervous system are based on communication among nerve cells, also known as neurons.



UNIT LINKS

Legacy of Lost Canyon
Chapter 4
Science boxes, p. 11-12

Brain Chemistry Explorations
"Brain Busters!" p. 7
Neuron photograph, p. 2

In many ways, a neuron is like any other cell in the body. Each neuron is surrounded by a membrane, is filled with liquid (cytoplasm) and has a nucleus containing its genetic material. However, just as many other cells within the body are specialized to do a particular job, neurons are specialized to receive and transmit information. Even though they may differ in appearance, all neurons collect information from either the environment (information detected by the sensory system) or from other cells in the body. They transmit the information to other neurons and/or other kinds of cells (such as muscle).

A typical neuron has an enlarged area, the cell body, which contains the nucleus. Neurons typically also have two types of specialized extensions that project away from the cell body. The branches on which information is received are known as dendrites. Each neuron usually has many dendrites. Each neuron usually also has a longer taillike structure, or axon, which transmits information to other cells. Axons can be branched at their tips. The axons of many kinds of neurons are surrounded by a fatty, segmented covering called the myelin sheath. This covering acts as a kind of insulation and improves the ability of axons to carry nervous system signals rapidly.

Neurons communicate with one another through special junctions known as synapses. With the most common type of synapse, known as a chemical synapse, neurons do not actually touch. Rather, the end of the axon (or axon terminal) of one neuron is separated from the next neuron by a tiny gap called a synaptic cleft. Messages traveling from one neuron to the next must cross this gap and bind to the next neuron for the signal to continue along its path. Typically, a single neuron may be capable of

CONCEPTS

- Messages within the brain and the rest of the nervous system are sent very rapidly.
- Messages are conducted by cells called neurons.
- Neurons are specialized to receive and transmit messages.
- Neurons are connected in networks.

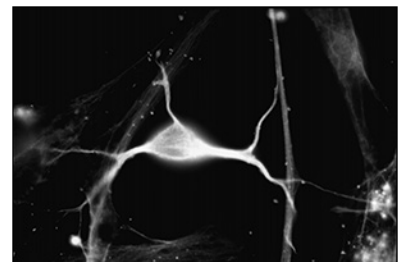
SCIENCE & MATH SKILLS

Predicting, inferring and modeling

TIME

Setup: 10 minutes

Activity: 45 minutes

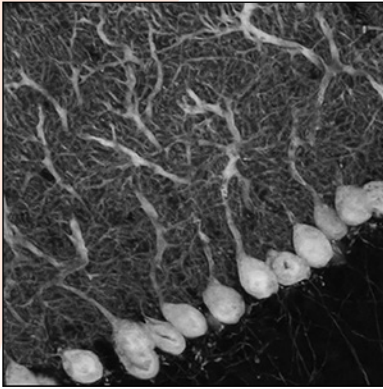


Microscopic image of a neuron from the hippocampus. Most neurons receive signals from many other neurons. The combined effects of these signals determine the response of the receiving neuron.



Continued

PURKINJE NEURONS



Purkinje cells are large neurons with branching, tree-like dendrites. These neurons form the sole output pathway of the cerebellar cortex, and they serve as an essential link in regulating the body's muscle tone and movement.

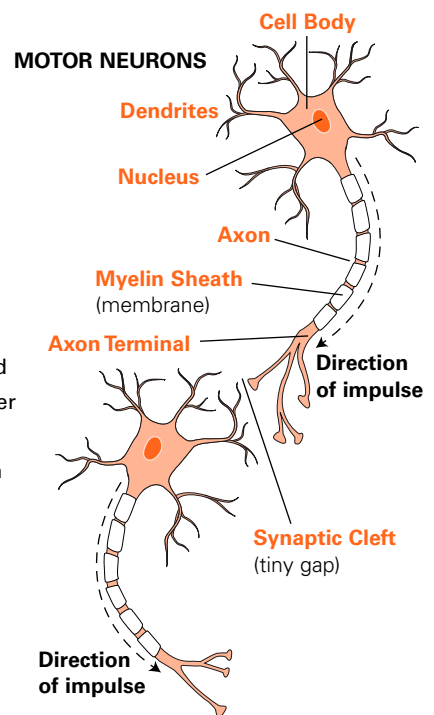
DID YOU KNOW?

- New neurons are “born” throughout life and may play an important role in learning and memory. Scientists have discovered that the number of new neurons born in the brain is increased by physical exercise and decreased by factors such as stress and aging.
- In humans, axons can vary from only a fraction of an inch to more than 3 feet in length! The longest axons extend from the base of the spine all the way to the big toe of each foot.
- Neurons are accompanied and supported by other kinds of cells.

TYPICAL STRUCTURE OF NEURONS

A typical neuron has an enlarged cell body which contains the nucleus. Most neurons have branches, known as dendrites. Each neuron typically also has a longer tail-like fiber, or extension, called an axon. Information typically is received on the dendrites or on the cell body and is transmitted down the axon to other cells. (The myelin sheath, illustrated in the neurons to the right, has been enlarged for viewing its location on the axon.)

Neurons vary greatly in size and shape. Although neurons generally have only a single axon, they can have hundreds of dendrites.



receiving messages simultaneously on its dendrites and cell body from several thousand different neurons.

This activity provides students with a general introduction to neurons and to their role as message carriers within the body.

MATERIALS

Teacher (See Setup)

- Document projector (or overhead projector and a transparency of “Transmitters & Receivers” page)

Per Group of Students

- Resealable plastic bag, approx.

12 in. x 15 in. (or gal size)

- Roll of masking tape, 0.75 in.

Per Student

- 4 pipe cleaners
- Modeling clay (or small styrofoam ball)
- Copy of “Transmitters & Receivers” page

SETUP

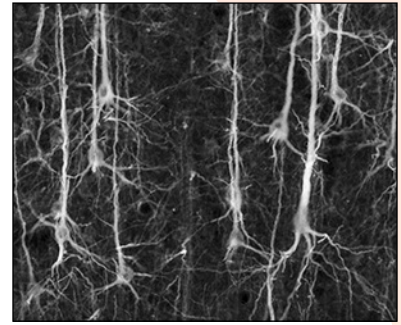
Organize materials in one plastic bag for each group and place in a central location. Conduct the initial portion of this activity with the entire class. Then have students work in groups of four.

PROCEDURE

1. Begin by asking students how they react to touching something hot. Ask, *What happens when you accidentally touch a hot dish or iron?* Students might mention that they jerk their hands away quickly from the hot items. Ask, *Why might it be important for you to react quickly?*



PYRAMIDAL NEURONS



Pyramidal cells, like the ones shown above, are found in the cerebral cortex and other parts of the central nervous system. Pyramidal cells have a pyramid-shaped cell body and many dendritic branches.

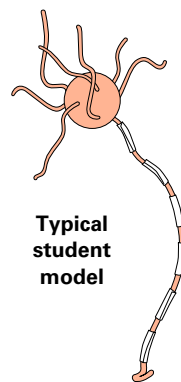
EXTENSIONS

- Obtain prepared slides of neurons and other cells in the nervous system from a commercial biological supply company. Or find photographs of neurons on the Internet. Help students find the cell bodies, dendrites and axons on the neurons. Students will observe that actual neurons are much more complex than their models, but still have the same basic parts.
- Try envisioning the following. If the cell body of a typical motor neuron (a neuron that sends messages to muscles) were the size a tennis ball, its dendrites would extend the length of a normal room and its axon would be about the size of a garden hose nearly 1/2-mile long.
- Neurons are not the only cells in the nervous system. They are assisted by other cells. Some types of cells even wrap around the axon to form the myelin sheath. Challenge students to use the Internet or library resources to find out more about these helpers, called glial cells.

2. Point out to students that components of the nervous system work together to conduct signals very rapidly. Reflex responses (which can be essential for survival) are especially fast, because the signal from sensors can be routed directly to muscles through the spinal cord without first passing through the brain.
3. Next ask students as a group to respond to some simple arithmetic questions. Ask, *What is two times four? Three times three? Three times nine? Ten times ten?* Follow by asking, *Did it take a long time for your brain to figure out the answers? Did it take long for your brain to send messages to your lips and tongue to form the words?* Reiterate that components of the brain and the rest of the nervous system work together very rapidly.
4. Project the “Transmitters & Receivers” page on the board. Mention that there are many different kinds of neurons (about 10,000!), but that all of them are designed to receive and transmit messages. Point out the “message-receiving” parts (dendrites and cell bodies) and “message transporting” parts (axons) on the two neurons. Mention the myelin sheath that surrounds the axons of some neurons and helps them conduct signals more rapidly (not unlike the insulation on an electrical wire).

You also may want students to look at the photograph of a neural network (sidebar, upper right). In the photograph, students can easily observe the cell bodies of neurons. They also can observe that axons and dendrites form complicated networks.

5. Distribute copies of the student sheet and have students complete it. Make sure students understand that messages flow in only one direction on each neuron.
6. Challenge students to use a variety of materials to create their own neurons (see “Typical Student Model,” right). Use modeling clay or small styrofoam balls to create cell bodies, and pipe cleaners to create axons and dendrites. Remind students that, even though printed images give neurons (and other cells) a flat appearance, these structures actually have a variety of shapes in three dimensions.
7. Provide masking tape for students to create short myelin sheath segments on the axons of their neurons.
8. After students have made their neurons, ask them to identify on their models where incoming messages would be received from other neurons and from where their models would be able to transmit messages to other neurons.
9. Display the completed neuron models on a board or table. Or encourage students to work together to create networks of interconnected nerve cells using the neuron models they have created and display these constructions.



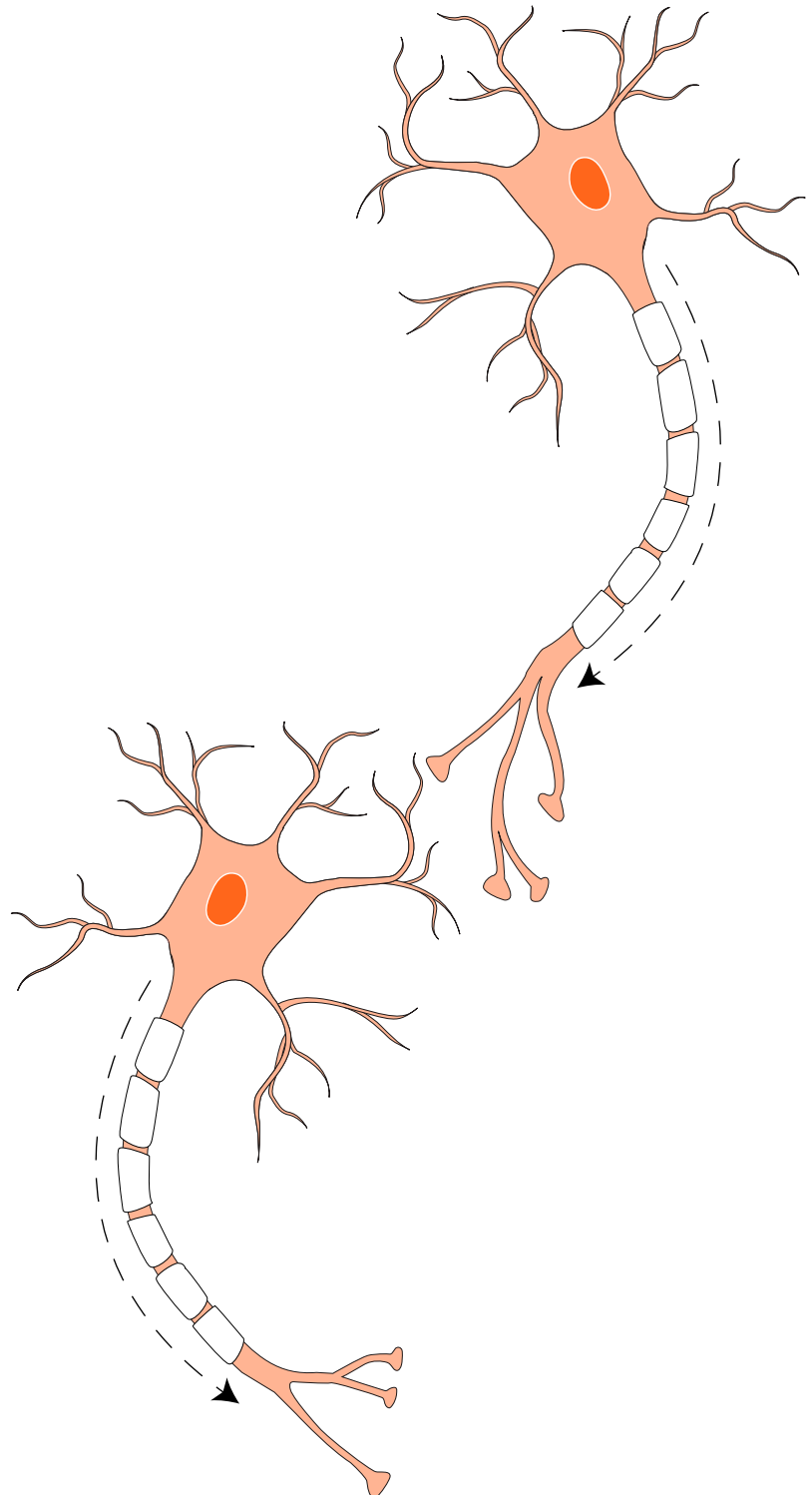


TRANSMITTERS & RECEIVERS

Neurons are special cells that pass messages throughout the body.

1. Locate the cell body and the nucleus of each neuron.
2. Find the axons (long fibers) that lead from one neuron to the next.
3. Locate the dendrites (short branches) on the neurons.
4. Find the myelin sheath that wraps around each axon.
5. Locate the ends of each axon (or axon terminals). Notice the slightly rounded shapes.
6. Find the Synaptic Cleft (tiny gap between the neurons, across which messages must pass).
7. Label the parts of the neurons.
8. Notice the arrows on the drawing. What do you think they mean?

9. A single neuron may receive messages from many other neurons at one time. Think about how messages are passed between neurons. Add another neuron to this image.



OVERVIEW

Students create an electrical circuit and investigate whether or not different dissolved substances conduct electricity.

NEURAL NETWORK SIGNALS

Neurons communicate with one another and with other cells, such as muscle cells, by sending signals along the length of a special type of output fiber known as an axon. More than a century ago, biologists discovered that these signals, also known as nerve impulses or action potentials, involved electricity. At first it was believed that electricity flowed through axons much as it travels along a wire. However, further investigation revealed that electricity does not flow passively through axons. Rather, electrical signals are actively transmitted along the length of axons.

Eventually, biologists discovered that electrical impulses are transported along the cell membranes of axons. Chemical changes along the length of the membrane cause an electrical charge to move

along the length of the axon. This movement resembles a line of dominoes, in which each domino triggers the next one to fall. Once the signal reaches the end of the axon, it is passed to the next nerve cell either electrically or by a chemical messenger that crosses the synaptic cleft between nerve cells.

Movements of sodium, one of the components of salt, help generate the electrical charge that travels along the neuron membrane. Potassium, chlorine and calcium also are involved. This activity helps students observe the relationship between certain substances dissolved in water and the conduction of an electrical signal.

Students will build a circuit that connects a bulb to a battery. Electricity, which is the movement of electrons (negative charge), will flow from the negative terminal to the positive terminal.

Students will use their setups to investigate whether distilled water conducts electricity and compare the results to those achieved with salt water and sugar water. Students also will test the conductivity of a sports

CONCEPTS

- Nervous system messages are sent as electrical signals along the length of axons.
- Dissolved salts are important for electrical signaling in cells.

SCIENCE & MATH SKILLS

Predicting, observing, comparing, recording observations and interpreting


TIME

Preparation: 20 minutes

Class: 45 minutes or more

ELECTRIC SIGNALS

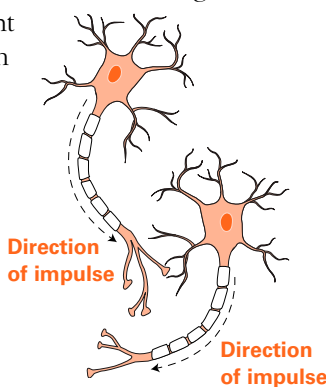
- Electricity flows in one direction (negative to positive).
- Chemicals, such as salt, that dissolve into positively and negatively charged atoms (ions) in water will conduct electricity.
- Chemicals, such as sugar, that do not acquire a charge when dissolved do not conduct electricity.
- Electricity in living cells depends on positively and negatively charged atoms (ions) dissolved in water.
- Electrical signals in neurons travel very quickly—up to several hundred miles per hour.
- Nerve impulses involve the opening and closing of tiny tunnels in the cell membrane. The movement of charged atoms (such as sodium), through the tunnels creates an electrical impulse.



UNIT LINKS

Legacy of Lost Canyon
Chapters 5-6
Science box, p. 13

Brain Chemistry Explorations
“Did You Know?” p. 4
“Sending Signals,” p. 7



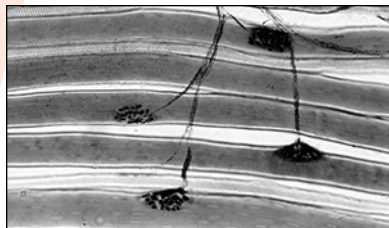
Signals are conducted electrically in one direction along the length of a neuron's axon and passed either electrically or chemically across the synaptic cleft to the next neuron or series of neurons.

Continued



NEURON FIRING

The photo below is of a motor neuron's nerve endings on top of skeletal muscle fibers. The dark, bumpy areas at the end of each nerve are called motor end plates (neuromuscular junctions). Each motor end plate is associated with only one muscle fiber.



When the neuron fires, acetylcholine (a neurotransmitter) is released into the space between the motor neuron (synaptic cleft) and that of the muscle fiber; it diffuses across the space and triggers the series of events that leads to contraction of the muscle.

THE ROLE OF SALT

In addition to its role in the nervous system, salt is important for muscle movement, digestion and the movement of fluids into and out of cells. Salt lost from the body in sweat and in urine must be replaced. Normal human blood contains about 0.9% salt.

drink. Pure water is a poor conductor of electricity. However, when salt is added, water conducts electricity very efficiently. Dissolved salt (NaCl) separates into negatively charged atoms (chloride ions, written as Cl⁻) and positively charged atoms (sodium ions, written as Na⁺). The current is carried by Cl⁻ ions, which migrate toward a wire connected to the positive terminal of a battery.

MATERIALS

Teacher (See Setup, below)

- 60 mL of sports drink
- 8 cm black electrical tape
- Clear plastic cup, 9 oz
- Graduated cylinder (100 mL)
- Marker, black
- Measuring spoons
- String of mini-size holiday lights
- Wire cutter
- Wire stripper

Per Group of Students

- 180 mL distilled water
- 4 clear plastic cups, 9 oz
- 2 clear plastic cups, 2 oz

- 2 coffee stirrers
- 2 squares of aluminum foil, 3 cm x 3 cm each
- 1/2 teaspoon of table salt
- 1/2 teaspoon of sugar
- Battery, 9 volt
- Copper wire, 20-cm piece
- Mini-size holiday light bulb and socket, with wiring trimmed to approximately 9 cm length on each side and 3 cm of insulation stripped from each end
- Copy of “Sending the Signals” student sheet

SETUP

Purchase a set of mini-size holiday lights (or LED lights). For each group, cut a bulb/socket from the string of lights so that the socket has two 9-cm pieces of wire extending from its base. Strip 3 cm of insulation off the end of each wire to expose the copper wire inside. Also, cut a 20-cm piece of insulated copper wire (with 3 cm of insulation stripped off of each end), and provide two squares of aluminum foil (about 3 cm x 3 cm each) per group.

Label each of three 9-oz cups as “distilled water,” “salt water” and “sugar water.” Pour 60 mL of distilled water into each cup.

Label two 2-oz cups as “salt” and “sugar.” Measure 1/2 teaspoon of salt into one cup and 1/2 teaspoon of sugar into the other cup.

If using powdered sports mix, prepare the mix according to package directions and have ready for open inquiry (see Items 10–11). Pour 60 mL of sports drink into a 9-oz cup for class discussion.

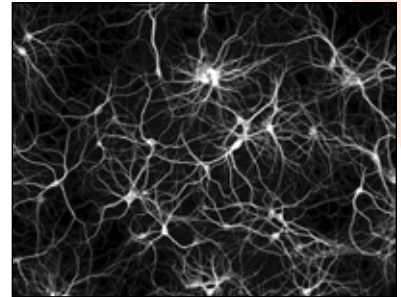
Make six copies of “Sending the Signals” sheet. Place all materials in a central location. Have students work in groups of four.

PROCEDURE

1. Remind students of the activity, “What Is a Neuron?” in which they learned about neurons. Ask, *Did you know that neurons rely on electricity to carry messages along the length of the axon? Can you think of other examples of ways that living things use electricity?* Students may offer examples such as electric eels.

NEURON CIRCUITS

When a neuron “fires,” it sends an impulse to one or more other neurons. The trigger can be a sensory signal (light, heat, sound, etc.) or it can be a signal or impulse received from other neurons.



Some neurons are coupled directly, so that an electrical signal traveling down one neuron passes directly to the next one. This type of transmission occurs very rapidly and usually is found in places in the nervous system where speed of conduction is important. Other neurons use chemical messengers, known as neurotransmitters, to send signals to other neurons. Shown above is a culture of a neuronal network.

SAMPLE TABLE

	Prediction	Reason	Result
Distilled Water			
Salt Water			
Sugar Water			

EXTENSION

Salt is an important part of the diet for humans, but it has not been plentiful at all times throughout history. Have students investigate the roles salt has played in human culture, civilization and politics.

- Ask students, *Which substances in living things might be important for electrical signals in neurons?* Students may not have much prior knowledge of materials in cells. If necessary, remind students that living things consist mostly of water. In addition, a number of dissolved materials such as salts, sugars and other carbohydrates, and proteins are present in cells and other parts of living organisms.
- Tell students that they will build an electrical circuit and use it to investigate which substances might be important for conducting electricity in cells. Have the Materials Managers from each group collect the materials.
- Distribute copies of the student sheet. Have students follow the instructions on the sheet to build and test their circuits.
- Ask, *Where is the source of energy for the bulb?* [battery] *Where is the electricity traveling?* [from terminal to terminal, along a wire] Point out that electricity flows in only one direction (negative to positive). Relate this to neurons by pointing out that tiny electrical impulses also travel in only one direction along the length of axons.
- Tell students that they will use the circuit setups to conduct three tests using distilled (pure) water, a salt water solution and a sugar water solution. For each test, students will insert the foil wrapped tips of their circuits into a liquid and observe the bulb.
- Have students create a table on the back of their student sheets or on a separate sheet of paper (see “Sample Table,” right). They will need to leave enough room on their tables to record predictions, reasons for their predictions and results. Give students time to predict the outcomes of each test and justify their predictions.
- Have students conduct each test and record the results.
- Discuss students’ outcomes: salt water conducted electricity; distilled water and sugar water did not conduct electricity. Ask, *Which of the two dissolved substances might be involved in electric signaling in neurons?* (salt)
Note. To promote safety, make sure that students understand that tap and rain water also are good conductors of electric current. Point out that students never should use a hair dryer, radio or television near a bathtub or sink; and never should touch anything that runs on electricity with wet hands.
- Continue by showing students the sports drink. Ask, *Why do people use these drinks?* Students may or may not know that the drinks are promoted as sources of body salts lost as sweat during exercise. Ask, *How might you be able to investigate whether the advertising claims are valid?* Challenge students to use their circuit setups to test whether the sports drink is a good source of lost salt.
- You may want to give students time to plan and bring in other drinks or brands of sports drinks to test the next day. Students should compare their findings to the information provided on the sports drink label. Have each group present its investigation and results to the class.



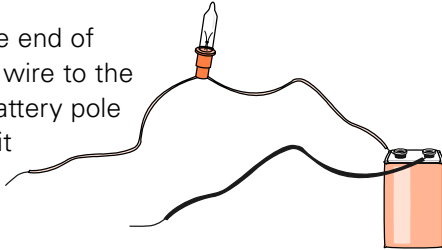


SENDING THE SIGNALS

BUILD A CIRCUIT

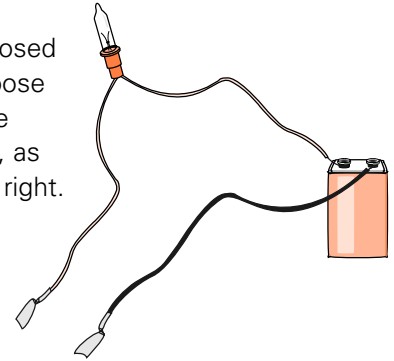
1. Wrap the exposed end of one wire from the light bulb around one pole on the battery. Tape it in place with a piece of electrical tape.

2. Attach the end of the other wire to the second battery pole and tape it in place.



3. Test the connection by briefly touching the exposed ends of the two loose wires together. (The bulb should burn brightly.)

4. Wrap the exposed ends of the loose wires with the aluminum foil, as shown to the right.



TESTING SOLUTIONS

All cells contain water, some dissolved salts and sugar. *Which substances in cells help conduct electricity?* You will investigate what happens when a tiny amount of electricity passes through distilled water, a salt-water solution, and a sugar-water solution.

1. You have three labeled cups of distilled water, a container of salt and a container of sugar. Pour the salt into the cup of water labeled "salt," and stir until the salt dissolves. Pour the sugar into the cup of water labeled "sugar," and stir until the sugar dissolves.

2. On a separate sheet of paper, or on the back of this sheet, create a chart (see sample chart, right) to record your predictions, reasons for your predictions, and test results for each liquid tested (see sample chart).

	Prediction	Reason	Result
Distilled Water			
Salt Water			
Sugar Water			

3. What do you think will happen when you put the foil-wrapped wires in the different solutions? Record your predictions and reasons.
4. Test the first solution by inserting both foil-wrapped tips below the surface of the liquid. Keep the tips apart. Record the results. Next, test each of the other two liquids and record the results.
5. Based on your observations, which substances in cells would you say helped conduct electricity? Write a paragraph describing the steps you followed, your observations and your answers to this question.

Illustrations by M.S. Young © Baylor College of Medicine.



OVERVIEW

Students play a simple card game to learn the sequence of events in the transmission of nervous system signals.



NEUROTRANSMITTERS CONTAIN CHEMICALS

Each of the billions of neurons in the nervous system communicate with one another and with other cells, such as muscle cells, through special junctions known as synapses. Some neurons share synapses with thousands of other cells. Others connect with only a few cells. As noted earlier, nervous system signals travel along the cell membranes of individual neurons, but what happens at the ends of neurons? How does a signal move across the synapse to other neurons? The answers to these questions involve highly efficient mechanisms that allow signals to be transmitted from neuron to neuron.

Nervous system signals generally travel in only one direction along a neuron. Signals are received on dendrites or on the cell body and trigger an electrical impulse that moves along the axon. Once the signal reaches the end of the axon (or axon terminal) of a neuron, it must move

through the synapse to the next neuron. At the most common type of synapse, known as a chemical synapse, the impulse triggers the release of chemical messengers, called neurotransmitters, from special pockets known as vesicles. Neurotransmitters released from the vesicles leave the cell and physically move through the narrow watery space (the synaptic cleft) between neurons. The space between neurons is about 20 nanometers (one nanometer equals 0.000,000,1 centimeters). Once on the other side of the gap, the neurotransmitters attach to special receptor molecules on a dendrite or on the cell body of the receiving neuron. The joining of the neurotransmitters to their specific receptor sites can promote the generation of a new electrical impulse (the neuron “fires”) OR the neurotransmitters can have an inhibitory effect, making it harder for the neuron to fire.

Biologists have identified more than 100 different neurotransmitters. Each has a different three-dimensional shape, which fits only a certain kind of receptor site. The relationship between a neurotransmitter and its receptor is similar to that of a key and a lock.

The story does not end, however, with the binding of the chemical messengers to receptors on the next neuron. If the messengers remained in place, no new signals could be received. Thus, mechanisms to remove the messenger from the synapse also exist.

UNIT LINKS

Legacy of Lost Canyon

Chapter 7
Science boxes, p. 22-24

Brain Chemistry Explorations

“Chemistry Connections,”
p. 5

CONCEPTS

- Nervous system signals are transmitted electrically along individual neurons.
- Neurons are separated from each other by a tiny gap.
- Chemical messengers called neurotransmitters cross the gap between neurons.
- Neurotransmitters fit into special receptor sites on receiving neurons.

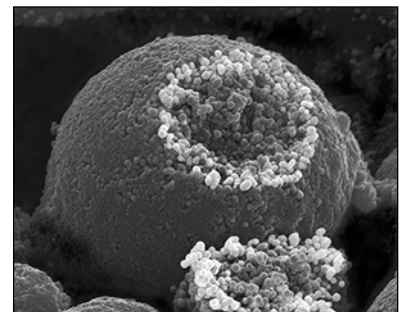
SCIENCE & MATH SKILLS

Sequencing, communicating, applying knowledge and identifying patterns

TIME

Preparation: 10 minutes

Class: 45 minutes



A scanning electron microscope image of a nerve ending (large, dark gray round object). It has been broken open to reveal vesicles containing chemicals (light gray oval shapes) used to pass messages in the nervous system.

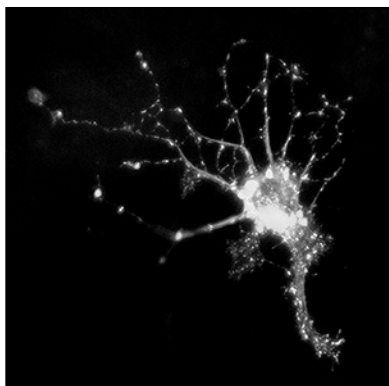


Continued

DEFINITION: NEUROTRANSMITTER

Researchers define a substance as a neurotransmitter when it meets the following criteria.

- The substance is synthesized in a neuron.
- The substance can be found in axon terminals of the neuron believed to release the neurotransmitter.
- The substance is released in response to an electrical signal in the cell membrane.
- When released from a neuron or applied (as a drug) onto an appropriate cell, the substance causes a biological effect.
- A mechanism exists to inactivate and/or remove the substance from the synaptic cleft.



Microscopic image of a single neuron stained to reveal specific receptors.

In some cases, neurotransmitters simply float (diffuse) away from the synapse. Other neurotransmitters are broken down or degraded by enzymes found within the synaptic cleft. Many neurotransmitters are transported, whole, back into the neuron that released them. Some drugs, such as cocaine and fluoxetine (Prozac[®]), exert their effects by interfering with the removal of neurotransmitters from the synapse.

Sometimes, neurons do not communicate through neurotransmitters. Instead, an electrical charge passes directly from neuron to neuron through what is known as an electrical synapse. This type of signaling, in which the communicating neurons are very close together, is very fast and allows many interconnected neurons to fire at the same time. Electrical synapses are less common than chemical synapses, but they are very important for the normal development and function of the nervous system.

MATERIALS

Teacher (See Setup)

- 24 sheets of 8-1/2 in. x 11 in. white card stock
- 6 bags, resealable plastic (approx. 4 in. x 6 in.)
- Document projector (or overhead projector and transparency of the “Transmitters & Receivers”

page from the activity, “What Is a Neuron?”)

Optional: Set of dominoes or small wooden blocks

Per Student

- Copy of “Locks & Keys Cards” and “Rules of Play” pages
- Pair of scissors

SETUP

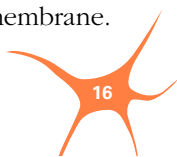
Make photocopies of the “Locks & Keys Cards” page using white card stock (four per group) and photocopies of “Rules of Play” page using copy paper (one per student). Have students conduct this activity in groups of four.

PROCEDURE

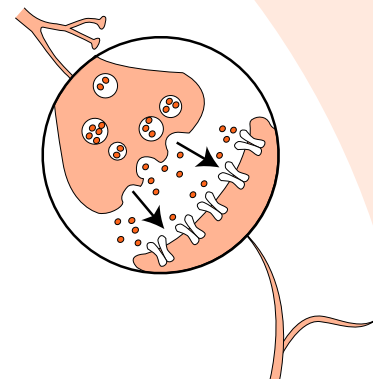
Learning About Chemical Messengers

1. Remind students of the “Neural Network Signals” activity by asking, *What happened when you tested whether salt water would conduct electricity?* Students should remember that salt dissolved in water carried the electrical current from one foil strip to the other, thus completing the circuit.
2. Tell students that rapid movements of dissolved substances like those in salt also make it possible for neurons to transmit electrical signals along the lengths of their axons. In the case of neurons, a single pulse of electricity is transmitted along the axon rather than a current.

Optional: You may want to set up a row of dominoes or small wooden blocks to demonstrate how toppling one domino will set off an impulse that topples each domino in sequence, and correlate this action to the movement of an electrical impulse along a cell membrane.



CHEMICAL COMMUNICATION



In most cases, communication across the synapse occurs chemically instead of electrically. Chemical messengers, called neurotransmitters, can either promote or inhibit the firing of receiving neurons.

GASES AS NEUROTRANSMITTERS

Scientists have discovered that some gases, such as nitric oxide, can serve as neurotransmitters. Unlike classical neurotransmitters, these molecules are made on demand and released from neurons by diffusion (the movement of dissolved substances through water or other medium).

3. Project the “Transmitters & Receivers” page. Point to the top neuron and ask, *Where would signals be received on this neuron?* (dendrites or cell body). *If a signal travels along this neuron, where will it go?* (signal will travel the length of the axon).
4. Point to the gap between the two neurons and ask, *What happens when the signal reaches the end of the axon? How could the message get to the next cell?* Allow students to discuss different scenarios. List their suggestions on the board. (You may want to group their suggestions into two broad categories: one representing scenarios related to electrical transmission and the other related to possible kinds of chemical transmissions.)
5. Use questions to help students evaluate their list of possible ways for signals to cross the synapse from one neuron to the next. Ask, *Which of these choices would allow for rapid communication?* (electrical-type communications). *Which might allow neurons to send and receive different messages?* (systems that use different messengers, such as chemicals).
6. Point out that in some cases, neurons in the human nervous system transmit messages electrically to other neurons. However, in most cases, special chemical messengers (neurotransmitters) are released and travel across the gap to the next neuron, where they attach to molecules called receptors.
7. Distribute photocopies of the “Locks & Keys Cards” and “Rules of Play” pages (see Setup) to each group of students. Have students cut out the cards and arrange one set of cards in a logical sequence using the text at the bottom of each card as a guide. Discuss the sequence of events shown in the cards with the class. Point out that even though the cards depict a sequence in which a neurotransmitter promotes the firing of another neuron, neurotransmitters also can communicate a “stop” message, which makes it harder for the next neuron to fire.
8. Make a list on the board of the transmission sequence in neuron communication: 1) Message Received; 2) Neuron Fires!; 3) Axon; 4) Neurotransmitters; 5) Synapse; 6) Receptor; 7) New Message; and 8) Recycle. List the sequence in order (top to bottom), but do not number the list.

Playing the Game

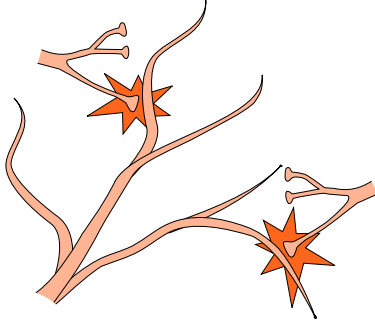
1. Leave the list of steps on the board to help students as they play the game. Depending on the ages and prior knowledge of your students, you may want to erase the sequence after students have played a few rounds of “Locks & Keys.”
2. Explain game rules to students, which are similar to the card game “Go Fish.”
3. Have students play the game for two or more rounds, or until they are comfortable with the sequence of events depicted on the cards.
4. Have students place cards in the clear plastic bags for storage.





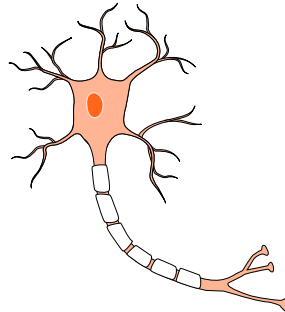
LOCKS & KEYS CARDS

MESSAGE RECEIVED



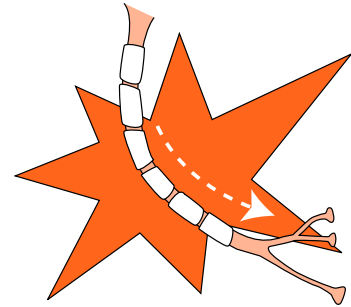
Messages are received on dendrites or on the cell body.

NEURON FIRES!



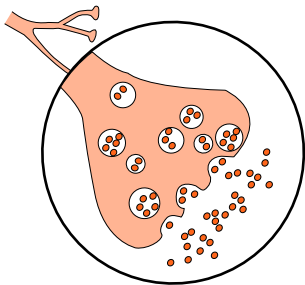
The combined messages generate an electrical impulse.

AXON



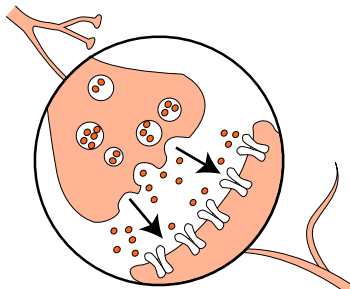
The impulse travels to the end of the axon.

NEUROTRANSMITTERS



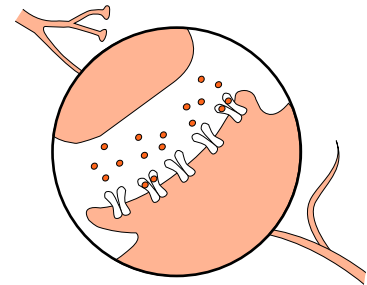
The impulse causes neurotransmitters to be released from the axon.

SYNAPSE



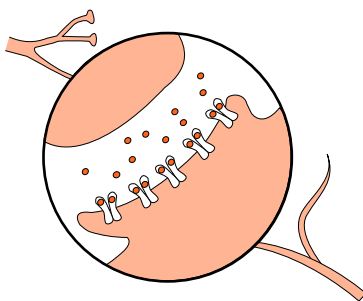
Neurotransmitters move across the gap (synaptic cleft) between neurons.

RECEPTOR



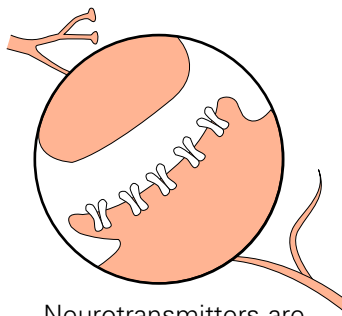
Some neurotransmitters attach to special receptors on the receiving neuron.

NEW MESSAGE



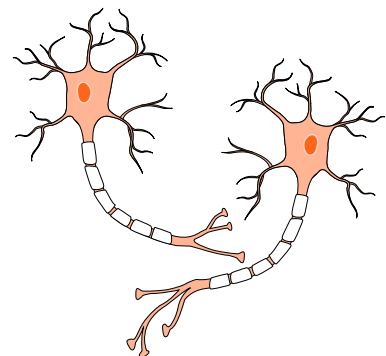
A new impulse can start in the receiving neuron.

RECYCLE



Neurotransmitters are cleared from receptor sites and the synapse.

WILD CARD



Substitute for any card.

RULES OF PLAY



- Each player is dealt five cards. The remaining cards are placed in a pile in the center of the table. Play proceeds to the left.
- Players take turns trying to obtain at least three cards in a neurotransmission sequence (run). For example:

Axon
Neurotransmitters
Synapse

- A run may contain the last and first elements of a sequence. For example:

Recycle
Message Received
Neuron Fires!

- Each player begins his or her turn by asking any player for a card by name. For example, "Max, do you have any Axons?"
- If Max has one or more Axon cards, he gives all of them to the asking player, who then receives another turn to ask any player for another card. If Max does not have any Axon cards, he replies, "Locked Up!" and the asking player draws one card from the pile. Wild Cards may not be requested or given.
- If the requested card (not a Wild Card) is drawn from the pile, the asking player receives another turn. Otherwise, the player to the left begins his or her turn.

- Sets of three or more cards in sequence may be laid down at any time during a player's turn, including after a card has been drawn from the pile. Players may add cards to their existing runs, but only during their turns.

For example, if a player draws a Neuron Fires! card from the pile, he or she may add it to the run beginning with the Axon card that he or she already had laid down.

- Only one Wild Card may be included in any run (regardless of the number of cards in the run). Once a Wild Card has been used in a run, it may not be moved to another position.
- If a player has no cards in his or her hand at the end of a turn, he or she draws another card from the pile and waits until his or her next turn.
- The game proceeds until all cards have been drawn from the center pile, and no player can lay down or add to any more runs.



- **SCORING:** A player's score consists of the number of cards in the runs he or she laid down minus the number of cards still held in his or her hand.



5

CONCEPTS

- Neurotransmitters can either stimulate the next neuron to send a signal or inhibit that neuron from sending a signal.
- Certain chemicals change the way signals are sent and received.

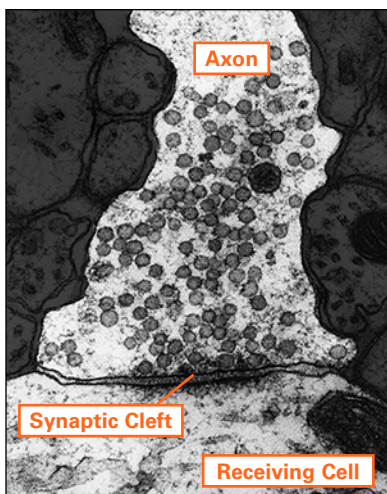
SCIENCE & MATH SKILLS

Predicting, comparing and contrasting, recording observations and interpreting results

TIME

Preparation: 10 minutes

Class: 30-45 minutes



This microscopic image has been modified to reveal the synaptic cleft between the axon of a nerve cell in the hippocampus (part of the limbic system needed for memory) and a receiving cell. Vesicles (small, circular objects in the axon) release neurotransmitters into the synaptic cleft.

OVERVIEW

Students conduct a simulation to demonstrate how multiple incoming signals influence the action of neurons.

CROSSING THE SYNAPTIC GAP

Most neurons in the brain communicate with each other by releasing chemical messengers called neurotransmitters. Neurotransmitters cross the gaps between neurons or between neurons and other cells, such as muscle, and match up with specific receptors. Chemical signaling between neurons allows different kinds of messages to be sent. For example, some chemical messengers stimulate neurons to fire, while other messengers make it harder for an electrical impulse to be generated in the receiving neuron. Since one neuron can share synapses with thousands of other neurons, the combined effects of different messages ultimately determine whether a signal will be triggered or not.

Many drugs interfere with communication between nerve cells. Some drugs act directly on neurons, neurotransmitters and receptors. Curare, for example, is a deadly poison used by South American Indians. It causes death from paralysis by blocking receptors on muscle cells. Since the receptors are blocked, the real chemical messenger for muscle contraction (acetylcholine) can no longer stimulate the muscles to contract.

Drugs also can interfere with communication between neurons in other ways, such as by preventing the manufacture or release of neurotransmitters, by causing excessive firing of neurons by stimulating massive releases of neurotransmitters, by mimicking the effects of chemical messengers, or by preventing the normal breakdown and recycling of chemical messengers.

This activity will help students learn about the relationships between chemical messengers, receptors and the actions of common chemicals in alcoholic beverages, cigarettes and illicit substances on brain functions.

MATERIALS

Teacher (See Setup)

- 6 sheets of card stock
- Document projector (or overhead projector and transparency of “Transmitters & Receivers,” page from the activity, “What Is a Neuron?”

Per Group of Students

- 1 square, 6-sided, numbered die
- Prepared set of “Brain Chemical” cards

Per Student

- Copy of “Fire Those Neurons!” student page



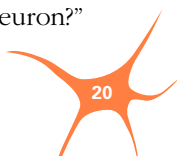
UNIT LINKS

Legacy of Lost Canyon

Chapter 8
Science boxes, p. 22, 25

Brain Chemistry Explorations

“Think About It,” p. 8



COMMONLY ABUSED DRUGS

ALCOHOL depresses the central nervous system (brain and spinal cord). It causes slowed movements, loss of balance and sleepiness by enhancing the activities of several neurotransmitters that inhibit neuron firing. Alcohol affects neurons in many parts of the brain, which explains why it has numerous effects on thinking and movement. Even one drink may cause poor judgment and unrealistic estimations of risk.

INHALANTS damage or destroy the myelin sheath that insulates nerve axons. Without myelin, nervous system signals to muscles are disrupted. This loss leads to tremors and muscle spasms. In addition, inhalants can cause irregular heart rhythms leading to heart failure and even death or can cause death by filling the lungs

with poisonous substances instead of oxygen.

NICOTINE stimulates the activity of neurons in many parts of the brain and nervous system. It causes increases in blood pressure and heart rate, faster respiration, narrowing of arteries and stimulation of the central nervous system. It also stimulates the release of a neurotransmitter (dopamine) in the part of the brain related to addiction and pleasure.

COCAINE is a strong central nervous system stimulant that interferes with the reuptake of dopamine, a neurotransmitter associated with pleasure and movement. Dopamine is released as part of the brain's reward system and is involved in the "high" that characterizes cocaine consumption.

DRUGS AND THE NERVOUS SYSTEM

Research on how drugs affect neurons has led to improved medicines and to better understanding about how drugs of abuse act on the nervous system.

- **Fluoxetine** (Prozac) blocks the reuptake of the neurotransmitter serotonin and keeps it active in brain circuits related to emotional states. Fluoxetine and similar drugs are used to treat depression.
- **L-Dopa**, an important drug for treating the muscle tremors of Parkinson's disease, supplies raw material for the neurotransmitter dopamine.
- **Marijuana** contains a substance (THC) that connects to receptors on neurons in parts of the brain that influence pleasure, memory, thought, concentration, sensory and time perception, and coordinated movement.
- **MDMA** (Ecstasy) increases the activity levels of serotonin and other neurotransmitters in the brain. MDMA is linked to long-term damage of parts of the brain critical for thought, memory and pleasure.
- **Morphine** and **Heroin** mimic chemical messengers that trigger brain pathways responsible for pleasure and blocking pain. With regular heroin use, tolerance develops. This means that the abuser must use more of the drug to achieve the same effect—eventually leading to addiction.

SETUP

Make six photocopies of "Brain Chemical Cards" on white card stock. Cut out the cards to make six sets of the four different cards. Each group should receive one set of cards. Make 24 photocopies of the "Fire Those Neurons!" page (one per student). Have students conduct this activity in groups of four.

PROCEDURE

1. Review the steps in nervous system communication that students learned while playing "Locks & Keys" (see the activity, "Message in a Neuron"). Tell students that they will be simulating what happens when chemical messengers, or neurotransmitters, go from one neuron to the next. Point out that most neurons can receive messages from many other neurons. Some of these messages "stimulate" or cause firing, other messages "inhibit" or prevent firing. Neurons "decide" to fire or not depending on the kinds of messages they receive.
2. Distribute a copy of "Fire Those Neurons!" to each student.
3. Students in each group will take turns rolling a die twice. The first roll will determine how many incoming signals excite the neuron to fire. The second roll will determine how many signals inhibit firing (or have students use two different colored die and roll them together). During each trial, students should subtract the second

Continued



HELPFUL CHEMICALS: MEDICINE

Diseases such as depression, anxiety and schizophrenia often are treated with medicines that affect one or more steps in the synthesis, release or breakdown of certain neurotransmitters. In fact, learning how these drugs work has provided insight into the mechanisms in the brain underlying these disorders.

- number from the first. If the outcome is zero or a positive number, the neuron will “fire” or pass the message. If the outcome is a negative number, the neuron will not fire. Have students conduct at least four trials, so that each student collects data on his or her sheet.
4. Conduct a class discussion of the results of the model thus far. Ask, *Did it matter how many “stimulating” messages were present for firing as long as the number was greater than the “stopping” or “inhibiting” messages?* Point out that the firing of a neuron is like turning on a light switch—either an impulse is created or it is not.
 5. Tell students that they will be conducting another round of the simulation. This time, however, give each student a “Brain Chemical” card with additional instructions for each trial. Have students take turns investigating the effects of each brain chemical. As they progress through the simulation, students will discover that the drugs have changed the patterns of neuron firing.
 6. After students have completed the second round, ask, *Did you receive different results this time? Did the neurons fire more or less often? Did the responses of the neurons change over time?* Help students conclude that each of the chemicals on the Brain Chemical cards changes the way neurotransmitters work. In addition, at least two of the examples (cocaine and inhalants), cause changes in neurons. Revisit the neuron diagram (“Transmitters & Receivers,” from the activity, “What Is a Neuron?”) to find the places affected by these chemicals.
 7. Conduct a class discussion to help students correlate the effects of drugs on the nervous system to physical or behavioral changes that can be observed or felt. Detailed information about the substances listed on the “Brain Chemical” cards are given in the box, “Commonly Abused Drugs,” (p. 21). For additional information on other substances, read “Drugs and the Nervous System” (sidebar, p. 21).

EXTENSION

Encourage students to learn more about how different chemicals affect the brain by conducting research in the library on the Internet. A good place to start is the National Institute on Drug Abuse, National Institutes of Health, at www.nih.nida.gov and teens.drugabuse.gov/.



FIRE THOSE NEURONS!



Can chemicals change neuron communication? You will investigate this question by simulating how a neuron processes many incoming messages. Messages can signal a neuron to fire (a stimulating signal) or make it harder for a neuron to fire (an inhibiting signal).

ROUND 1

- Roll the die 2 times. The first number you roll will tell you how many incoming messages stimulate the neuron to signal other neurons. The second number you roll will tell you how many incoming messages tell the neuron not to fire.

Subtract the second number from the first. If the answer is zero or a positive number, your neuron is activated and it fires (sends a message to other neurons). If the answer is a negative number, then the neuron does not fire.

- After 10 trials, count the number of times the neuron was activated and fired. Write the number in the box.

ROUND 2

- You have been given a Brain Chemical card with additional instructions. Read the card and predict whether the brain chemical described on your card will increase or decrease neuron firing. Record your prediction on the back of this sheet.

- Roll the die as you did for Round 1, but make additions or subtractions to the numbers you roll, as directed by the instructions on the card.

- After 10 trials, count the number of times that the neuron was activated and fired. Write the number in the box.

- Card investigated: _____

How were the Rounds similar? How were they different? To what do you attribute the differences? Were there any changes in the pattern of neuron firing from Trial 1 to Trial 10 in either round? Write your answers on the back of this sheet.

Trial	Number of Stimulating Signals	Number of Stimulating Signals	Result
1		–	=
2		–	=
3		–	=
4		–	=
5		–	=
6		–	=
7		–	=
8		–	=
9		–	=
10		–	=

Trial	Number of Stimulating Signals	Number of Stimulating Signals	Result
1		–	=
2		–	=
3		–	=
4		–	=
5		– =	
6		–	=
7		–	=
8		–	=
9		–	=
10		–	=





BRAIN CHEMICAL CARDS

A L C O H O L



Trials 1 through 10

Add 2 to the second number (inhibiting signal) you roll during each trial.

Causes slower movements, sleepiness and loss of alertness, because it makes it harder for some neurons to fire.

N I C O T I N E



Trials 1 through 5

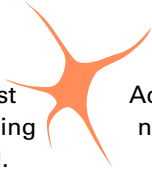
Add 2 to the first number (stimulating signal) you roll.

Trials 6 through 10

Add 1 to the first number (stimulating signal) you roll.

Acts like a neurotransmitter that stimulates neurons to fire. Over time, neurons adjust and the nicotine is less effective.

C O C A I N E



Trials 1 and 2

Add 6 to the first number (stimulating signal) you roll.

Trials 3 and 4

Add 2 to the first number you roll.

Trials 5 and 6

Do not add or subtract any numbers.

Causes a build-up of neurotransmitters and a temporary increase in neuron firing, particularly in the part of the brain related to feelings of pleasure. However, neurons adjust so that neurotransmitters become less effective and the pleasure is no longer felt as intensely.

Trials 7 and 8

Add 2 to the second number (inhibiting signal) you roll.

Trials 9 and 10

Add 6 to the second number (inhibiting signal) you roll.

I N H A L A N T S



Trials 1 through 10

Add 5 to the second number (inhibiting signal) you roll during each trial.

Permanently damages the myelin sheath, which insulates the axons of neurons. When myelin is destroyed, signals cannot get through to muscles.



OVERVIEW

Students will describe a stressful situation and how their bodies responded to it.



HORMONES AND STRESS

Stress is a common human condition. Most of us can recognize the symptoms: feelings of nervousness, sweating of the palms of the hands, pounding of the heart, or a dry mouth. These are signs that the body is preparing for a difficult situation in which survival may be at stake. Remarkably, our bodies' reactions to stress are controlled by the

brain. Immediate stress responses are directed through pathways in the brainstem and spinal cord to the major internal organs of the body. However, chemicals circulating in the bloodstream also help prepare the body to handle a crisis. The brain coordinates the release of these chemicals, which belong to the family of messengers known as hormones.

Unlike the chemical messengers between neurons (neurotransmitters), hormones can have wide-reaching effects on many dif-

ferent body tissues at the same time. Hormones, which circulate in the bloodstream, act as messengers to the nervous system and other tissues in the body. They act only on cells that have compatible receptors.

Hormones have many vital functions in mammals, such as regulating digestion; controlling the metabolism of sugars, proteins and fats; and regulating growth and development. Many of our most basic drives—sleeping, hunger, thirst, sex—are regulated through hormones.

The master control system for all hormones is located within the brainstem. Known as the hypothalamus, this small structure interconnects with many regions of the brain. It is adjacent to the pituitary gland, which produces hormones that control other glands in the body. Together, the hypothalamus and the pituitary gland regulate many different body functions. During periods of stress, these tiny structures direct the two small adrenal glands near the kidneys to produce hormones, such as adrenaline (also called epinephrine), that prepare the body for action.

MATERIALS

Per student

- Copy of “Fight or Flight?” student sheet

SETUP

Photocopy the student page (one per student). Begin this activity as a

CONCEPTS

- The brain coordinates the release of chemicals, called hormones, that affect many different tissues at the same time.
- The reaction to stressful situations is mediated by hormones.
- Stress can harm health.

SCIENCE & MATH SKILLS

Observing, sequencing and interpreting

TIME

Preparation: 5 minutes

Class: 45 minutes

STRESS AND LEARNING

Changes in the nervous system and body during times of stress make it harder for the brain to learn. Students who are stressed because of circumstances inside or outside of school can have difficulty learning or paying attention in class.

ENDOCRINE TISSUES

Endocrine tissues produce and release hormones. The word, endocrine, comes from the Greek *endo* (meaning within) and *krinein* (meaning to secrete). Hormones are released directly into the blood.



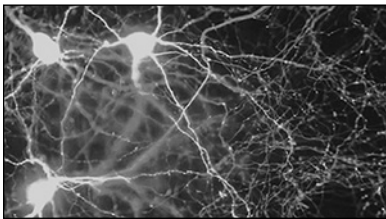
Continued

THE HYPOTHALAMUS

Located just above the brainstem, the hypothalamus produces hormones that control many body functions.

- Body temperature
- Hunger
- Moods
- Release of hormones from many glands, especially the pituitary gland
- Sex drive
- Sleep
- Thirst

A BALANCE OF HORMONES



Special neurons in the hypothalamus region, like the three shown above, release hormones associated with high calorie intake and lower energy levels. Other neurons in the hypothalamus release hormones that act in direct opposition, thereby providing clues as to how the brain controls our food intake and sleep patterns.

discussion with the entire class. Have students work individually for the writing portion of the activity and in groups of four to share results and brainstorm stress-reducing solutions.

PROCEDURE

1. Ask students, *Have you ever been in a situation in class where you felt nervous, when perhaps your heart was pounding and your hands became sweaty? Why do you think that you felt the way you did?* Encourage students to share a few experiences.
2. Distribute the “Fight or Flight?” student sheets. Ask students to think of a stressful situation that has happened in class and to describe it under Item 1 on the sheet.
3. After students have finished writing, ask, *Did any of you have a hard time thinking of a class situation that was stressful? Why might that be?* Next, ask, *Why do you think your body responded the way it did to the stress you were feeling?* Help students understand that their bodies were preparing to react to a possibly difficult situation. Ask, *How did your body know that the situation might be stressful?* Lead students to understand that their brains used information coming from their senses and information retrieved from memory to evaluate the situation.
4. Mention that stress is a reaction by many different parts of the body to help an organism survive. Ask, *Can you think of any situations that might be stressful for an animal in its natural surroundings? How might an animal react in a dangerous or other stressful situation?* Help students understand that under stress, the body experiences many changes very rapidly. These changes include an increase in blood pressure and fuel for the brain, and a partial shutdown of body systems (such as the digestive system) not needed for fighting or running. Mention that all of these changes are managed by the brain, both directly through the brainstem and spinal cord, and indirectly, by controlling chemical messengers, such as the hormone adrenaline, that circulate in the blood to many parts of the body. This process sometimes is called the “fight or flight” response. Ask, *When do you think it might be important for humans to be able to respond quickly and efficiently?*
5. Mention that, while these reactions sometimes can improve performance by the body, there are many situations in life in which the “fight or flight” reaction to stress can be unhealthy. For example, high blood pressure can harm the heart and circulatory system over time.
6. Place student into groups of four. Then, direct students to share the stressful experiences they described for Item 1 within their groups. After students have discussed what they wrote, ask, *Was there anything you could have done to make the scenarios you described less stressful?*
7. Have each group share some of the stress-reducing strategies they devised. List the strategies on the board. Ask, *Do you think any of*

these strategies will work for situations outside of school? Allow students to share their ideas. If not mentioned by students, you might want to discuss general stress-reducing strategies, such as being prepared in advance for tests, homework assignments, etc.; allowing adequate time to finish tasks; planning for situations in advance; learning to recognize potentially stressful social situations and finding an appropriate response; creating a mental picture of a successful outcome; and breathing slowly and deeply. Point out that, since the brain interprets and controls the stress reaction, certain things can be done to reduce stress.

8. Have each student complete the second question on his or her “Fight or Flight?” sheet.

EXTENSION

Different species of animals react differently to dangerous situations. Some animals flee, while others become motionless so that they blend into the background. Some look for a safe place to hide, and still others wait for an opportunity to fight. Have students investigate the habits and lifestyles of various animals to learn how the animals react to life-threatening scenarios, and how the responses are related to 1) each animal’s specific characteristics (fast runners, good fighters, etc.), and 2) the characteristics of the environments in which they live.

REACTIONS TO STRESS

During periods of stress, the brain shuts down some bodily functions, such as digestion. In addition, there is an increase in the amount of glucose (an important fuel for the brain) and amino acids (necessary to repair damage to muscles) in the blood. Blood pressure becomes elevated. All of these changes can help an animal, including a human being, deal with a life-threatening situation. However, they are not healthy on a long-term basis.

CHRONIC STRESS

Continuous periods of stress can cause a number of health problems, including high blood pressure, diabetes, and arthritis. Chronic stress also can trigger depression or anxiety and may cause damage to various regions of the brain, including those that are important for learning and memory.





FIGHT OR FLIGHT?

Stress causes a number of changes in the body when it prepares for a difficult situation. While some reactions to stress are good, continuously stressful circumstances can damage the body over time.

1. Think of a recent situation in class in which you felt stressed or worried. Describe the event and how your body responded to it.

2. Could the stress associated with the situation you described above have been avoided? Why or why not? Explain your answer. Use a separate sheet of paper if necessary.



OVERVIEW

Students will estimate risks associated with different events and compare their estimates to the real probabilities.

DRUGS, RISKS AND THE NERVOUS SYSTEM

People perceive risks differently, depending on the nature of the risk and their individual experiences. Risk perceptions are strongly influenced by issues of choice and control; risks often seem “riskier” to people if they have not voluntarily chosen to bear them. Conversely, people are more willing to accept or ignore risks that they choose voluntarily, especially if the immediate benefit seems to outweigh the potential for negative outcomes much later in time. In the case of chemical substances that affect the brain, the risks can be very high indeed.


It is important to note that most people begin to use brain-altering chemicals voluntarily. Over time, however, the brain and body may adapt to the effects of a chemical. This can create a new “normal” state, adjusted to the presence of the introduced substance. This adaptation may lead to a physical dependence on the substance,

such that the individual requires the chemical to function normally.

For example, more than 80 percent of the current US population chooses to consume the stimulant caffeine in coffee and/or cola drinks because of its taste and/or perceived enhancement of mental and physical performance. Eventually, most caffeine consumers develop a dependence on its stimulating effects and experience mild withdrawal symptoms, such as sleepiness and headaches, when they do not have caffeine. Other chemicals have more dramatic effects on the brain and body, affecting the brain’s natural reward centers, which are responsible for generating feelings of pleasure or well-being. However, feelings of euphoria, comfort or pleasure often decrease or disappear after the first few uses of the substance.

Drugs that act on areas of the brain related to sensations of pleasure are sometimes used inappropriately by people. Unfortunately, continued drug use actually changes the way the brain works. In some cases, it can cause permanent changes in the structure and function of the brain. This is the biological basis of addiction.

Many mind-altering chemicals abused by children and adults in the US lead to permanent changes in the brain that lead to addiction, and also may cause damage to other parts of the body. Marijuana use can alter memory regions of the brain and affect coordination and the senses in



UNIT LINKS

Legacy of Lost Canyon
Chapter 10

Brain Chemistry Explorations
“How Risky Is It?” p. 8
“Careers for NeuroExplorers,”
p. 6

CONCEPTS

- Perception of risk is affected by issues of personal choice and control.
- Many chemicals influence the function of the nervous system.
- Health risks associated with tobacco, alcohol and other drugs of abuse often are underestimated.

SCIENCE & MATH SKILLS

Predicting, sorting and classifying, comparing, sequencing, inferring and understanding probability

TIME

Preparation: 10 minutes

Class: 45 minutes

ADOLESCENTS AND RISKY BEHAVIOR

Adolescents commonly take more risks than younger children and adults do, but not because they are attracted to danger. Rather, adolescents are simply more willing than other age groups to accept risks when consequences are unknown. A recent study showed that when risks are precisely stated, adolescents avoid them as much—if not more—than adults do.

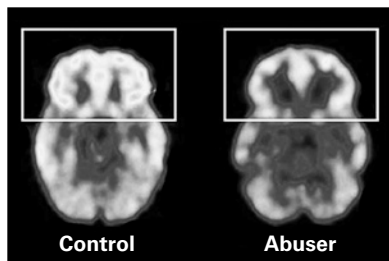
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CHEMICALS FOR BETTER HEALTH

Studies on how chemical messengers work within the nervous system hold promise for unraveling many basic questions about the actions of drugs and the causes of some diseases. Almost all drugs that influence the way the brain works do so by altering the transmission of chemical messages. This influence can have important medical applications for the treatment of severe pain or illnesses such as schizophrenia or depression. Some medicines used to treat depression, for example, act on chemical messengers involved in regulating sleep and body temperature. Morphine, a potent pain medication, mimics the effects of a natural chemical messenger found in brain pathways involved in minimizing pain and producing a sense of well-being.

SEEING ADDICTION IN THE BRAIN



Drug addiction compromises the brain circuits involved in processing reward and punishment, and in exerting control over one's actions. The MRI scans above show what happens in the brain when drugs are abused. On the left is a scan of a normal brain. Notice the bright areas of activity. The scan on the right is of a person who is abusing cocaine. The large dark areas show the loss of neuronal activity. This loss can be reversed if an abuser stops taking the drug.

the short term. Heroin changes the way nerve cells in the brain receive and process messages. Inhalants, which are taken up by fatty tissue in the body, damage or destroy the fat-containing myelin sheath on nerve cell axons and disrupt nervous system communications, sometimes permanently. LSD can contribute to the development of chronic mental disorders. Alcohol, which depresses physical and mental abilities, damages many tissues throughout the body, including the liver and the brain. Alcohol also is a major contributing factor to automobile accidents because it affects coordination and judgment. Nicotine, a stimulant in tobacco, is a very addictive substance that can damage the circulatory system. However, the greatest health risk from smoking comes from other compounds in cigarette and cigar smoke that are linked to development of lung and other cancers.

MATERIALS

Per Group of Students (See Setup)

- Roll of clear tape, 0.5 in.

Per Student

- Pair of scissors

- Sheet of paper, 8.5 in. x 11 in.
- Copy of “What Are the Odds?” and “The Risks Are Real” student pages

SETUP

Make photocopies of the student pages (one set for each per student). Begin with a class discussion, followed by students working in groups of four to complete the activity.

PROCEDURE

1. Begin with a class discussion of the previous activity in which students simulated the effects of chemicals on neuron signaling. Ask, *What are examples of substances that change the way the brain works or how a person feels?* Give students time to think of some of the most common examples, such as alcohol, coffee and soft drinks with caffeine, cigarettes (nicotine), marijuana, inhalants (“sniffing” glue, paint or aerosols), etc.
2. Follow by asking, *Do you think people evaluate possible health risks when they take a substance that affects the brain? Why or why not? Do you think they should?*
3. Tell students that one way to quantify risk is to state it as a probability that something will occur. For example, when students rolled a die in Activity 4, they had a one in six chance of rolling a “two” on any given toss because the die has six sides. Explain that by studying how frequently events have happened in the past, scientists and statisticians have been able to calculate the risk of many different types of occurrences.
4. Give each group of students a copy of the “What Are the Odds?” page and have them read all of the statements. Have students cut the statements into strips (so that they can be rearranged easily). Next,

ABUSE OR ADDICTION?

There is a difference between drug abuse and drug addiction. Drug abuse involves any illicit use of a substance, including nonmedical use of prescription drugs. Drug addiction is a chronic, relapsing disease characterized by compulsive drug seeking and use despite harmful consequences, as well as neurochemical and molecular changes in the brain.

People abuse drugs for many reasons. Sometimes, it is because drugs produce feelings of pleasure, or because they remove feelings of stress and emotional pain.

Over time, the body can become “used” to a drug, causing severe withdrawal symptoms when the substance is removed. People who are physically dependent on a drug continue to use it to avoid the pain of withdrawal, not because they derive any pleasure from the experience.

HISTORICAL AND CULTURAL DRUG USE

Anthropologists have uncovered ancient uses of mind-altering substances for medicinal and ritualistic purposes in cultures around the world.

The use of the substances in ritualistic practices was strictly controlled by community leaders and involved plant-based medicines that were less refined and often less potent than many of the drugs used today.

have students discuss within their groups how likely it is that each event will occur.

- Students should rank the events numerically, from most likely to occur to least likely. The number “1” should be given to the most likely event. Have students place the strips in order of likelihood from most risk (top) to least risk (bottom). You may want to provide tape and a separate sheet on which students can arrange and secure their strips.
Note. Tell students that some items have the same odds.
- Discuss students’ predictions briefly by asking which events they placed at the tops and bottoms of their lists. Let each group share some of its predictions and the reasoning behind the choices. Allow student groups to rethink or revise their predictions based on the discussion.
- Distribute a copy of “The Risks Are Real” page to each group and ask students to compare their predictions to the actual risk calculations.
- Conclude by discussing the actual risks as compared to students’ predictions. Ask guiding questions such as, *Which ranking surprised you the most? Which were you able to predict most accurately? Do you think you or any of your friends might be ignoring long-term risks because you are making choices based on short-term benefits?*





WHAT ARE THE ODDS?

Read the statements below. Cut the statements into strips and place the events in order from most likely (top) to least likely to occur (bottom). Rank the statements numerically, assigning "1" to the most likely event. Keep in mind that some items are equally likely, so they will share the same number.

Being born left-handed

Living to the age of 116 years

Being killed by a shark

Picking all 5 winning numbers in a lottery (total of 49 numbers)

Quitting smoking successfully without any help

Becoming addicted to caffeine if you regularly drink caffeinated coffee, tea or soft drinks (such as cola)

Being electrocuted

Becoming a professional basketball player if you play basketball in high school

Becoming addicted to nicotine if you smoke cigarettes

Being involved in an alcohol-related car accident

Having poor driving skills after smoking one marijuana cigarette

Being killed by falling out of bed

Permanently damaging the myelin sheath on nerve cells in the brain by "sniffing" paint or glue

Dying from influenza (the flu)

Being pressured by a friend to smoke or use alcohol

Having a fatal accident while playing sports

Becoming dependent on crack or cocaine, if injected

Dying of a smoking-related illness if you start smoking as a teenager



THE RISKS ARE REAL



These are the real odds for the events you ranked, from most likely to occur to least likely. Compare the odds to your rankings. Surprised?

1. Having poor driving skills after smoking one marijuana cigarette	1 in 1
2. Becoming addicted to caffeine if you regularly drink caffeinated coffee, tea or soft drinks (such as cola)	1 in 1.25
3. Becoming addicted to nicotine if you smoke cigarettes	1 in 2
3. Permanently damaging the myelin sheath on nerve cells in the brain by “sniffing” paint or glue	1 in 2
4. Being pressured by a friend to smoke or use alcohol	1 in 3
4. Being involved in an alcohol-related car accident	1 in 3
4. Dying of a smoking-related illness if you start smoking as a teenager	1 in 3
5. Becoming dependent on crack or cocaine, if injected	1 in 4
6. Being born left-handed	1 in 10
7. Quitting smoking successfully without any help	1 in 10
8. Dying from influenza (the flu)	1 in 5,000
9. Becoming a professional basketball player if you play basketball in high school	1 in 10,000
10. Having a fatal accident while playing sports	1 in 25,000
11. Being electrocuted	1 in 350,000
12. Picking all 5 winning numbers in a lottery (total of 49 numbers)	1 in 1,953,393
13. Being killed by falling out of bed	1 in 2 million
14. Being killed by a shark	1 in 300 million
15. Living to the age of 116 years	1 in 2 billion

Compiled from public domain statistics made available by the National Institutes of Health, Center for Substance Abuse Prevention, National Clearing House for Alcohol and Drug Information, American Cancer Society, CareerQuest and Dartmouth University.



CONCEPTS

- The brain needs many different kinds of raw materials from food.
- Breakfast is important.
- Recommended serving sizes are often smaller than the size actually served or the amounts people eat.

SCIENCE & MATH SKILLS

Observing, recording, inferring and drawing conclusions

TIME

Preparation: 30 minutes (to bake and cool pizza)

Class: 45 minutes for pizza dissection and class discussion

THE BRAIN NEEDS BREAKFAST

According to the American Dietetic Association, it is important for children to start their days with a healthy breakfast. In general, children who regularly eat breakfast perform better in school, and may even score higher on tests. Breakfast eaters have better attendance records and fewer behavior problems in school. They concentrate better, solve problems more easily and have better muscle coordination. Also, students who eat breakfast are less likely to be overweight.

OVERVIEW:

Students will learn about nutrients important for health by dissecting a slice of pizza.

FOOD FOR THE BRAIN

The brain needs many different kinds of nutrients. Glucose, a kind of sugar, is the main source of energy for the brain. While all carbohydrates can serve as sources of glucose, some are better than others. Breads, pastas, cereals and other foods made with whole grains provide the brain with steady supplies of glucose. Foods that contain white sugar or corn syrup, white rice, white flour (found in white bread and most cakes, crackers and cookies) and other refined carbohydrates also supply energy. However, they cause glucose levels in the bloodstream to rise rapidly and then crash.

Proteins from food provide the amino acids used to make neurotransmitter molecules. Meat, fish, poultry, dairy products, eggs and beans (including soy beans) are good sources of proteins. The cell membranes of neurons are made of fats. The healthiest fats are liquid at room temperature. Olive, flaxseed and canola oils are examples of healthy fats. In addition, oils from coldwater fish, such as mackerel, salmon and trout are good sources of a kind of fat needed to build cell membranes in the brain.

Minerals such as calcium, sodium and potassium are vital for the generation and conduction of electrical impulses in neurons and are involved in the release of neurotransmitters from axon terminals. Vitamins are essential molecules needed in small amounts by cells throughout the body, including neurons. For example, choline, a vitamin found in egg yolks and leafy green vegetables, is the basis for the chemical messenger, acetylcholine, that transmits signals to muscles.

The diets of many adolescents are high in sugars and unhealthy fats. In addition, the “supersized portions” of snack and fast foods eaten by many students supply too many calories. Calories measure the amount of energy provided by food. They can be obtained from the breakdown of many different kinds of molecules, particularly fats, carbohydrates and proteins. The body needs a certain amount of calories each day as fuel.

Excess calories are stored as body fat. Unfortunately, even though many American children consume several times the amount of calories they actually need, they are not supplying their bodies with nutrients needed for optimum growth and development.



UNIT LINKS

Legacy of Lost Canyon

Chapter 11
Science box, p. 13

Brain Chemistry Explorations

“Fueling the Signals,” p. 4

FOOD AND HEALTH

- A child's brain grows rapidly before birth and for about two years after birth. Malnutrition during these periods can affect development of the nervous system.
- Chocolate contains about 380 chemicals. Some of these are stimulants, which may make you feel more alert. Other chemicals in chocolate may affect the pathways of neurotransmitters related to feelings of well-being.
- Vitamin A deficiencies can lead to night blindness (inability to adjust from light to dark environments) and other vision problems. Vitamin A is found in yellow and orange vegetables, dairy products and beef liver.

WHAT IS IN FOOD?

CARBOHYDRATES, a major source of energy, are found in fruits, vegetables and grains (including flour). Fiber, starches and sugars are carbohydrates. Most US students tend to eat too many snacks and prepared foods that are high in refined sugars and flours.

FATS are rich sources of energy. Cooking oils, lard, butter, margarine and shortening are almost pure fat. Foods that contain large amounts of fat include some red meats, bacon, dairy products, chocolate, cakes, cookies, fried snacks (chips, crackers, etc.) and nuts. Fatty foods should be eaten sparingly, because the body will store any unused energy as additional body fat. Fats from plants (like olive or canola oil) or fish generally are healthier than butter, fatty meat or lard.

PROTEINS are building blocks for the body. Muscles, hair, skin and nails are mostly protein, as is the flexible collagen network within bones. Proteins

help to carry out essential chemical reactions within every cell. The body can use protein as a source of energy. Lean meats, fish, poultry, eggs, low-fat dairy products, beans, peas and nuts are good sources of protein.

VITAMINS are substances needed by the body in small amounts. Vitamin C is necessary for the development of connective tissue and helps to prevent cell damage. Vitamin A is important for vision. Eating a variety of fruits and vegetables every day helps ensure that the body has the vitamins it needs.

MINERALS have many roles. Calcium, the most abundant mineral in the body, makes bones hard and is important in muscles and the nervous system. Good sources of calcium are low-fat dairy products, dark green leafy vegetables, tofu, sardines with bones and calcium-fortified juices and cereals.

DID YOU KNOW?

Fats account for more than half of the dry weight of the human brain.

This activity is designed to promote student awareness of portion sizes, nutrient content of food, and the brain's nutritional needs.

MATERIALS

Per Group of Students (See setup)

- 2 craft sticks
- 18-in. sheet of wax paper
- Prepared and cooled slice of frozen "supreme" pizza
- Copy of "Dissect That Pizza!" sheet

Per Student

- Copy of the "Nutrition Facts"

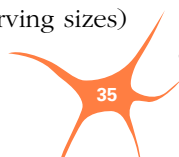
label from the pizza package

- Copy of the student sheets
- Optional:** Demonstration
- 2 slices of cheese
 - Apple or orange (medium)
 - Cup of raw, chopped carrots
 - Deck of cards
 - Slice of sandwich bread
 - Teaspoon of margarine

SETUP

Before class, bake one or more medium or large frozen pizzas with mixed or "supreme" toppings. Let the pizzas cool (refrigerate if necessary). Cut each pizza into the number of slices (serving sizes)

Continued



EXTENSIONS

- Encourage students to create or find recipes that include many nutrients needed by the brain. Share these with the class OR have a “Brain Food Day,” during which students (or parents) bring different foods to share in class, or prepare one or more of the students’ recipes in class.
- Have students use an online Calorie counter or App to investigate the caloric, fat and nutrient content of common fast foods.

recommended by the Nutrition Facts label on the pizza package. You will need at least one slice per group. Make one copy of the Nutrition Facts label from the pizza package for each student. Photocopy “Dissect That Pizza!” (one per group), and the remaining student pages (one per student).

Optional. If possible, bring the following items to use for demonstration with Step 2 below: 2 slices of presliced, prepackaged sandwich cheese (milk products); 1 slice of sandwich bread (carbohydrates); 1 cup raw, chopped carrots (vegetables); 1 medium apple or orange (fruit); 1 tea-spoon of butter or margarine (fats and oils); and 1 deck of cards (in place of 1 portion for meats, fish and poultry).

Have students conduct this activity in groups of 2–4.

PROCEDURE

1. Ask students, *What do you think your brain needs to function?* Students might respond that it needs some sort of food or fuel. Tell students that they will conduct an investigation of a popular food item to examine portion size and the amount and quality of brain food (or fuel) it provides.
2. Give each student a copy of the “Healthy Plates,” and “Estimates & Servings” pages. If time allows, have students complete the questions at the top of the “Healthy Plates” sheet. Discuss the portion sizes shown by the “Quick Hand Measures” and the recommendations on the “Healthy Eating Plate.”

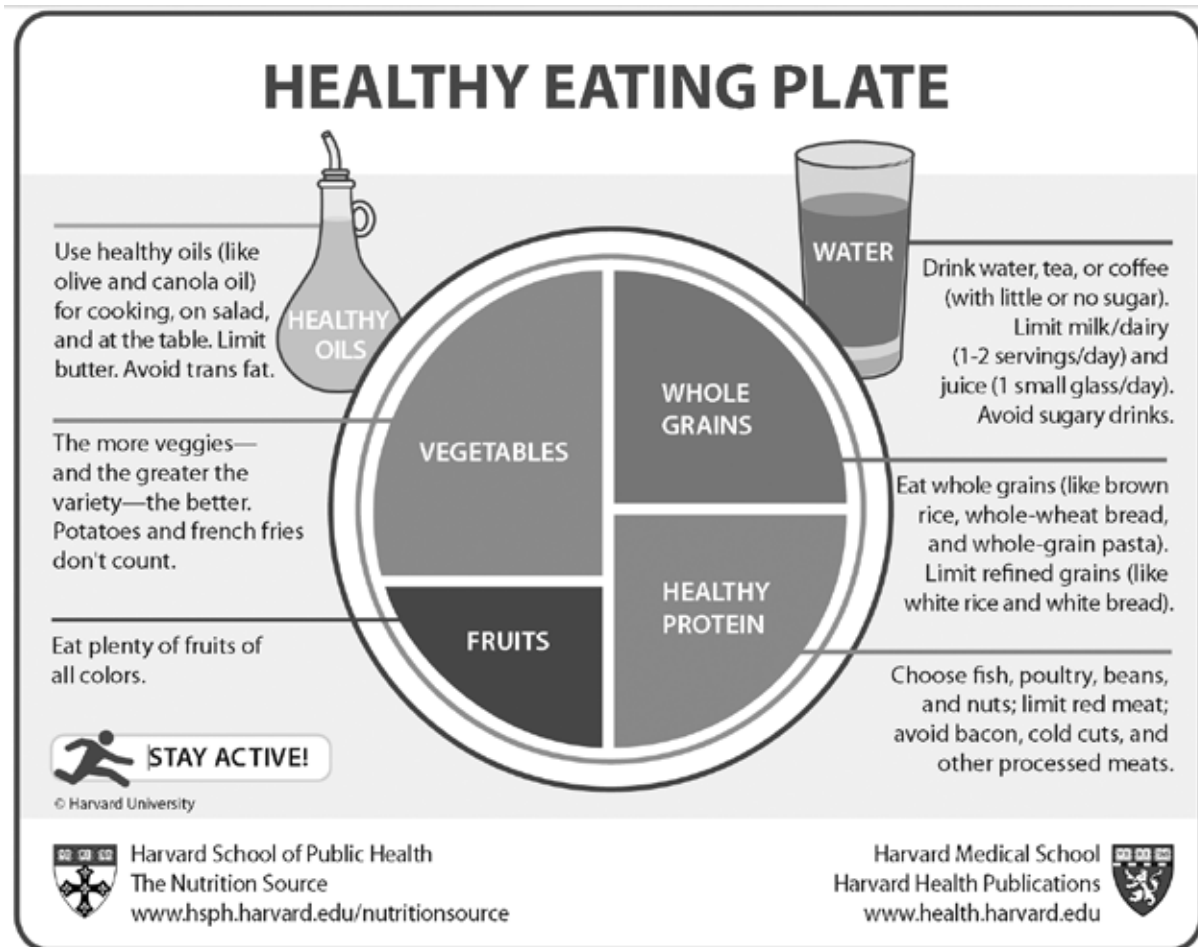
Optional. Show students actual serving size samples from each of the food groups.
3. Tell students that they are going to examine and dissect a popular food, pizza. But first, ask students, *What are the ingredients in a pizza?* Students probably will respond—crust, meat (various kinds), cheese, sauce and vegetables. Ask, *Do you think pizza is good for you or meets some of your daily nutritional requirements? Why or why not?* Record responses on the board.
4. Next, give each group of students a “Dissect That Pizza!” student sheet, a serving of pizza, a large piece of wax paper for a work surface, 2 craft sticks to use for the dissection and a copy of the “Nutrition Facts” label from the pizza package.
5. Have each group follow the directions on the student sheet and answer the questions. Next, have groups share their conclusions with the class. Ask, *How does pizza rate as a healthy food?*
6. Explain that fats and calories are only part of the story. To function at an optimal level, the brain needs specific nutrients. Give each student a copy of “Fueling the Signals” page.
7. Instruct students to write a paragraph explaining why pizza is or is not a good “brain food.” OR have students address the question, *Would you eat pizza for breakfast before an important test?*
8. Encourage students to share answers within their groups and then let each group present to the class.



HEALTHY PLATES



1. List all the foods you have eaten in the past 24 hours, by meal (including snacks), on a separate sheet of paper.
2. Compare the foods in each meal to the recommendations in the Healthy Eating Plate below. Keep in mind that many foods combine items from two or more groups.
3. On separate sheet of paper, make a chart with each food group shown in the diagram. List the foods you ate under the appropriate food groups.
4. Write an explanation of how closely the amounts and kinds of food you ate matched the recommendations in the Healthy Eating Plate.



ESTIMATES & SERVINGS

Serving sizes often are smaller than the portions we actually eat.

Look for low levels of saturated, hydrogenated and trans fats. These are unhealthy.

Cholesterol is found in foods of animal origin.

Look for foods that have more carbohydrates as fiber and fewer as sugar. Only foods from plants provide fiber.

Protein is important for muscles and growth. It is found in animal and plant foods.

Vitamins and minerals are essential for health. Calcium is important for bones and teeth.

Use this section as a guide for daily planning. The amount of calories needed by each person depends on many factors, including exercise. Foods with high amounts of saturated fats or sugars may not represent the best choices.

Refried Beans Fat Free

Nutrition Facts

Serving Size 1/2 cup (125g)
Serving Per Container 3.5

Amount Per Serving

Calories 130 Calories from Fat 0

% Daily Value*

Total Fat 0g	0%
Saturated Fat 0g	
Trans Fat 0g	0%
Cholesterol 0mg	0%
Sodium 490mg	20%
Total Carbohydrate 24g	8%
Dietary Fiber 7g	28%
Sugars 0g	0%
Protein 9g	16%
Vitamin A	0%
Vitamin C	0%
Calcium	6%
Iron	15%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

QUICK HAND MEASURES



A closed fist

=

Piece of fruit or cup of raw vegetables



Two fingers

=

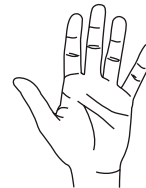
Ounce of cheese



A cupped hand

=

Cup of dry cereal



An open palm

=

Single serving of meat



Tip of thumb

=

Teaspoon of butter



Use the Quick Hand Measures to estimate the size of one serving of different foods. Use the Healthy Eating Plate to guide meal planning.

FUELING THE SIGNALS



A healthy nervous system requires many different kinds of raw materials. These raw materials come from food. Amazingly, glucose (a kind of sugar) is the main source of energy for the brain and the rest of the nervous system. Under normal conditions, the brain depends on a continuous supply of glucose provided by the blood. Have you ever felt cranky after missing a meal or had trouble concentrating on a test when you skipped breakfast? Your brain probably was running low on glucose.

High carbohydrate foods such as bread, pasta and potatoes are important sources of glucose. Your body also can manufacture glucose from proteins and other energy-rich foods. The best kinds of carbohydrates are digested slowly and provide an even supply of energy. Breads, cereals and pastas, when made from whole grains, provide healthy carbohydrates. Candy and other sugary foods actually deprive your brain of fuel because they cause glucose levels in the bloodstream to rise rapidly and then crash.

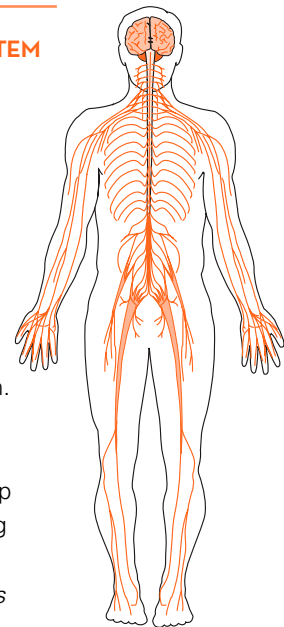
Remember the electrical signals that are carried along neurons? The signals travel through the outer membrane (covering) of nerve cells. The cell membrane is made of fats. Certain kinds of fats and oils are healthier than others. Try to avoid saturated fats (found mainly in animal products) and fats that are solid at room temperature (such as shortening, butter and lard). Instead, choose healthier fats, such as olive, flax or canola oils. Some people call fish “brain food” because oily, cold-water fish like

mackerel, salmon and trout supply a kind of fat needed to build cell membranes in the brain.

CENTRAL NERVOUS SYSTEM

Virtually all functions of the nervous system—and thus, the whole body—are based on electrical and chemical communications inside and among neurons.

The foods you eat provide fuel for your brain and the rest of your nervous system. They also supply the nutrients, such as fats, proteins and vitamins needed to keep the nervous system working efficiently. When selecting foods to eat, ask yourself, *Is this a good brain food?*



Proteins from food provide amino acids that are used to make neurotransmitters (chemical messengers between neurons). Meat, fish, poultry, dairy products, eggs and beans are good sources of protein. In addition, choline, a substance found in egg yolks, whole wheat products and leafy vegetables, is the basis for the neurotransmitter, acetylcholine, which carries signals to muscles and also is important for memory.





DISSECT THAT PIZZA!

1. You have been given one slice of pizza. Using the craft sticks provided, carefully separate the pizza slice into as many different kinds of foods as possible.
2. List each pizza ingredient in the “Food Part” column below. For example, you might find pepperoni, tomato sauce, cheese, olives, etc.
3. Use the information on the “Estimates & Servings” sheet to:
 - a. identify and record the Food Group or Groups to which each part belongs; and
 - b. estimate the Number of Servings of each food group represented by the parts of the pizza.

	FOOD PART	FOOD GROUP(S) IN WHICH IT BELONGS	NUMBER OF SERVINGS (APPROXIMATE)
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

4. Use the information listed on the Nutrition Facts label from the pizza package to fill in the blanks.
 - a. List the total number of Calories in one slice. _____ Calories
 - b. List the total number of Calories from fat in one slice. _____ Calories from fat
5. How does the serving size, listed on the Nutrition Facts label from the pizza package, compare with the serving sizes recommended by The Food Pyramid? What does this imply? Write your answer on the back of this sheet.
6. Considering all the ingredients in a slice of pizza, could it make a good breakfast? Why or Why not? Write your answer on the back of this sheet.



OVERVIEW: POST-ASSESSMENT

In this post-assessment, students will demonstrate what they have learned about brain chemistry.

BRAIN CHEMISTRY

Students will demonstrate what they have learned about brain chemistry by revisiting and revising the pre-assessment from the beginning of the unit.



UNIT LINKS

Legacy of Lost Canyon
Review all Science boxes.

MATERIALS

Per Student (see Setup)

- Notebook paper

SETUP

Have students' pre-assessment sheets ready to distribute to students. The pre-assessments should not be graded. Students will

work individually to revise their student sheets.

PROCEDURE

1. Begin with a class discussion. Encourage students to share something they have learned from this unit. Ask questions to prompt further discussion, if necessary.
2. Return the "Know Your Brain?" pre-assessments to each student.
3. Instruct students to review the statements and decide if they would like to change any responses. On a separate sheet of paper or on the back of the student sheet, have each student list the responses he or she would like to change and his or her reasoning for making the change.
4. Next, have students examine their corrected responses and identify statements that they marked as false. Instruct students to rewrite each false statement as a true statement.
5. With the class, discuss answers that students changed and the ways in which they corrected the false statements.

EXPLANATION FOR FALSE STATEMENTS

- | | |
|--|--|
| 4. More than 100 different chemicals, neurotransmitters, have been identified. | 16. Nicotine is one of the most addictive substances in common use. |
| 7. Neuroscience is a constantly evolving field of science with many new discoveries every year. | 17. Judgment and planning functions of the cerebrum develop throughout adolescence, later than many other functions. |
| 11. There are more than 10,000 different kinds of nerve cells. | 18. The cerebrum is responsible for many functions, including thinking, learning and memory. |
| 13. Addiction is a disease caused by changes in the brain and characterized by an overwhelming need to use a drug. | 21. Neurotransmission involves chemical messengers that transmit signals between neurons. |

CONCEPTS

- The human brain is complex.
- Messages within the brain and the rest of the nervous system are conducted by cells called neurons.
- Drugs and other substances can interfere with or modify the transmission of messages between neurons.

SCIENCE & MATH SKILLS

Summarizing ideas and presenting results

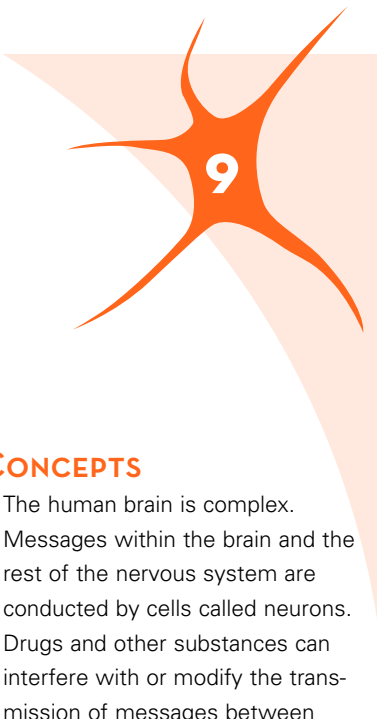
TIME

Preparation: 10 minutes

Class: 30-45 minutes

EXTENSION

Have students write a letter to an anonymous teen, explaining the consequences of abusing drugs.





GLOSSARY

addiction - a disease characterized by changes in the structure and workings of the brain, caused by prolonged use of habit-forming drugs; addiction involves a compulsive need to use a habit-forming drug, loss of control over the amounts of the drug taken, and an intensive craving for the drug when it is not available.

adrenaline or epinephrine - hormone that prepares the body for action.

anatomy - the structure (both inside and outside) of a person, plant or animal.

archaeologist - a scientist who studies the remains of past human life.

axon (or nerve fiber) - long-tailed branch of a neuron along which outgoing signals are transmitted to other cells.

brain - the control center of the central nervous system, located within the skull and attached to the spinal cord; the command center of the body.

brainstem or brain stem - structure that connects the rest of the brain to the spinal cord and controls automatic body functions, such as breathing, heart rate, blood pressure, body temperature and digestion.

cell - the smallest unit of life that is capable of functioning on its own and of which all living things are composed; tiny living unit surrounded by a thin layer (membrane).

cerebrum - the top area of the brain, composed of two hemispheres connected by the corpus callosum, where thinking, learning, memory and decision-making occur.

cerebellum - part of the brain located directly behind the brainstem that controls the sense of balance and helps the muscles work together for learning and coordination of rote movements.

cerebral cortex - the outer layer of nerve cells surrounding the cerebral hemispheres.

corpus callosum - thick bundle of nerve fibers connecting the two cerebral hemispheres.

cytoplasm - jelly-like substance in a cell enclosed by the cell membrane.

dendrite - one of many tree-like branches extending from the body of a neuron, on which signals are received.

depression - a brain disorder characterized by feelings of sadness, despair, hopelessness and low self-esteem, and sometimes accompanied by other symptoms, such as loss of appetite and energy.

disease - sickness; a condition that interferes with the normal function of some part or parts of the body, caused by environmental factors, microbes or inherited conditions.

drug - substance which may have medicinal, intoxicating, performance enhancing or

other effects when taken or put into a human body or the body of another animal.

fiber - a thread or threadlike part; sometimes used to describe an axon.

glia or neuroglia - cells that form myelin; surround neurons and hold them in place, supply nutrients and oxygen to neurons, insulate one neuron from another, destroy pathogens and remove dead neurons.

gyri - raised area or bumps in the cerebral cortex.

hippocampus - a seahorse-shaped structure found in each temporal lobe of the brain; participates in the processing and formation of long-term memories (hippocampi, plural).

hormone - chemical messenger that circulates in the blood stream and can affect many different tissues of the body, including the nervous system, at the same time.

hypothalamus - small structure within the brainstem that helps regulate a wide range of body functions; works with the pituitary gland.

limbic system - a number of interconnected brain regions involved in emotion, behavior, motivation, long-term memory and the sense of smell; highly interconnected with the brain's pleasure center, which plays a role in sex and the "high" derived from recreational drug use.

motor neuron - a type of nervous system cell, originating in the brain or the spinal cord, that sends impulses which cause movement.

muscle - body tissue consisting of cells that contract and produce motion when stimulated.

myelin - fatty substance that forms a thick sheath around the axons of some nerve cells.

nerve - bundle of neuron fibers.

nerve ending - the terminal structure of an axon.

nerve impulse - an electrical signal that travels along an axon.

nervous system - the brain, spinal cord and network of nerves in the body.

neurology - a branch of medical science that deals with the nervous system.

neuron (or nerve cell) - a cell of the nervous system that is specialized to receive and transmit information.

neuroscience - a branch of science related to research on the nervous system.

neurotransmitter - chemical messenger that transmits signals between neurons; neurotransmitters are released from the axon of one neuron, cross the synaptic cleft (tiny gap) between neurons and bind to special receptors on a dendrite or the cell

body of a second neuron.

nucleus - membrane-bound compartment of a cell that contains genetic material.

peripheral nervous system - part of the nervous system that is outside of the brain and spinal cord.

pituitary gland - produces hormones that control other glands in the body; works with the hypothalamus.

receptor - specialized molecule to which a chemical messenger (hormone or neurotransmitter) binds; the shape of each receptor fits only a specific chemical messenger.

recreational drugs - chemical substances that affect the central nervous system, such as opioids or hallucinogens.

reflex - an involuntary motor response to a sensory stimulus, often for the purpose of protection.

schizophrenia - severe brain disorder that can make it difficult to know what is real and what is not, and can involve a number of symptoms, such as hallucinations, delusions and withdrawal from other people.

sensory neuron - a type of nervous system cell that transmits impulses from a sense organ toward the central nervous system.

sensory receptor - a specialized cell or group of cells that receives sensory information from inside or outside the body.

skull - all the bones of the head, including the cranium and the facial bones.

spinal cord - the thin rope of nervous tissue inside the bones of the spine.

spine - a series of connected bones along the back of a skeleton, also known as the backbone.

stimulus - an agent that influences the activity of sensory nerves.

sulci - grooves or creases in the cerebral cortex.

synapse - tiny gap between the axon of one neuron and the cell body or dendrite of another neuron, across which messages are transmitted chemically or electrically.

synapse firing - chemical or electrical transmission of signals from one neuron to another across a synapse.

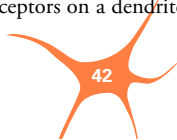
tissue - many cells of the same kind, joined together to do a specific job.

vertebra - any of the bony segments that make up the spine (plural: vertebrae).

vertebrate - animal that has a spine.

vesicle - special pocket in a neuron that contain neurotransmitters.

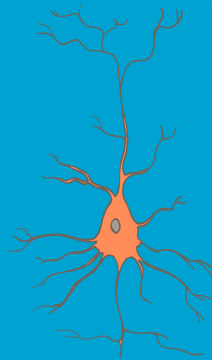
white matter - nervous system tissue made up of nerve fibers covered with a myelin sheath.



THE LEARNING BRAIN: BRAIN CHEMISTRY TEACHER'S GUIDE

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