

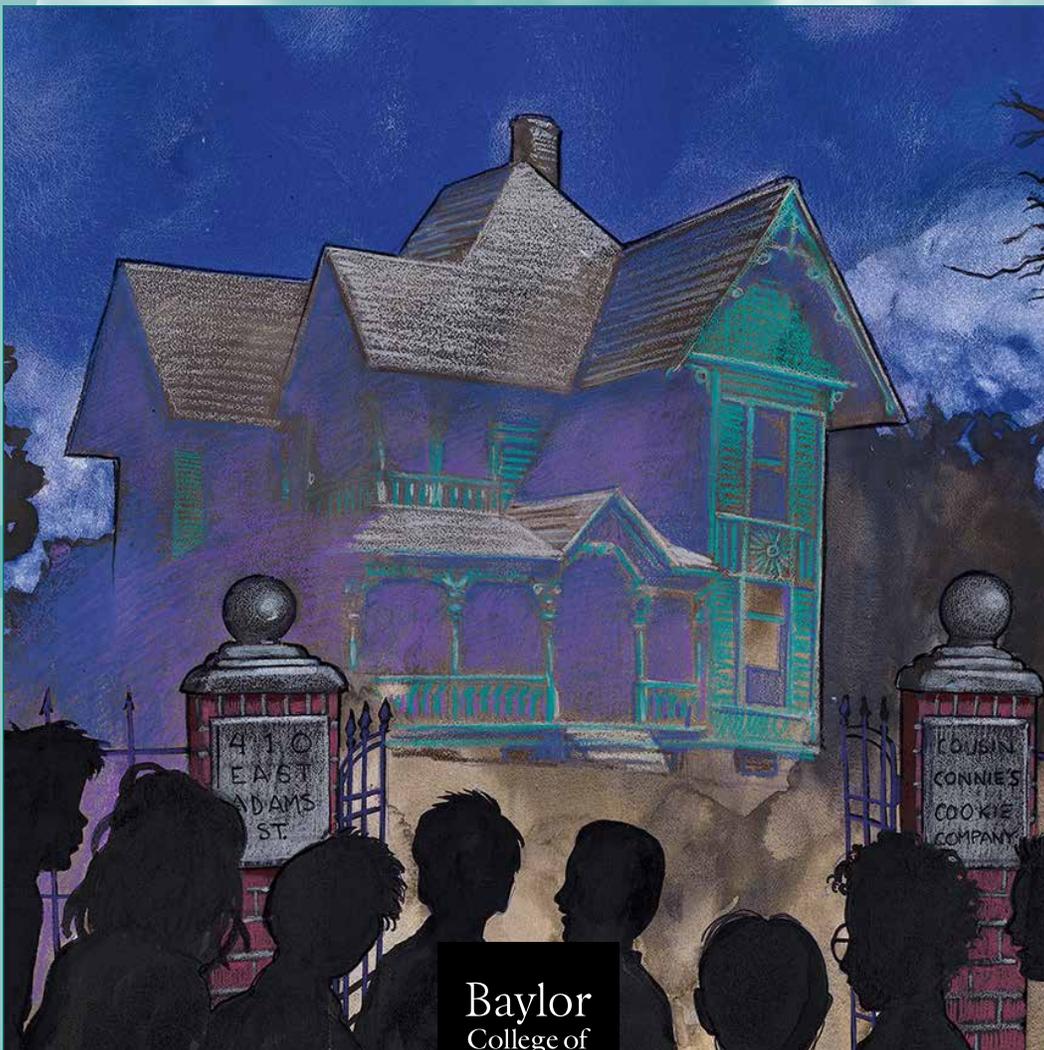


THE SENSORY SYSTEM

Teacher's Guide

Written by

Nancy Moreno, Ph.D., Leslie Miller, Ph.D., Barbara Tharp, M.S., Katherine Taber, Ph.D., Karen Kabnick, Ph.D., and Judith Dresden, M.S.



Baylor
College of
Medicine



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BioEd Teacher Resources from the
Center for Educational Outreach
Baylor College of Medicine

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The activities described in this book are intended for school-age children under direct supervision of adults. The authors, Baylor College of Medicine and the publisher cannot be responsible for any accidents or injuries that may result from conduct of the activities, from not specifically following directions, or from ignoring cautions contained in the text.

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THE SENSORY SYSTEM

This BrainLink® teacher's guide is designed to be used with the following other components of this unit.

- *The Cookie Crumbles: A Case of Sensory Sleuthing*
- *Explorations*
- *The Reading Link*



ACKNOWLEDGMENTS

“The brain is the last and grandest biological frontier, the most complex thing we have yet discovered in our universe. It contains hundreds of billions of cells interlinked through trillions of connections. The brain boggles the mind.”

James D. Watson from
Discovering the Brain, National
Academy Press, 1992

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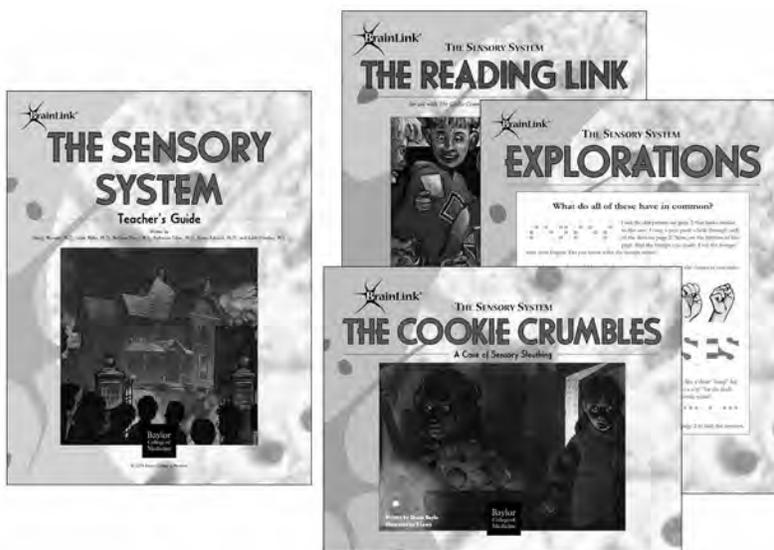
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We are especially grateful to the many classroom teachers in the Houston area who eagerly participated in the field tests of these materials and provided invaluable feedback.

ABOUT BRAINLINK®



The BrainLink Project's exciting activities, explorations and adventures “link” students, teachers and parents to advanced knowledge of the brain and nervous system and to vital science and health information. Prepared by teams of educators, scientists and health specialists, each BrainLink unit focuses on a different aspect of the brain and the nervous system. The activity-based, discovery-oriented approach of the BrainLink materials is aligned with the National Science Education Standards and the National Health Education Standards.



The four components of each BrainLink unit help students learn why their brains make them special.

- *The Cookie Crumbles* presents the escapades of the NeuroExplorers Club in an illustrated storybook that also teaches science and health concepts.
- *Explorations* is a colorful mini-magazine full of information, activities and fun things for children and adults to do in class or at home.
- *The Reading Link* provides language arts activities related to each BrainLink story.
- *The Sensory System Teacher's Guide* presents inquiry-based lessons that entice students to discover concepts in science, mathematics and health through hands-on activities.

BrainLink materials offer flexibility and versatility and are adaptable to a variety of grade levels and teaching and learning styles.

BRAINLINK UNITS

BioEd offers the following BrainLink teaching units to help you and your students learn more about the brain and central nervous system.

BRAIN COMPARISONS

(major structures of the brain in humans and other animals)

MEMORY AND LEARNING

(how the brain stores and retrieves information)

THE MOTOR SYSTEM

(reflexes, movements, and coordination between the brain and body)

THE SENSORY SYSTEM

(how the senses work, visual illusions, and how the brain processes sensory information)

BRAIN CHEMISTRY

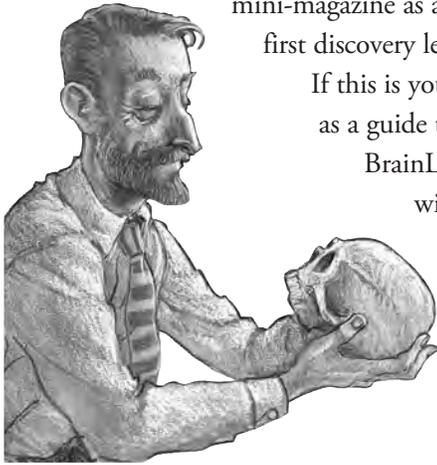
(the brain and neurons, chemical communication in the body, risk perception vs. reality, and how personal choices can affect brain function and performance)

For complete resources, visit www.bioedonline.org today!



WHERE DO I BEGIN?

The teachers guide to activities, adventures storybook, reading supplement mini-magazine and components of each BrainLink® unit are designed to be used together to introduce and reinforce important concepts for students. To begin a BrainLink® unit, some teachers prefer to generate students' interest by reading part or all of the adventures story. Others use the cover of the mini-magazine as a way to create student enthusiasm and introduce the unit. Still others begin with the first discovery lesson in the teacher's guide.



If this is your first BrainLink® unit, you may want to use the pacing chart on the following page as a guide to integrating three of the components of the unit into your schedule. When teaching BrainLink® for 45–60 minutes daily, most teachers will complete an entire BrainLink® unit with their students in two to three weeks. If you use BrainLink® 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.

The BrainLink® *Teacher's Guide* provides background information for you, the teacher, at the beginning of each activity. In addition, a listing of all materials, estimates of time needed to conduct activities and links to other components of the unit are given as aids for planning. Questioning strategies, follow-up activities and appropriate treatments for student-generated data also are provided. The final

activity in each guide is appropriate for assessing student mastery of concepts and may also be given as a pre-assessment prior to beginning the unit.

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 students are “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 components of this BrainLink unit can be used together in many ways. If you have never used these materials before, the following outline might help you to coordinate the activities described in this book with The Sensory System unit’s adventure story (*The Cookie Crumbles*) and *Explorations* mini-magazine.

Similar information also is provided for you in the “Unit Links” section of each activity in this book.



ACTIVITY	CONCEPTS	CLASS PERIODS TO COMPLETE	LINKS TO OTHER COMPONENTS OF UNIT	
			THE COOKIE CRUMBLES	EXPLORATIONS
1. Windows to the World	Senses provide us with information about the world.	1	Story, Chapters 1–3 Science boxes, p. 3, 4 and 6	Cover activity (answers, p. 2) “Brain Busters!” p. 7
2. The Big Receiver	Different areas of the cerebrum receive information from the senses.	1	Story, Chapters 4–5 Science boxes, p. 8 and 9	“Matter of Fact!” p. 2 “Is Seeing Believing?” p. 3
3. Sensory Messages	The brain receives and integrates information from the senses.	1 or 2	Story, Chapters 6–7	“Matter of Fact!” p. 2 “Sensible Games,” p. 5–6
4. Vision and Illusions	Optical illusions provide clues about how the brain processes visual information.	1 or 2	Story, Chapters 8–9 Science box, p. 16	“Is Seeing Believing?” p. 3 “The Eyes Have It!” p. 4 “Camouflage” p. 8
5. Can You Hear Me?	Some kinds of hearing loss are preventable.	1	Story, Chapters 10–11 Science boxes, p. 6, 18 and 19	“Matter of Fact!” p. 2 “Did You Know?” p. 5 “Sensible Games” p. 5–6
6. Tactile Tests	The sense of touch varies on different parts of the body.	1	Story, Chapters, 12–13 Science box, p. 23	Cover activity “Matter of Fact!” p. 2; “Careers for NeuroExplorers, p. 7
7. Get The Point?	Receptors in the skin receive information from within their receptive fields.	1	Story, Chapters 14–15 Science box, p. 26	Cover activity “Matter of Fact!” p. 2
8. My Sensory Strip	The somatosensory cortex receives information from receptors in the skin.	1	Story, Chapters 16–18	“Matter of Fact!” p. 2
9. Super Senses	Summary and pre-/post-assessment activity	1	Story, Chapters 19–20 Science boxes: Review all.	“Matter of Fact!” p. 2 “Did You Know?” p. 5





UNIT MATERIALS

Activity 6 Suggested Pairs of Objects

- Aluminum foil and waxed paper
- Brass screw and wire nail
- Copy paper and a paper towel
- Crayon and chalk
- Fake fur and cotton ball
- Fine and course sandpaper
- Penny and plastic coin
- Piece of gravel and of marble
- Rubberband and aluminum wire
- String and yarn
- Styrofoam ball and steel ball
- Wool and cotton fabric

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)

- 24 hand lenses
- 12 brown paper lunch bags
- 6 cups unsalted popcorn, warmed
- 6 cups salted popcorn
- Access to a microwave
- Marker
- Staple or tape

ACTIVITY 2 (p. 4)

- 24 sets of 5 different colors of pencils or crayons
- Projector

ACTIVITY 3 (p. 8)

- 60 meters of medium weight cotton string,
- 48 paper clips
- 24 pairs of scissors
- 24 white paper cups, 9 oz
- “What Would You Be Doing If?” riddle card sets
- Colored pencils or markers

ACTIVITY 4 (p. 16)

- 24 hand lenses
- 24 white index cards, 3 in. x 5 in.

ACTIVITY 5 (p. 23)

- 24 pairs of disposable earplugs
- Audio file or CD of sounds
- Audio player

ACTIVITY 6 (p. 27)

- 12 pairs of similar materials that can be discriminated by touch (about the same size, i.e., for paper, sandpaper, cloth, etc., use about 1 sq. in. of each piece; see sidebar for suggested pairs of objects)
- 12 brown paper lunch bags

ACTIVITY 7 (p. 30)

- 24 large paper clips
- 12 thin, flat rulers
- 12 pairs of scissors
- Tape

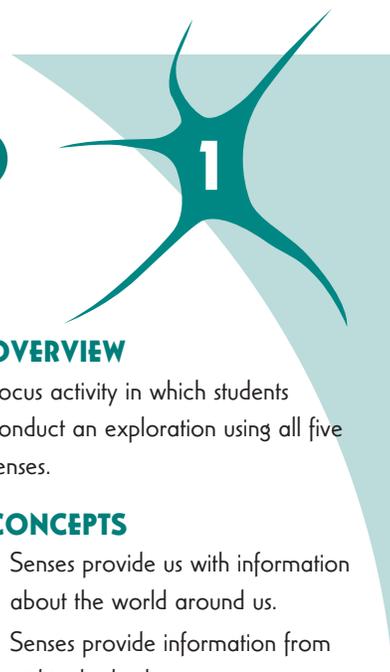
ACTIVITY 8 (p. 33)

- 24 pipe cleaners
- 12 metric rulers (millimeters)
- 12 pairs of scissors
- Clear tape (or glue)

ACTIVITY 9 (p. 36)

- Does not require special materials.

WINDOWS TO THE WORLD



1

Like all other forms of life, we need to interact with our surroundings to obtain water and nutrients, protect ourselves from danger and reproduce. Our senses are our “windows to the world,” allowing us to obtain information necessary for survival. Senses also work within our bodies to provide cues about varying states of our body organs and positions of our muscles and limbs.

Simple one-celled organisms, such as the amoeba, detect light, temperature and other characteristics of the environment over much of



THE COOKIE CRUMBLES

Story, Chapters 1-3
Science boxes, p. 3, 4 and 6.
(If using BrainLink for the first time, have students read “How the NeuroExplorers Club Began,” and “The NeuroExplorers,” p. iv-vi.)

EXPLORATIONS

Cover activity (answers, p. 2)
“Brain Busters!” p. 7

their external surfaces. More complex animals have evolved specialized cells, called receptors, that respond to specific aspects of their environments by sending messages to the rest of the nervous system. Receptors translate information about the physical world and conditions inside the body into impulses that travel along nerve cells or neurons. Most receptors are specialized to respond best to a particular kind of stimulus. Thus, the simple nerve endings in the skin respond to pressure or temperature, while rods and cones, receptors in the back of the eye, react only to the presence of different kinds of light.

Specialized regions within the brain receive and integrate information detected by sensory receptors. Through this process, we are able to interpret and react to our environment. Senses enable us to participate in the world—to learn, to achieve, to discover, to communicate.

Taste and smell, in particular, are emphasized as students embark on a sensory exploration that introduces this unit of BrainLink activities. You may wish to highlight some of the interesting facts about taste and smell listed on the following page.

SETUP

This focus activity will lead students to think about the basic scientific questions, *What do you think is happening?* and *How do you know?*

You will need to pop or purchase plain, unsalted popcorn in advance so

OVERVIEW

Focus activity in which students conduct an exploration using all five senses.

CONCEPTS

- Senses provide us with information about the world around us.
- Senses provide information from within the body.

SCIENCE AND MATH SKILLS

Observing, predicting and drawing conclusions

TIME

Preparation: 15 minutes

Class: 30 minutes

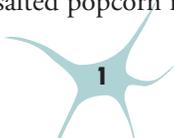
MATERIALS (See Setup)

Teacher

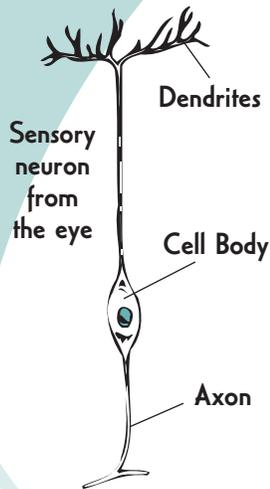
- 12 brown paper lunch bags
- 6 cups unsalted popcorn, freshly popped, warmed
- 6 cups salted popcorn, cooled
- Access to a microwave
- Marker
- Staple or tape

Per Student

- Hand lens



Sensory Neurons



Neurons are specialized cells that conduct and transmit messages within the nervous system. Neurons that are part of the sensory system provide information about the environment, both inside and outside the body.

that it is cool before you begin the activity. You will need a second batch of plain, salted popcorn that is freshly prepared and still warm.

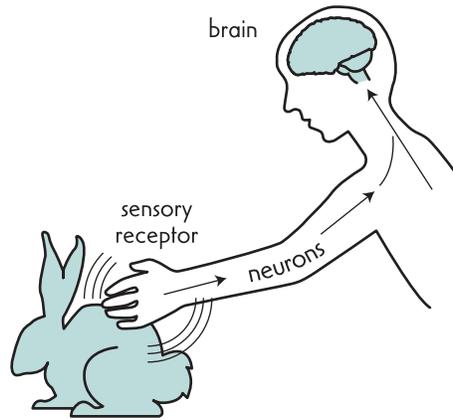
Out of sight of students, label six brown paper lunch bags as “A” and six bags as “B.” Place about one cup of the freshly popped, plain, unsalted popcorn into each of the six “A” bags. Into each of the six “B” bags, put about one cup of the previously popped (cooled) or purchased salted popcorn. To keep students from peeking, you may want to staple or tape the bags closed. Conduct the activity with students in groups of four.

PROCEDURE

1. Give one bag “A” and one bag “B” to each group of students. Tell students that they should not touch the bags or look inside until instructed to do so.
2. Ask, *What do you think is in the mystery bags?* Give students time to respond. They will provide a variety of answers. Direct students to pick up each bag and shake it gently. They should listen carefully to the sounds produced by each bag. Repeat the question, *What do you think is in the mystery bags?* Most students now will be able to determine that the bags contain small objects, and some may guess that the bags contain popcorn. Follow by asking, *How did you know?* Students should mention sound as a clue about the type of object in the bag. Some students also may have smelled the popcorn.
3. Let students smell the bags without opening. Repeat the questions, *What do you think is in the bag? Why?* Students should mention that they used their senses of smell to identify the contents of one or both of the bags. If necessary, allow students to open the bags just enough to smell the contents.
4. Ask, *How could you tell which batch was just popped?* Let the students touch the bags again. This time students should notice that one bag felt warmer.
5. Now ask, *Is either batch salted or flavored? How could you tell without using your sense of taste?* Allow students to open the bags and remove some of the popcorn to observe with hand lenses. Students may notice tiny salt crystals on some of the kernels. Finally, allow students to confirm which batch is salted by sampling one kernel from each of the bags.
6. Conclude by conducting a discussion with the students about how they were able to solve the popcorn mystery. If students have not yet mentioned “senses,” introduce the concept. Senses bring information from inside and outside the body to the brain. Very briefly discuss the common senses (sight, hearing, smell, taste, touch/feeling).
7. Ask the students to tell you all the parts of the body and the nervous

system that they used in this exploration (eyes, nose, mouth, tongue, ears, fingers, brain, neurons, etc.)

8. Stimulate further discussion by asking, *What did your brain do? How did the information get from the sense organs (eye, ear, fingers, nose, etc.) to the brain?* These questions will build interest for Activity 2.
9. Draw a simple diagram on the board to illustrate the relationship between detecting a stimulus, sending a message to the brain and interpreting the message in the brain.



Make a simple diagram of sensory pathways.

BRAIN JOGGING

Here are more ideas for you and your students to explore.

- What do you think a sense is? Is the ability to detect the passage of time a sense? How about balance? Hunger? Detecting gravity?
- Can you think of anything that you do or have ever done without using any of your senses?
- Some people believe that our brains can receive information directly. This controversial phenomenon is called extrasensory perception (ESP). What does the word “extrasensory” mean? Do you think that it’s possible for the brain to receive information that does not pass through the sensory system?

Taste and Smell Facts

- Taste and smell depend on receptors that normally are stimulated by chemicals. Molecules dissolved in liquid are detected by receptors on the tongue. Molecules carried in air are recognized by receptors inside the nose.
- Even though the sense of smell is about 10,000 times as sensitive as taste, the senses of smell and taste usually work in concert, allowing us to distinguish among thousands of different odors and flavors.
- There are about 10,000 receptor units, or taste buds, organized in small clusters on the tongue.

OVERVIEW

Students learn about the special areas of the brain that receive information from the senses.

CONCEPTS

- Different areas of the cerebrum receive information from each sense.

SCIENCE AND MATH SKILLS

Modeling and inferring

TIME

Preparation: 5 minutes

Class: 30 minutes

MATERIALS (See Setup)

Teacher

- Projector
- Transparency of “Sensory Areas of the Cerebrum” page

Per Student

- 5 different colors of pencils or crayons
- Copy of “Sensory Areas of the Cerebrum” and “Sensory NeuroKid” pages

Certain parts of the brain are dedicated to each sense. Initially, different areas of the cerebrum are responsible for receiving messages from each kind of sense organ. For example, a specific region of the cerebrum in the back of the brain is dedicated to receiving information from the eyes. Not only are areas of the brain specialized with regard to the senses, but scientists have discovered that, within each specialized area of the brain, neurons respond to particular aspects of sensory information. In the visual region, for instance, some neurons are devoted to motion, others to color, and yet others to shapes and patterns. The diagram at the bottom of the page shows the primary sensory processing area for each of the five senses. While not shown on the drawing, it should be noted that all sensory information, except for the sense of smell, is routed through a central location deep inside the brain (known as the thalamus), before being sent to the appropriate sensory area.



THE COOKIE CRUMBLES

Story, Chapters 4-5

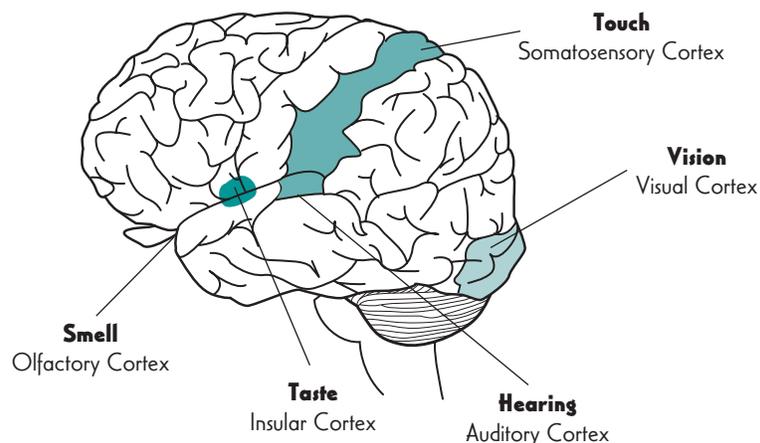
Science boxes, pp. 8 and 9

EXPLORATIONS

“Matter of Fact!” p. 2

“Is Seeing Believing?” p. 3

Primary Sensory Areas of the Cerebrum



After sensory signals are initially processed, they are forwarded to other areas of the cerebrum for more complex integration. In addition, there are areas in the cerebrum where the brain puts together information from all the senses. When we obtain information from several senses, we often are

Unusual Animal Senses

Many animals have developed different types of senses, depending upon the particular environments in which they live and what, specifically, they need to know about their surroundings.

- Mosquitoes detect the presence of potential prey by sensing the carbon dioxide (CO₂) given off as waste from animal respiration.
- Crabs and flies taste with their feet, allowing them to know immediately if they have landed upon something edible.
- Some male moths can smell and then locate a potential mate several miles away by detecting airborne chemicals (pheromones) produced by the female.
- Bats and whales send out sound signals and monitor the echoes to assess the nearness of obstacles, danger and food (echolocation).
- Homing pigeons and other birds are believed to sense the Earth's magnetic fields and use that information for navigation.
- Electric fish generate electric fields around themselves that allow them to detect objects in their immediate vicinity.
- Rattlesnakes use a special organ (the pit organ) to locate other animals, even in total darkness, by seeing an aura indicating the warmth of the other animal's body.

better able to understand a situation than when we have only one form of sensory input.

SETUP

Photocopy “Sensory Areas of the Cerebrum,” and “Sensory NeuroKid” pages, one per student. Make a transparency of or project the “Sensory Areas of the Cerebrum” page.

Conduct this activity with the entire class.

PROCEDURE

1. Project an overhead or distribute copies of the “Sensory Areas of the Cerebrum” page. Have students identify basic parts of the brain (such as cerebrum, cerebellum and brainstem) before pointing out the special areas where information from each sense is first processed. Ask, *Can you find where information about things we see is sent? About things we smell? About things we hear?*
2. Give each student a copy of the “NeuroKid” page. Have the students draw a line from each sensory stimulus (lamp, food, radio, etc.) to the primary receptor organ associated with it (eye, ear, tongue), and on to the area of the cerebrum where that particular sensory information is processed.
3. You may want to assign a specific color for each sense to make the diagram easier to follow. Students may use that color to fill in the corresponding area of cerebral cortex.
4. Note that the stimuli may evoke more than one sensory response. For example, food can be tasted, smelled, seen and touched. After their initial responses, urge older students to note all the senses that could be stimulated by each item.

BRAIN JOGGING

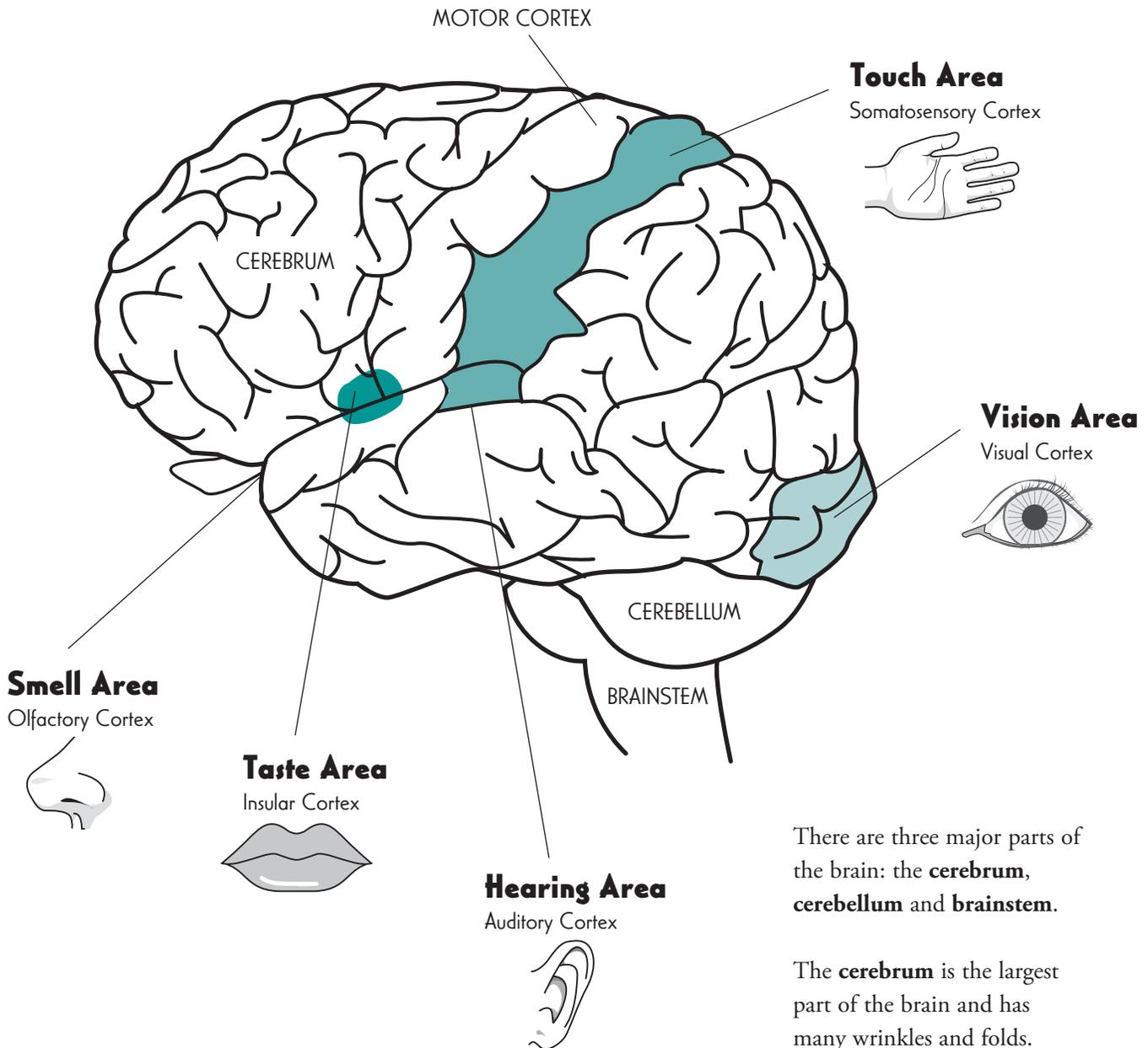
Here are more ideas for you and your students to explore.

- Which sense do you usually rely upon most? Explain why that sense is more important to you than all your other senses.



SENSORY AREAS OF THE CEREBRUM

Information (or signals) from each kind of sensory receptor is processed in a different part of the **cerebrum**. Information from these areas is sent to other parts of the brain for further processing.



SENSORY NEUROKID



There are many things this NeuroKid can see, hear, smell, taste or touch.

1. Draw a line from each item to one or more locations on NeuroKid's body where he might sense (receive) information about the item (ear, eye, nose, mouth and/or hand). Use a different color for each sense.
2. Continue to draw the line to the location in the brain where the sensory information first will be received.





3

SENSORY MESSAGES

OVERVIEW

Students create a string and cup model of sensory receptors and the brain that allows them to explore how the brain puts together information from each of the senses.

CONCEPTS

The brain receives and integrates information from all of the senses.

SCIENCE AND MATH SKILLS

Using variables, measuring, modeling, problem solving and inferring

TIME

Preparation: 10 minutes

Class: 45-60 minutes

MATERIALS (See Setup)

Per Student Group

- 15 meters of medium weight cotton string
- 12 paper clips
- 6 pairs of scissors
- 6 white paper cups, 9 oz
- Colored pencils or markers
- Copy of “Sense Phone Instructions”
- Set of “What Would You Be Doing If?” riddle cards

The brain continually is bombarded by sensory signals from inside our bodies and all around us. Incredibly, it is able to filter out much of that input, enabling us to ignore some of the signals, but to utilize others. Complex communication and processing occur continuously within the brain’s neural networks to produce “understanding” of what is happening around us.

Sensory information is received by neurons or other cells, called receptors, which translate different types of physical information (light, heat, presence of certain molecules, etc.) into nervous system messages or signals. These signals then travel along sensory neurons to the brain.

Most sensory receptors are specialized to respond to a particular type of information. For example, there are different receptors in the skin devoted to receiving and transmitting information about pain, pressure, heat, cold and touch. Interestingly, there are many aspects of the physical environment to which our receptors do not respond. For example, we “see” light only between wavelengths of 400 and 700 nanometers (one nanometer is equivalent to one billionth of a meter) in the electromagnetic spectrum. Other animals, such as many species of bees, are able to see wavelengths that are invisible to us.

This activity is designed to help students discover, in a basic way, how the senses work together. It emphasizes the very important role the brain plays in deciphering and integrating sensory information.

SETUP

You will need to copy the “What Would You Be Doing If?” pages and cut out the individual cards. Students may do this if you prefer.

Divide the class into groups of six students to conduct this activity.

PROCEDURE

1. Have each group construct a sensory nervous system model using the “Sense Phone Instructions” sheet as a guide. Each Sense Phone will consist of five cups (sensory receptors), each connected by a string (sensory neurons) to a central cup (receiver or brain). The string from each “receptor” cup will enter the “brain” cup at an area representing



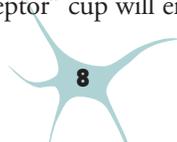
THE COOKIE CRUMBLES

Story, Chapters 6-7

EXPLORATIONS

“Matter of Fact!” p. 2

“Sensible Games” p. 5 and 6



Extension

If desired, students may experiment with different types of string, cups, attachment methods, lengths of string, indoor and outdoor settings, etc. to get the best results from their model.

- the specific area of cerebrum for that sense. Five students from each group will represent the five different senses and one student will represent the brain.
2. Have students test their Sense Phones (item 7 on instruction sheet) before continuing with the rest of the activity.
 3. Distribute one set of cards from the “What Would You Be Doing If?” pages among the Sensory Receptors in each group (different set for each group). Retain the Brain (answer) cards for yourself.
 4. Within the groups, have each Sensory Receptor read his/her clue (one at a time) into the cup, so that only the Brain can hear it. After listening to all of the clues, the Brain should put all the information together (integrate it) to come up with a solution. Allow the Brain a few moments for thinking.
 5. The answer cards contain only one interpretation of the sensory information. There may be more than one correct answer to each riddle. Accept all answers that are plausible.
 6. After the Brain has proposed a solution, have each Sensory Receptor read his or her information to the group. Ask the students in each group, *Was the information from any of the individual senses enough to figure out the answer? Did the brain have enough information to solve the riddle?*
 7. Have groups switch riddle card sets. Students within each group also should rotate positions (i.e., ear, brain, etc.) to solve the riddle. Repeat for the remaining two riddles. Students may enjoy creating their own riddles on blank cards (see p. 15).
 8. Facilitate a class discussion about the senses and sensory integration by asking the students, *Do you think that you could describe an object using only one sense? If so, which sense? If not, which sense might give you the most information? What about describing a whole situation or activity? Why might you be able to describe an object, but not an activity, using only one or two senses?*

BRAIN JOGGING

Here are more ideas for you and your students to explore.

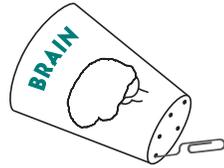
- Write about a situation in which information from only a single sense is not enough to understand what is happening.
- Why do you think the sensory receptors for hearing, seeing, smelling and tasting are located on your head?



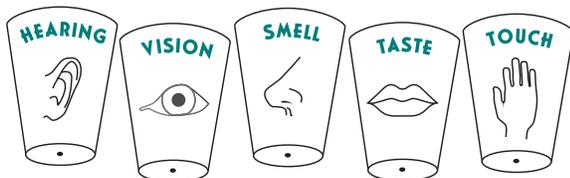
SENSE PHONE INSTRUCTIONS

Before you begin, read all the instructions.

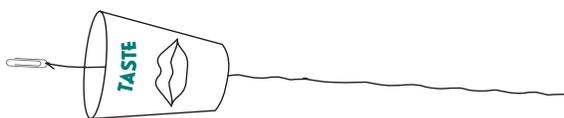
1. Obtain six cups. Label one cup as the “Brain” (or draw a brain on the cup). Draw five dots on the bottom of the cup to represent the primary sensory areas in the brain. Carefully open a paper clip and use the end to punch a small hole through each of the dots.



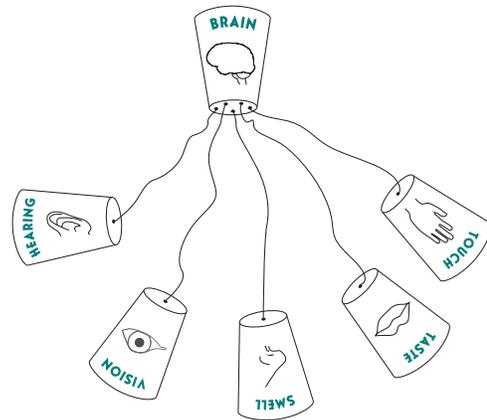
2. The five remaining cups represent sensory receptors for each of the five senses. Label them as “Hearing,” “Vision,” “Smell,” “Taste,” and “Touch.” Draw a dot on the center of the bottom of each sensory receptor cup. Use an opened paper clip to punch a small hole through the dot.



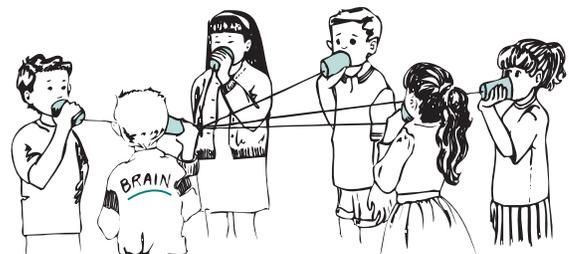
3. Measure and cut five pieces of string, each 2.5 m (8 ft) in length. The string represents a signal (neurons) pathway to the brain.
4. Thread one piece of string through the hole in the bottom of each sensory receptor cup. Tie the part of the string that is inside of each cup to a paper clip. Then, gently pull the string so that the paper clip comes to the inside bottom of the cup. This will keep the string from pulling out of the hole.



5. Thread the other end of each string through one of the holes at the bottom of the brain cup. Tie the part of each string that is inside of the brain cup to a paper clip. Gently pull the string so that the paper clips on the end of each string come to the inside bottom of the brain cup.



6. Stand as far apart from each other as possible so that the lines are taut (do not overstretch the strings). **Brain:** Hold the brain cup tightly against your ear and listen. **Sensory Receptors:** Hold the cup over your mouth and take turns speaking clearly in low voices to test the sense phone. Be sure to keep the string tight while speaking.



WHAT WOULD YOU BE DOING IF?



RIDDLE SET 1

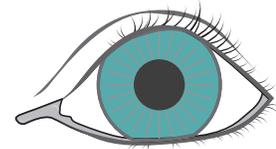
RIDDLE 1

I feel something hard and smooth.



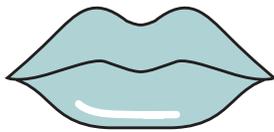
RIDDLE 1

I see something red and round.



RIDDLE 1

I taste something sweet and sour.



RIDDLE 1

I smell something sweet and tart.



RIDDLE 1

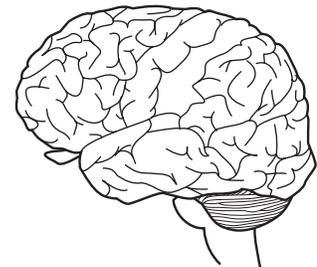
I hear something crunching.



RIDDLE 1

Possible Brain Solution:

I am eating a red apple.





WHAT WOULD YOU BE DOING IF?

RIDDLE SET 2

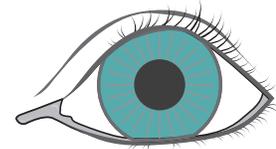
RIDDLE 2

I see something round and yellow.



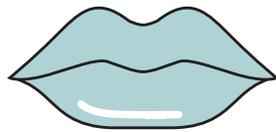
RIDDLE 2

I hear something dripping.



RIDDLE 2

I smell something sharp and refreshing.



RIDDLE 2

I taste something sour.



RIDDLE 2

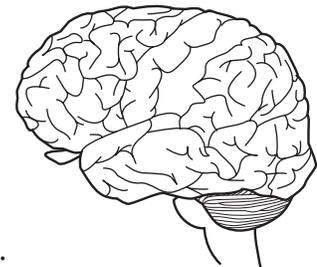
I feel something slick, bumpy and wet.



RIDDLE 2

Possible Brain Solution:

I am squeezing a slice of lemon.



WHAT WOULD YOU BE DOING IF?



RIDDLE SET 3

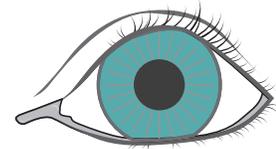
RIDDLE 3

I smell something fishy.



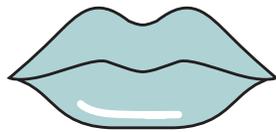
RIDDLE 3

I see blue and white.



RIDDLE 3

I feel something wet.



RIDDLE 3

I hear wind blowing and water rushing.



RIDDLE 3

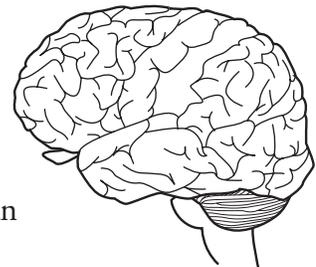
I taste something salty.



RIDDLE 3

Possible Brain Solution:

I am at the ocean shore or beach.





WHAT WOULD YOU BE DOING IF?

RIDDLE SET 4

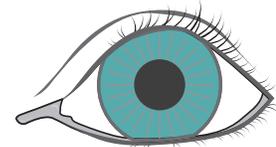
RIDDLE 4

I taste something salty.



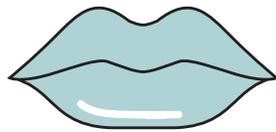
RIDDLE 4

I hear crowd noises and music.



RIDDLE 4

I feel hot and dusty.



RIDDLE 4

I smell popcorn and hot dogs.



RIDDLE 4

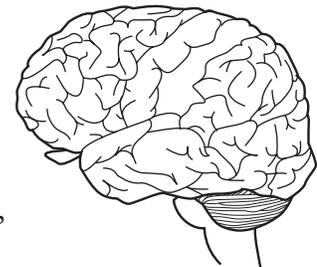
I see movement, colors and many people.



RIDDLE 4

Possible Brain Solution:

I am at a rodeo, carnival or fair.



WHAT WOULD YOU BE DOING IF?



BLANK RIDDLE SET

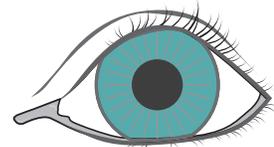
RIDDLE

I hear:



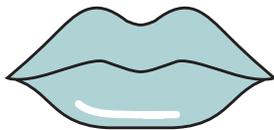
RIDDLE

I feel:



RIDDLE

I see:



RIDDLE

I smell:



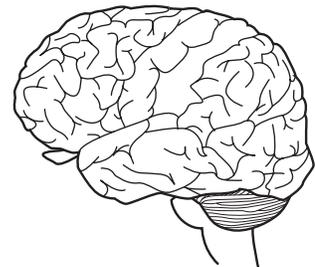
RIDDLE

I taste:



RIDDLE

Possible Brain Solution:



4

VISION AND ILLUSIONS

OVERVIEW

Students learn about the brain's role in vision by experiencing well-known optical illusions.

CONCEPTS

- Some optical illusions provide clues about how the brain processes visual information.
- The brain can be fooled by insufficient or conflicting visual input.

SCIENCE AND MATH SKILLS

Observing, identifying variables, identifying relationships and measuring

TIME

Preparation: 10 minutes

Class: 30-45 minutes

MATERIALS (See Setup)

Per Student

- White index card, 3 in. x 5 in.
- Hand lens
- Copy of "The Vanishing Spot" and "Brain Illusions" pages

Most of our knowledge about the surrounding world comes from the sense of vision. This seemingly miraculous sense transforms signals produced by light energy entering the eye into perceptions of movement, color and form. The abilities to recognize a face, identify an object under different conditions of light or interpret the components of a landscape result from complex processes that take place in many areas of the cerebrum. The strategies used by the brain in vision cannot be duplicated, even by the most sophisticated existing computers and software.

We only are beginning to understand how the visual system in the brain works. While it was once believed that vision worked like a simple camera, we now know that it is a much more complex process. Light enters the eye through the pupil and is focused by the lens on the retina, where it activates special light-sensitive cells (rods and cones). These cells convert light energy into electrical signals that travel along the optic nerve to the visual centers of the brain. The primary visual

cortex, where signals are first processed, is located at the back of the head. However, there are at least 20 other areas of the cerebral cortex devoted to processing visual information. Cells in different areas of the visual cortex respond to different characteristics of objects (for example, motion, form, color). Each of these areas receives special information carried over separate pathways. This information is assembled along parallel routes, not yet fully understood, to form a three dimensional mental perception of the world.

Optical illusions provide clues about the ways in which the brain processes visual information. The brain appears to make certain assumptions about what is to be seen in the world. When insufficient information is provided or the information is conflicting, the brain can be "tricked."

In this activity, students will explore several well-known illusions. They are based upon the following principles.

- **Inverted image.** Light enters our eyes in the same way that it enters a pinhole camera or passes through

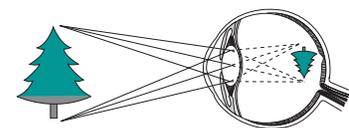


THE COOKIE CRUMBLES

Story, Chapters 8-9
Science box, p. 16

EXPLORATIONS

"Is Seeing Believing?" p. 3
"The Eyes Have It!" p. 4
"Camouflage!" p. 8

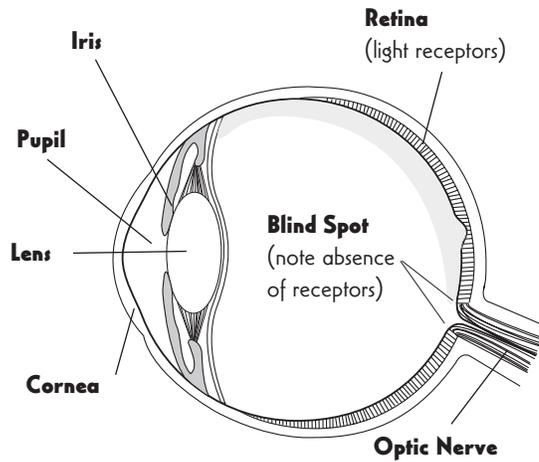


Images are inverted when they are focused on the retina.

a simple lens (such as a hand magnifier). As a result, the light that becomes focused on the retina presents an image that is upside down relative to the outside world. Higher levels of the brain adjust for this, so that we “see” the world in its correct orientation.

- **Filling in.**

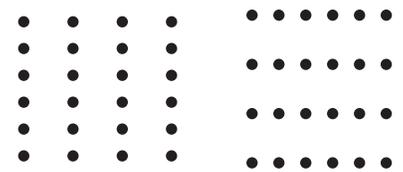
Sometimes, when the brain receives incomplete information about the physical world, it tries to fill in the gaps. For example, there is a “blind spot” in our field of vision, where the optic nerve connects the eyeball to the brain. The blind



Blind Spot. The blind spot has no receptors for light, yet we do not see a blank space in our field of vision.

spot contains no receptor cells and cannot react to incoming light. However, we do not “see” a blank space in our field of vision, because the brain fills in the missing area with an estimate of what should be there. This astonishing process can be experienced in the illusion presented on the student page, The Vanishing Spot. This illusion is constructed so that a black circle or a gap in a line falls exactly on the blind spot of the eye. When the brain “fills in” the blind spot, the image of the circle disappears and the line appears unbroken!

- **Grouping.** Light coming into the eye is detected as tiny points by the individual receptors in the retina. This information must be processed through many levels in the brain before it becomes useful. In fact, one of the primary tasks of the visual cortex is to process and combine separate points of light into more meaningful mental images. One way the brain organizes visual information is by clustering objects that are close together. Because of this tendency, the groups of dots (right) appear to be arranged either in columns or in rows, depending upon the spacing.



Grouping

- **Figure vs. ground.** The visual system works on a “winner takes all” basis. The eye and brain can focus intently on only one object at a time. Everything else is reduced to background. When a figure is ambiguous, as in psychologist Edgar Rubin’s famous vase example (to

the right), the brain jumps from one interpretation to another. Thus, the figure can appear as either two faces in profile or a symmetrical vase, but not as both at the same time.

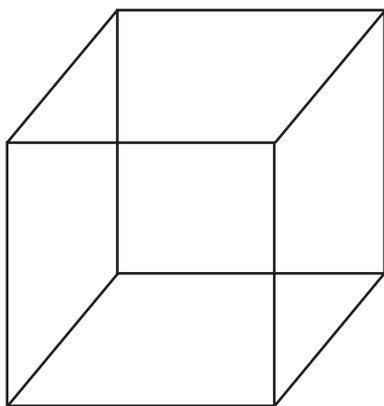


Figure vs. Ground

- Context clues.** One of the brain's most difficult tasks is building a three-dimensional perception of the world from the two-dimensional image received on the retina. The brain uses several context clues to estimate depth and distance. One clue is shading. Look at the rows of circles below right. The circles will appear as spheres or cavities, depending upon where you assume the light is coming from. It is virtually impossible to see both rows of spheres as concave or convex*. Another clue is perspective. Objects that appear small or nearby can be interpreted as being far away, depending upon the relative size or distance of surrounding objects. Examples include railroad tracks that converge in the distance, or an automobile that gradually increases in size as it approaches. The brain uses clues about the relative size of nearby objects to interpret these examples correctly.



Context Clues: Shading



Context Clues: Perspective

When provided with insufficient or conflicting information, the brain can be fooled. The open cube to the left is a good example of this. Since there are no clues about which surface is closest to the viewer, the brain will switch among different interpretations of the cube. (This illusion was first devised by L.A. Necker in 1832.)

SETUP

Conduct the following explorations in one longer or several short sessions, depending on the ages of your students and the time available. Students may work individually or in pairs.

PROCEDURE

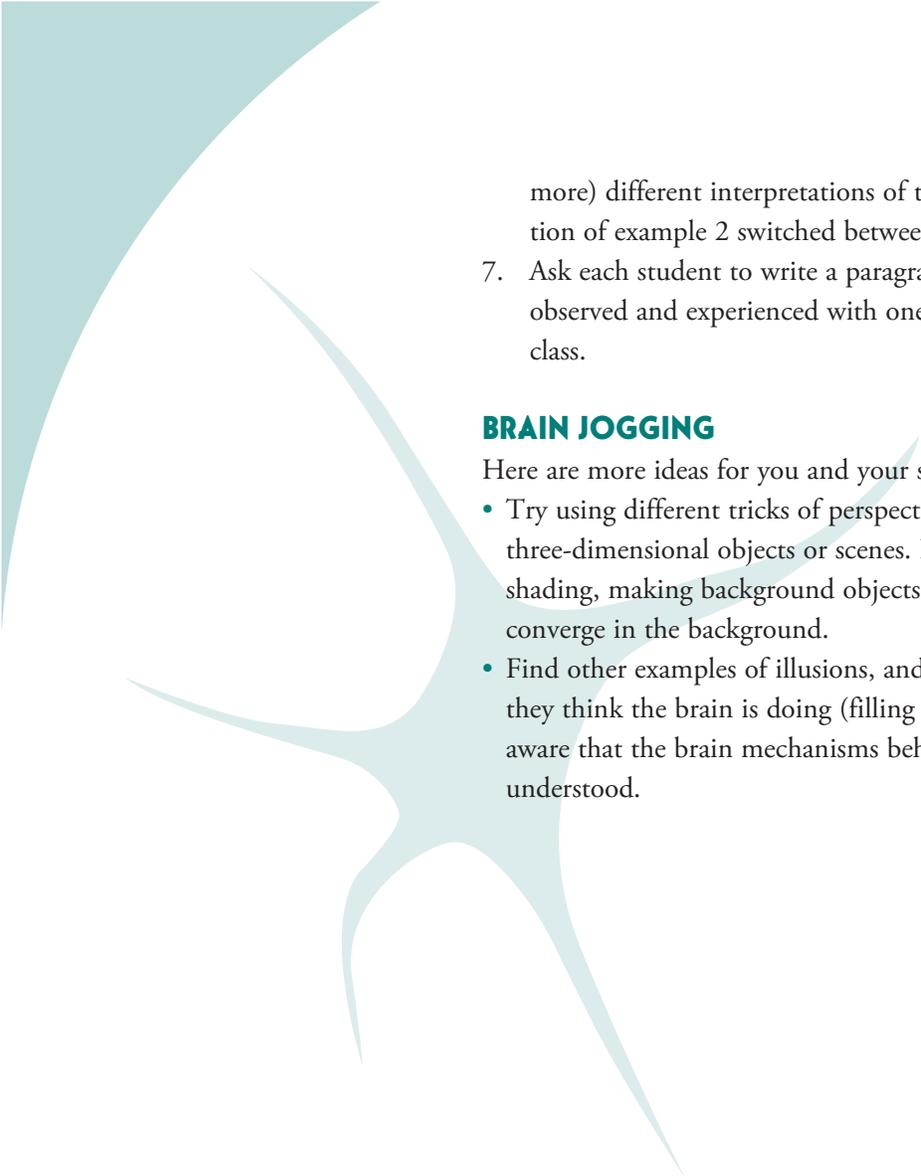
- Inverted image.** Give a hand magnifier and a note card to each student. Direct the students to stand

*Adapted from Ramachandran, V. 1988. Perceiving Shape from Shading. *Scientific American* 259(2):76-83).



with their backs to a window as they hold the hand lenses a few inches in front of the note cards. The students should observe an image projected onto the card. (If the image is not sharp, have them move the magnifier forward or backward until it becomes focused.) Ask, *What do you see? Is it right side up?* The image will be upside down. Help the students understand that the image projected onto the retina of the eye also is inverted. The brain “flips” the image to its correct orientation as it builds a mental picture of the physical world.

2. **Filling in.** Distribute copies of “The Vanishing Spot” student sheet and direct each student to follow the instructions. Ask, *What happens to the black circle? To the space in the black line? What do you think is happening?* Lead the students to conclude that the brain is filling in the space corresponding to the “blind spot” on the retina.
3. **Grouping.** Give each student a copy of the “Brain Illusions” page. Have students focus their attention on the dot patterns in example 1. Students should count the number of dots in each group to establish that both groups contain the same number of dots. Ask, *Are the dots in the first group arranged cross-wise or up-and-down? Why do you think so? What about the dots in the second group?* Lead the students in a discussion about the role of spacing in altering their perceptions of the arrangement of the dots.
4. **Figure vs. ground.** Let the students look at example 2. Ask them to describe what they are seeing. (Some will see a vase, others a pair of faces, and others may mention that the image switches between the faces and the vase.) Encourage the students to think about what might be happening. Explain that the eye and brain can be busy with only one object or image at a time and that everything else becomes background. In the case of this illusion, the brain jumps from one interpretation of the figure to the other. Follow by asking whether it is ever possible to watch two different things closely at the same time.
5. **Context clues.** Direct students’ attention to example 3. Ask them to imagine that the light illuminating the spheres is coming from above. Have them identify which row of spheres looks like it is concave and which row looks convex. Next, ask them to imagine that the light source is below the figure. Which row is concave and which is convex now? Challenge the students to establish whether it is possible to see both rows simultaneously as concave or convex. Discuss why or why not.
6. Challenge students to identify which side of the open cube in example 4 is facing forward. Ask, *Is it possible to tell which side is facing forward? What kinds of clues would we need to determine which side is closest?* Students also may notice that their attention will flip between two (or



more) different interpretations of the cube, much as their interpretation of example 2 switched between the vase and the two faces.

7. Ask each student to write a paragraph describing what he or she observed and experienced with one of the optical illusions explained in class.

BRAIN JOGGING

Here are more ideas for you and your students to explore.

- Try using different tricks of perspective to create drawings that represent three-dimensional objects or scenes. Possible techniques include using shading, making background objects smaller, and letting linear objects converge in the background.
- Find other examples of illusions, and ask students to describe what they think the brain is doing (filling in, using context clues, etc.). Be aware that the brain mechanisms behind some illusions still are not understood.

THE VANISHING SPOT



1. Hold this sheet about 18 inches from your face. Close your right eye. Stare at the x using your left eye. Move the sheet back and forth slightly. What happens to the black circle?



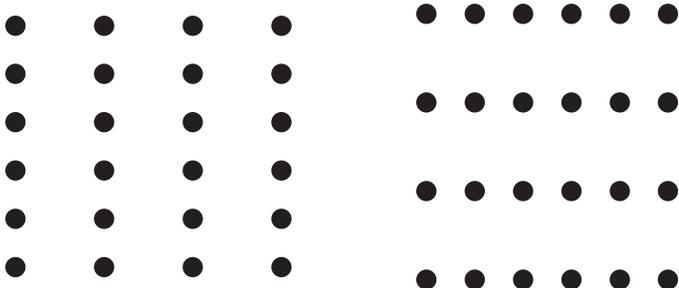
2. Close your right eye and try again, this time focusing on the triangle. What happens?





BRAIN ILLUSIONS

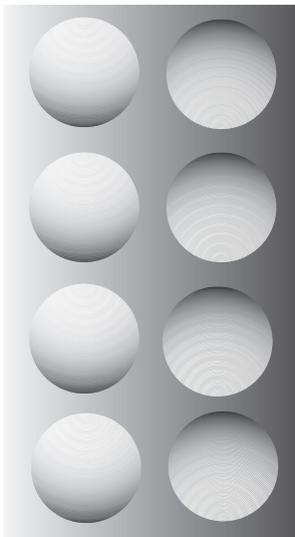
1.



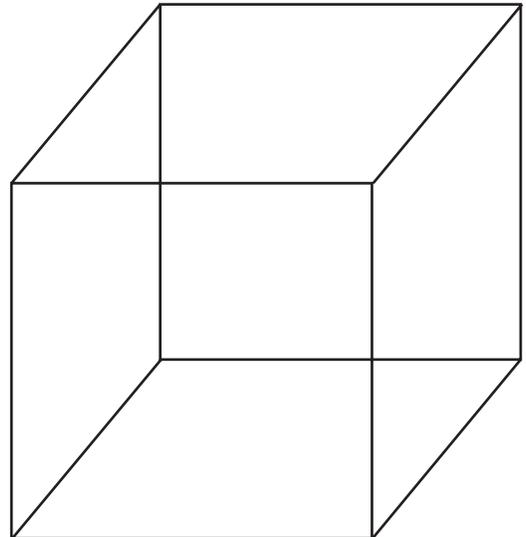
2.



3.



4.



CAN YOU HEAR ME?

5

Sound is produced when an object vibrates in air (or another medium, such as water) and produces alternating bands of high and low pressure, known as sound waves. Even though sound waves possess very low levels of energy, our ears and brain are able to detect the frequency and loudness of sounds, and to locate sound sources.

The human ear is designed to collect sound waves and detect minute changes in air pressure. The outer ear consists of the ear flap and a short

Unit Links

THE COOKIE CRUMBLES

Story, Chapters 10-11

Science boxes, p. 6, 18 and 19

EXPLORATIONS

"Matter of Fact!" p. 2

"Did You Know?" p. 5

"Sensible Games" p. 5-6

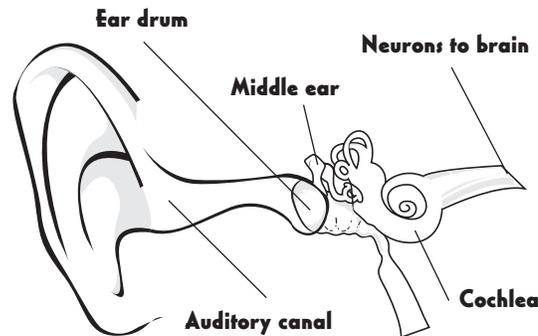
passageway known as the auditory canal. The eardrum, or tympanic membrane, is located at the inner end of the auditory canal. The eardrum bulges inward or outward in response to pressure changes caused by sound waves. This movement is amplified by the three tiny, interconnected bones residing in the middle ear.

Another membrane separates the middle and inner ears. The inner ear is a complicated labyrinth of interconnected fluid-filled chambers and canals. The upper group of canals is

important for the sense of balance. The lower canal is coiled like a snail shell and is filled with fluid. This structure, known as the cochlea, converts pressure waves into impulses that are sent along sensory neurons to the auditory centers in the brain.

Our ability to detect and process information from the outside world depends on the presence of intact and functioning sensory systems.

Whenever any of the components of a particular sense is harmed, our capacity to receive information through that sense may be diminished, distorted or eliminated. Damage to any of the parts of the ear described here could result in partial or complete hearing loss.



Capturing sound. The ear is designed to capture sound waves and transform them into impulses that can be sent along sensory neurons to the brain.

OVERVIEW

Students experience the effects of earplugs and learn about protecting the ear to help prevent sensory loss

CONCEPTS

- The human ear is designed to trap sound waves and convert information about sound into nervous system signals.
- Some kinds of hearing loss are preventable.

SCIENCE AND MATH SKILLS

Observing, considering and calculating variables, measuring and drawing conclusions

TIME

Preparation: 15 minutes

Class: 30 minutes

MATERIALS (See Setup)

Teacher

- Audio file or CD of sounds
- Audio player

Per Student

- Disposable earplugs
- Copy of "How Loud Is Too Loud?" page

Animal Hearing

- Bats use high frequency sounds to produce echoes that allow them to locate flying insects.
- Some moths have membranes on the thorax that pick up the echolocating sounds of hunting bats. The moths then can change direction to avoid being eaten.
- Owls have one ear positioned slightly higher than the other. The differences in the intensities of arriving sounds are used to pin-point the location of prey—even in total darkness.
- The ear flaps on many animals allow them to locate the direction from which a sound comes. Try this for yourself. Remove the bottom from a disposable cup. Place the cup around your own ear. Test the effectiveness of your enhanced ear flap by pointing it toward a source of sound.

Protect Your Hearing

Headphones and earbuds are particularly insidious contributors to hearing damage. If the volume on an audio player, music CD or television is so loud that another person can hear the sound coming from the earbuds or headset, the wearer may be harming his/her ears!

Some kinds of sensory loss are preventable! While we are not able to protect our sensory systems from every kind of damage, certain measures can be taken to limit harmful situations. This is particularly true of the sense of hearing. Simple actions, such as wearing earplugs in noisy settings, or lowering the audio when wearing earbuds often can prevent damage to delicate structures inside the ear. In addition, protective headgear and helmets for sports and certain occupations help avoid serious head injuries. Safety glasses, shaded lenses, heavy gloves, protective clothing and sun screens all shield valuable sensory receptors in the eyes and skin.

This activity lets students experience how earplugs reduce the amount of sound that enters the ear.

SETUP

This activity may be carried out with the entire class or with groups of three students. In either case, the activity requires three different categories of participants: 1) students with earplugs, 2) students without earplugs and 3) observers, who also will act as recorders.

Select or create one or more audio files, CDs or radio settings that present different kinds of sounds (i.e., speaking voices, instrumental music, sound effects, rock music, etc.). You will gradually increase the volume from the lowest setting possible to one that is between medium and high for each different sound. If possible, have students sit in a circle, all at an equal distance from the sound source.

PROCEDURE

1. After dividing them into groups, explain to students that they will be listening to sounds that will increase gradually in loudness. Tell the students in the “earplugs” and “without earplugs” groups that they will keep their eyes closed during the experiment and should raise their hands when they first begin to hear a sound. When they stop hearing the sound, they should lower their hands and wait for the next sound. The experiment will be repeated several times with different kinds of sounds. The “observers” should record which of the other two groups responded to the sound first during each trial. Depending on the age of your students, you may wish to have them record the actual time intervals between the responses of each group.
2. Have all the students with earplugs insert the plugs gently into their ears. The plugs should fit snugly, but not be uncomfortable.
3. Play each sound until all or most of the students have raised their hands. The sounds on the pre-recorded tape included in the kit will gradually become louder. If you are using another source of sounds, you will need to increase the volume manually for each trial.

- Repeat the experiment several times with different kinds of music or sounds. The “observers” should record which of the other two groups responded to the sound first during each trial. You may wish to have students calculate the actual time intervals between responses by the two groups.
- Lead a discussion of the results of the trials. You may do this informally, or you may wish to tabulate the observations on the board. Did students wearing earplugs hear the sound at lower or higher levels of loudness before the group without earplugs? What does this tell us, in general, about the usefulness of earplugs? For which types of sounds were the earplugs most effective? Discuss the information presented on the How Loud is Too Loud? sheet.

BRAIN JOGGING

Here are more ideas for you and your students to explore.

- Imagine a new invention that could help compensate for the loss of one of the senses or increase the acuity of a sense. Describe your sense-improvement invention in a short paragraph or story, or draw a picture of it.
- Use the Sense Phones to investigate the consequences of damage to different components of the sensory system. Have different groups simulate “damage” to receptors, sensory neurons or the brain by cutting or otherwise modifying the corresponding component of the Sense Phone (i.e., receptor cups, string or brain cup) and testing whether a message can be sent.
- Individuals who are deprived of a particular sense (vision, hearing, etc.) often learn to rely more on information they obtain through other senses. Common examples include the use of vision by deaf persons to “read” lips and understand spoken language, or the use of touch in the fingertips by blind persons to “read” Braille texts.

Sensory Loss

Sensory loss can result from disease or damage to any of the parts of the sensory system, as described below.

- Damage to sensory receptors (in the eye, ear, skin, etc.) can take place in small increments over time, or can result from a sudden catastrophe. Hearing loss from repeated exposure to loud noise is an example of gradual injury to sensory receptors. Severe blows to the eye or ear can cause permanent blindness or deafness by harming one or more of the delicate parts of these receptors. Extremely loud noises also can cause immediate and irreversible hearing loss.
- When the neurons that carry sensory information to the brain degenerate or are severed, no signal will reach the appropriate area of the brain, even if the sensory receptor remains intact. For example, multiple sclerosis is a disease that can lead to loss of the sense of touch and/or vision through the gradual breakdown of the myelin sheath protecting some sensory neurons.
- Sensory loss as a result of brain damage depends on the region of the brain that is affected. Specific injury to a very small area of the cerebrum can impact only one sense. However, swelling and other secondary consequences often lead to ill effects in many areas of the brain.



How Loud is Too Loud?

Sound is measured in units called decibels (db). See how different types of sound compare.

	Sound Units (db)	Sound Examples
Regular exposure to more than 1 minute risks permanent hearing loss.	140	firecrackers, jet engine, gun shot
	130	rock concert
	120	snowmobile, boom car
No more than 15 minutes unprotected exposure recommended.	110	subway train, chain saw
	100	wood shop
	90	lawn mower, motorcycle
	80	city traffic, hair dryer
	70	restaurant, vacuum cleaner
	60	normal conversation
	50	average home
	40	humming of a refrigerator
	30	soft whisper, quiet library

Ringling or a full feeling in the ear signals that you are being exposed to noise that could be harmful. Always wear earplugs when you are involved in a loud activity.



Prolonged exposure to **any noise above 90 decibels** can cause gradual hearing loss.

Source: National Institute on Deafness and Other Communication Disorders, 2002.

TACTILE TESTS

6

We often speak of the five senses: vision, hearing, taste, smell and touch. However, the tactile sense, traditionally called “touch,” actually encompasses a large group of more or less separate senses. These include pressure, vibration, warmth, cold, heat and pain, detected in the skin and deeper tissues.

The number of different kinds of receptors, or “sensors,” present in the



Unit Links

THE COOKIE CRUMBLES

Story, Chapters 12-13
Science box, p. 23

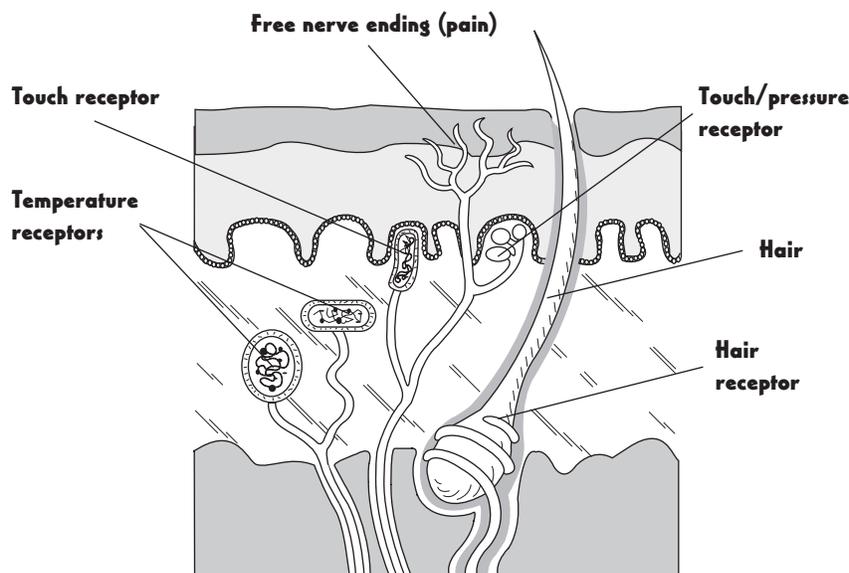
EXPLORATIONS

Cover activity
“Matter of Fact!” p. 2, “Careers for NeuroExplorers” p. 7

skin and the ways in which different dimensions of touch or feeling are detected by those receptors are not completely known. We do know that pressure receptors at the base of each hair detect minute movements that correspond to contact, or being touched. Other specialized receptors register temperature. Pain is detected by free nerve endings.

Receptors for different feelings are not distributed equally in the skin. For example, in any given area, there usually are more points that are

sensitive to pain than points that are sensitive to pressure or to temperature. In addition, some areas of the body have more sensory receptors of a



Cross-sectional view of skin. Characteristics of skin without hair and skin with hair are combined for purposes of illustration.

OVERVIEW

Students explore the sense of touch by comparing skin sensitivities on the upper arm and fingertips.

CONCEPTS

- The ability to discriminate between objects by using the sense of touch varies on different parts of the body.

SCIENCE AND MATH SKILLS

Observing, comparing, drawing conclusions

TIME

Preparation: 15 minutes

Class: 30 minutes

MATERIALS (See Setup)

- 12 brown paper lunch bags
- 12 pairs of similar materials that can be discriminated by touch (about the same size, i.e., for paper, sandpaper, cloth, etc., use about 1 sq. in. of each piece):
 - Aluminum foil and waxed paper
 - Brass screw and wire nail
 - Copy paper and a paper towel
 - Crayon and chalk
 - Fake fur and cotton ball
 - Fine and course sandpaper
 - Gravel and marble pieces
 - Penny and plastic coin
 - Rubberband and aluminum wire
 - String and yarn
 - Styrofoam ball and steel ball
 - Wool and cotton fabric

Animal Receptors

- Fish have a row of pressure sensors down each side of the body that lets them detect vibrations in water.
- Spiders feel vibrations of their webs to identify and locate trapped prey.
- Cockroaches have tiny hairs on the abdomen that can detect very fine air movements—even those created by the lightning fast tongue of a toad.
- Seals' whiskers are fine-tuned to pick up disturbances in water. Seals can follow the wake of prey as much as 180 meters away.

particular kind than others. For example, there are more pressure-sensitive receptors on the tip of the tongue and on the fingertips than anywhere else in the body.

This exploration allows students to compare the relative sensitivity of skin on different parts of their bodies (upper arm and fingertips). By trying to feel the difference between two similar objects with slightly dissimilar textures, students discover that some areas are more sensitive than others. This is because some parts of the body have more sensory receptors for touch than others.

SETUP

Prior to class, place similar pairs of objects in numbered brown paper lunch bags. (Suggestions for pairs of objects can be found in the sidebar on p. vi.) You will need one bag for each two students.

Conduct this activity with students working in pairs.

PROCEDURE

1. Distribute one of the bags you have prepared to each pair of students. Have one student (the “subject”) in each pair close his/her eyes. Have the other student remove the objects from the bag and gently rub them, one at a time, on the forearm or upper arm of the subject. Ask the subjects, *Can you feel any difference between the two objects?* Most students will not be able to discriminate between the two items when the objects are rubbed on the arm.
2. Next, have the teams repeat the test by rubbing the objects on the subjects' fingertips. Ask the subjects, *Are you able to feel a difference this time?* Ask them to describe the two things they felt.
3. Rotate the bags among groups, have the students in each group trade jobs and repeat the process as time allows.
4. Use these class discoveries along with the information at the front of this activity to lead a discussion about differences in skin sensitivity among body areas. Help students understand by asking questions such as, *Could you tell whether objects were the same or different with your fingers? With your arm? From which area of the body do you think the brain gets more sensory information? In which area might there be more sensory receptors? Why do you think the hands are more sensitive?*

BRAIN JOGGING

Here are more ideas for you and your students to explore.

- Try taping “whiskers” (straws, pipe cleaners, etc.) onto your cheeks. Imagine that you are a cat or other animal that navigates in the dark.



Would your “whiskers” help you judge the nearness of objects or the size of openings? How could you find out? Do you think the hairs on your body improve your sense of touch?

- Why do you think it is important for the skin to contain sensory receptors for heat, cold and pain in addition to those for simple “touch” (contact, pressure)? Do you suppose there are more receptors in the skin for pressure or for pain?

Try This!

Many of the sensations we feel consist of combined information from different kinds of receptors in the skin. For example, the feeling of wetness is generated by the simultaneous stimulation of receptors for cold and pressure.

To convince yourself of this, cover your finger with clear plastic and then place it in cold water. It will feel wet!



OVERVIEW

Students experiment to discover differences in the sizes of “touch” receptive fields in their inner arms, palms and fingertips.

CONCEPTS

- Sensations in the skin are detected by special receptors.
- Each receptor in the skin receives information from an area known as its receptive field.
- Some parts of the body have more receptors in the skin than others.

SCIENCE AND MATH SKILLS

Predicting, measuring, gathering data, comparing and drawing conclusions

TIME

Preparation: 10 minutes

Class: 45 minutes

MATERIALS (See Setup)**Per Student Team of Two**

- 2 large paper clips
- Pair of scissors
- Thin, flat ruler
- Tape
- Copy of “Get the Point?” page

The area of skin from which a sensory receptor receives information is called its receptive field. In a part of the body with more receptors or nerve endings, the receptive fields are smaller because the receptors are closer together. For instance, there are many more sensory receptors in our fingertips than in the upper arm or leg. As a result, the receptive fields are smaller on the fingers than on the arm. You might make the analogy that there are “more dots per square inch” in the skin on our fingertips than in the skin on the forearm or upper arm. This makes it possible for the fingers to make finer discrimination of texture or minute details than the upper arm.

This activity will allow students to experience and quantify the approximate sizes of receptive fields on their fingers, palms and forearms.

SETUP

Students will create a testing tool by unbending two large paper clips and taping them to a thin ruler. One paper clip should be taped in place and remain fixed. The other clip may be moved along the ruler to create different distances between the points for testing. Each time the distance is set, the paper clip tips must be tapped on a flat surface to make them even. Both points of the tester should touch the skin at the same time and with the same pressure.

To conduct this activity, divide the class into teams of two students.

PROCEDURE

1. Help each team create a testing tool as described under “Setup” and on the student sheet. Reinforce to students that each time a new distance is set, the fixed and unfixed paperclip tips must be gently tapped on a flat surface to make them even before testing the next area, and that both paperclip points must touch the skin at the same time and with the same pressure.
2. Diagrams at the top of the student sheet illustrate points on the body to be tested (fingertip, palm of hand and forearm) and the amount of tip separation for each trial. Space is provided on the sheet for both students to record their results.

**Unit Links****THE COOKIE CRUMBLES**

Story, Chapters 14-15
Science box, p. 26

EXPLORATIONS

Cover activity
“Matter of Fact!” p. 2

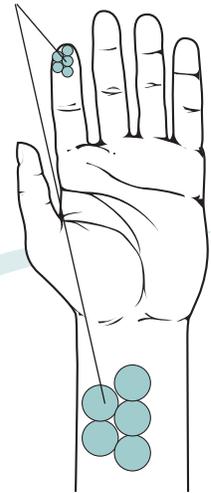
Amazing!

We feel only one pressure point (even though the testing tool has two) when both points fall within the same receptive field.

Encourage students to keep an open mind as they experience this remarkable phenomenon.

- Each team should test all three points shown at all four tip separation distances. For each test:
 - One student looks away and closes his/her eyes.
 - The other student sets the distance by using the scale on the discriminator as shown on the “Get The Point?” sheet and gently touches the first student at the indicated touch point.
 - The first student, whose eyes are closed, says “1” or “2” depending on whether he/she felt one or two points. Tell students they will not always be able to feel two points.
 - The other student writes a “1” or a “2” in the appropriate column on the Get The Point? data sheet. If the student being tested is not sure, the answer should be recorded as “1.”
 - Instruct students to intersperse the two-point tests with trials in which only one point is touched to all of the test locations. The results of the one-point tests will provide an element of unpredictability, which need not be recorded.
- After the first student completes the tests, have students switch roles and repeat the experiment
- Summarize data for the whole class by tallying student observations on the board. Have students compare results for the three test points. Conduct a discussion about differences in skin sensitivities among body areas. Help students to understand by asking questions such as, *How far apart did the points have to be before they felt like two points on your arm? On your palm? On your fingertip? Were there differences between you and your partner? Were there large differences in the class? Which of these three parts of your body must have the highest density of touch receptors? Which has the lowest density of touch receptors? Do you think that you can estimate the sizes of the receptive fields on your fingers, palm and forearm?*

Nerve endings and corresponding receptive fields



Comparison of receptive fields for touch in the finger and forearm.

BRAIN JOGGING

Here are more ideas for you and your students to explore.

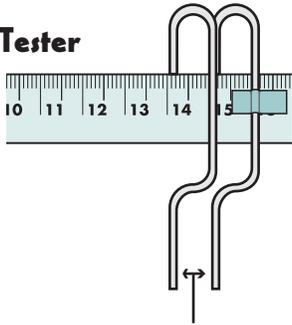
- Do you think that you have many or few sensory receptors in your nose? ears? back? thigh? scalp? sole of foot? elbow? knee? Try the two-point test on these or other parts of your body, if you wish. Why do you think it might be advantageous to have more receptors in one area than another?



GET THE POINT?

Create a testing tool by unbending two large paper clips and taping them to the thin ruler. One paper clip should be taped in place and remain fixed. Move the other clip along the ruler to create different distances between the points for testing.

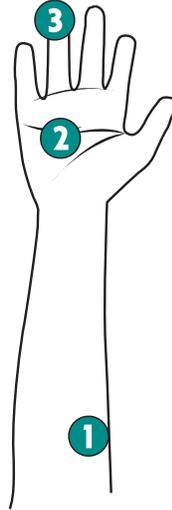
Tester



Each time the distance is set, gently tap the paper clip tips on a flat surface to make them even.

Test Point Locations

1. Inside of forearm
2. Palm of hand
3. Tip of finger



Tip Separation Measurements

5 mm	•	•
10 mm	•	•
15 mm	•	•
20 mm	•	•

How many points do you feel? Follow the instructions given by your teacher and complete the chart below.

		TIP SEPARATION			
		5 mm 1 or 2?	10 mm 1 or 2?	15 mm 1 or 2?	20 mm 1 or 2?
INSIDE OF FOREARM	Name				
	Name				
PALM OF HAND	Name				
	Name				
TIP OF FINGER	Name				
	Name				

MY SENSORY STRIP

8

A special part of the cerebrum, known as the *somatosensory cortex*, receives input only from the skin senses. This area lies right behind the motor cortex (see illustration, p. 4). The size of the cerebral area that receives information from each region of the body depends upon how many sensory receptors the particular body area contains. In other words, areas of the body with many sensory receptors (like

the fingers and lips) have much larger areas of cerebral cortex devoted to them than areas of the body with fewer receptors (like the legs).

In this activity, students will construct a “headband” that shows which parts of the somatosensory cortex receive information from different parts of the body. Students will compare the lengths of areas on the somatosensory cortex corresponding to

different parts of the body, and combine that knowledge with information from the previous activity about the sensitivity of the forearm, palm and fingertips.



Unit Links

THE COOKIE CRUMBLES
Story, Chapters 16-18

EXPLORATIONS
“Matter of Fact!” p. 2

OVERVIEW

Students make a model of the somatosensory cortex that they can wear, and they investigate which parts of the body correspond to the largest areas on the somatosensory cortex.

CONCEPTS

- A special part of the cerebrum, the somatosensory cortex, receives input from the body surface.
- Areas of the body that are important for the sense of touch have a large representation on the sensory cortex.

SCIENCE AND MATH SKILLS

Predicting, measuring, interpreting data and drawing conclusions

TIME

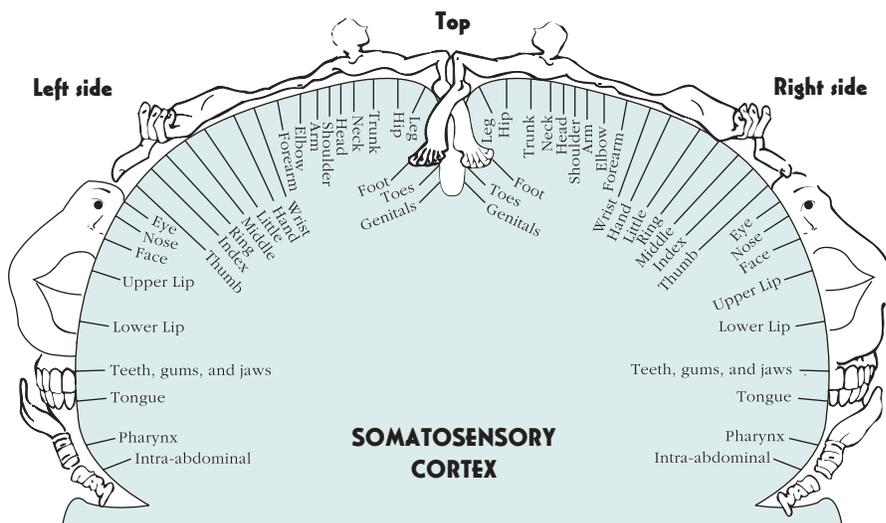
Preparation: 5 minutes

Class: 45 minutes

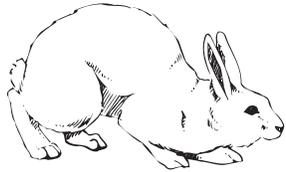
MATERIALS (See Setup)

Per Student Team of Two

- 2 pipe cleaners
- Clear tape or glue
- Metric ruler (millimeters)
- Pair of scissors
- Copy of “Sensory Strip” student page



Somatosensory cortex. The diagram above illustrates where touch information from different parts of the body are received in the somatosensory cortex. The diagram represents a cross section through the brain. The human shapes at the outer edges of the diagram provide a graphic representation of how much of the brain is devoted to the sense of touch from each body part. Traditionally, this representation is called a homunculus, which means “little human.”



Animals also have more sensory receptors in some parts of their bodies than in others.

SETUP

Divide the class into groups of 2–4 students to share materials. Each student will make a Sensory Strip.

PROCEDURE

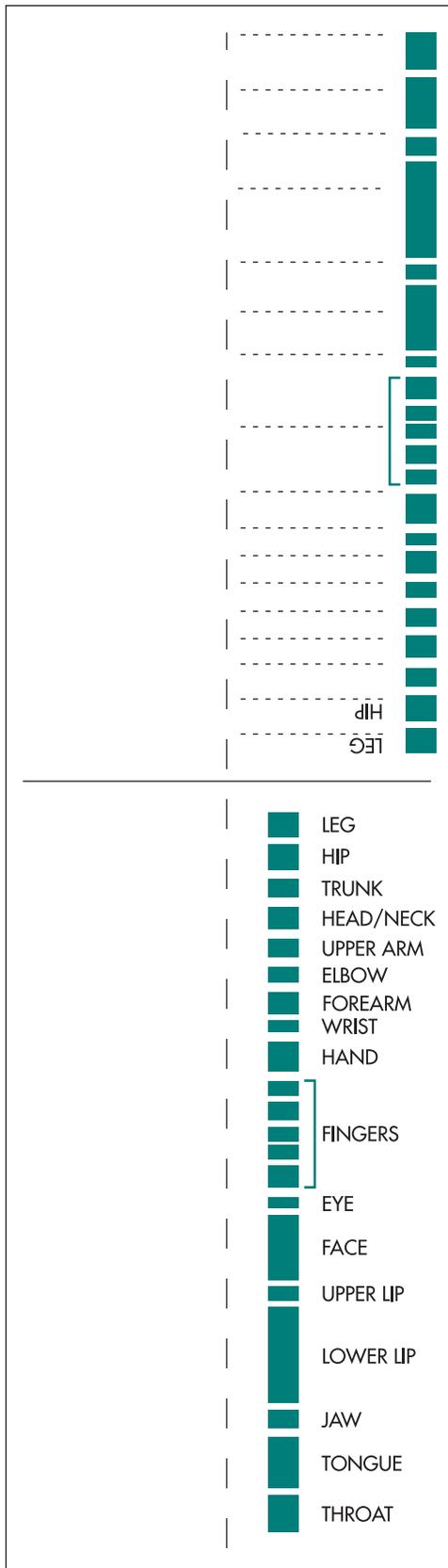
1. Tell students that they are going to create a model of the somatosensory cortex—the part of the brain that receives information about the sense of touch. If they already have created Motor Strips as described in the *BrainLink* Motor Highways unit, mention that the somatosensory cortex is similar to the motor cortex. In fact, it sits directly behind the motor cortex, across the top of the brain.
2. Have the materials managers pick up copies of the Sensory Strip student page, pipe cleaners and clear tape or glue for all members of their groups.
3. Explain that the areas marked on the Sensory Strip represent the approximate lengths of somatosensory cortex dedicated to information from the skin on different parts of the body. Larger areas of the sensory cortex correspond to regions of the body that have more receptors per unit area. Relate this information to the students' discovery about the sizes of receptive fields in the skin in Activity 7.
4. Have students measure the lengths of areas on the Sensory Strip corresponding to the upper arm, palm (hand) and fingertips. Write the numbers on the board or make a bar graph to compare them. Ask, *Which area is longer?* Next, have them use their Get the Point data sheets. Ask, *Which part had the smallest receptive fields (and, thus, the most receptors)? Which part had the largest receptive fields (fewest receptors)?* Relate this information to the measurements that they have made.
5. Let students make their strips by following the instructions on the Sensory Strip page.

BRAIN JOGGING

Here are more ideas for you and your students to explore.

- Like humans, other mammals have more sensory receptors for touch in certain parts of their bodies than in others. They also have correspondingly more cerebrum devoted to receiving input from the areas with more sensors. Based on each animal's lifestyle, try to deduce which body areas might occupy more of the sensory cortex in a rabbit, monkey, horse and cat.

SENSORY STRIP



The somatosensory cortex, or touch area, is a thin strip of nerve cells that sits across the top of the brain about where you would wear a set of headphones. It lies just behind the motor cortex. Different parts of the somatosensory cortex receive information from touch receptors in different areas of the body.

You can see where the touch area of your brain is located by making a Sensory Strip that you can wear. Each section of the strip will sit about where information from that part of the body is processed in your brain.

1. Cut out the large rectangle on this page.
2. Observe the labels on one side of the strip. Write in the names for each area on the other side of the strip, using the labeled side as a guide. Start at the midpoint. Both sides should be exactly the same.
3. Fold the rectangle along the dotted line.
4. Put a pipe cleaner inside the folded rectangle, and close the edges of the sheet with glue or tape.
5. Bend the strip into a U-shape like a headband or headphones, and try it on.

Can you find where your brain receives touch information from your fingers? Can you find where your brain receives information from your wrist? Which area takes up more space on the Sensory Strip? Why do you think that this is so?



OVERVIEW

Students apply concepts learned throughout the unit by creating and describing an imaginary “sense.” An opportunity also is provided for assessment through a language arts activity in which students read a poem and create their own verses. This activity may be used for pre- and/or post-assessment.

CONCEPTS

Concepts presented in preceding activities are reviewed and assessed.

SCIENCE AND MATH SKILLS

Modeling, problem solving and applying prior knowledge to new situations

TIME

Preparation: 5 minutes

Class: 45 minutes

MATERIALS (See Setup)**Per Student**

- Copy of “Senses! Oh, Senses!” page

The basic concepts covered in this unit answer the questions, “What are senses?” “Why do we have senses?” and “How do senses work?”

Senses are our “windows to the world.” It is through our senses that our brains obtain information about what is going on inside and outside our bodies.

Senses take in the information needed for survival.

External information is gathered by specialized receptors in the sense organs. Signals are then translated into a language that the entire nervous system understands, and relayed to the brain via sensory neurons. Specialized

parts of the cerebrum receive the signals. Other areas process, integrate and interpret the sensory signals.

SETUP

Students will have an opportunity to demonstrate what they have learned about the sensory system by inventing a unique “sense.”

This activity also may be used as a pre-test of student knowledge prior to beginning the unit.

The poem “Senses, Oh, Senses!” has been written by the BrainLink creators (with inspiration from Jack Prelutsky’s poem “Homework, Oh, Homework!” in his book, *The New Kid on the Block*). Many of the concepts presented and explored in this series of activities on sensory systems are included in the poem.

Students may add verses to “Senses, Oh, Senses!” or create their own poems. Each student’s poetry may be used as an additional post-assessment of the unit. Students may work individually or in groups.

PROCEDURE

1. If desired, review the major concepts in this unit, as outlined at the beginning of each activity.
2. Ask students, *Can you imagine a sense that you don’t have that you think would be fun or useful to have?* Examples might include a sense that detects the presence of chocolate or measures precisely the length of the school day! Review “Unusual Animal Senses” with students to prompt their thinking (see sidebar, page 37). Have students write a

**THE COOKIE CRUMBLES**

Story, Chapters 19-20

Science boxes: Review all

EXPLORATIONS

“Matter of Fact!” p. 2

“Did You Know?” p. 5

Unusual Animal Senses

Many animals have developed different types of senses, depending upon the particular environments in which they live and what, specifically, they need to know about their surroundings.

- What does the sense detect?
 - What would the sensory receptor look like and where would it be found on the body?
 - How would the information from the receptor be sent to the brain?
 - Where in the brain would the information be received for processing?
 - Why would this sense be useful or important?
3. Allow time for students to share their imagined sensory systems with the rest of the class or display their work somewhere in the classroom.
 4. To summarize concepts presented throughout the unit, use the poem, “Senses! Oh, Senses!” as a language arts extension activity.
 - Distribute the entire poem to the students and then ask them to create their own verses.
 - After reading the poem, let students write their own sensory poems.
 - Read a few of the verses to get them started, and then suggest that they write verses of their own.
 - Share the first few lines of each verse and have the students complete them with their own inspirations.
- Mosquitoes detect the presence of potential prey by sensing the carbon dioxide (CO₂) given off as waste from animal respiration.
 - Crabs and flies taste with their feet, allowing them to know immediately if they have landed upon something edible.
 - Some male moths can smell and then locate a potential mate several miles away by detecting airborne chemicals (pheromones) produced by the female.
 - Bats and whales send out sound signals and monitor the echoes to assess the nearness of obstacles, danger and food (echolocation).
 - Homing pigeons and other birds are believed to sense the Earth’s magnetic fields and use that information for navigation.
 - Electric fish generate electric fields around themselves that allow them to detect objects in their immediate vicinity.
 - Rattlesnakes use a special organ (the pit organ) to locate other animals, even in total darkness, by seeing an aura indicating the warmth of the other animal’s body.

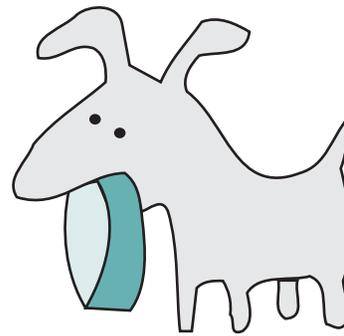


SENSES! OH, SENSES!

Senses! Oh, Senses!
I need you. You're great.
Without you I couldn't
taste what I ate,
or hear the homework
my teachers assign.
Senses! Oh, Senses!
You're truly divine.

I think that my eyes
give the best clues of all.
They show me what's out there
so I will not fall
right into a hole
or trip over a log,
or miss reading the comics
or seeing my dog.

Smelling's a sense
that all of us use.
Specialized neurons
give brains all the cues
to odors that smell good
and those that do not,
so we eat what smells yummy
and throw out the rot.



Thanks to those neurons
that signal my brain,
it's easy to tell
when I am in pain.
My fingertips have
such a keen sense of touch,
I can feel and not fumble.
I like that so much!

Senses! Oh, senses!
Oh, what would I do
without you to guide me?
I'd have not a clue
to what's going on
in the world all about.
My brain would be empty.
I'd really miss out!



GLOSSARY



auditory canal - part of the ear that leads from the outside of the head to the eardrum

auditory cortex - part of the cerebral cortex that receives information from the ears

axon - tail-like branch of a neuron along which messages are transported in the nervous system

blind spot - place in the back of the eye that contains no receptor cells and is the exit point for the optic nerve to the brain

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

central nervous system - the part of the nervous system in vertebrates that consists of the brain and spinal cord

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

cerebral cortex - the outermost component of the brain's cerebrum; controls our most advanced abilities, such as speech and reasoning

cerebrum - the large rounded outer layer of the brain where thinking and learning occur, sensory input is received and voluntary movement begins

cochlea - coiled structure of the inner ear, which is filled with tiny hairs that convert information received as sound waves by the eardrum into impulses that are sent along sensory neurons to hearing centers in the brain

cornea - clear membrane covering the front of the eye

decibel - a unit for measuring intensity, or loudness, of sound

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

ear canal - part of the ear that leads from the outside of the head to the eardrum

eardrum - a thin membrane, stretched tight inside the ear, which helps transmit sound waves to the inner part of the ear

inner ear - the inside part of the ear that functions in balance and in converting pressure waves originating as sound into nervous system signals

integration - putting or bringing parts together to make a whole

iris - colored portion of the front of the eye; surrounds the pupil

lens - part of the eye that focuses light on the retina; any clear object with at least one curved surface that focuses light

middle ear - a small cavity between the eardrum and the inner ear where three small bones pass sound waves along to inner ear

motor cortex - the region of the cerebrum responsible for starting and controlling voluntary movement, located in a narrow strip across the top of the brain

motor neuron - a type of nervous system cell, originating in the brain or spinal cord, that conducts signals to muscles, resulting in movement

multiple sclerosis - nervous system disease in which the myelin sheath covering nerve fibers is broken down—results in a gradual weakening of the muscles

nanometer - unit of measurement equivalent to one billionth of a meter

nerve cell - neuron; a cell of the nervous system that conducts a signal from one part of the body to another

nerve - a bundle of nerve fibers and associated cells

nerve ending - one of many tree-like branches extending from the body of a neuron on which signals are received; also called a dendrite

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

neuron - a cell of the nervous system that conducts a signal from one part of the body to another



neuroscience - a branch of science related to the study of the nervous system

olfactory cortex - part of the cortex that receives information about smell from receptors inside the nose

optic nerve - bundle of axons leading from the back of the eye to the visual cortex

pupil - opening in the front of the eye where light enters

receptive field - the area from which one sensory receptor cell receives information

receptor - a cell or group of cells that receives stimuli from inside or outside the body

retina - portion of the eye upon which light is focused; consists of specialized light-sensitive cells (rods and cones)

sensation - an awareness of stimulation of any of the senses, such as sight, smell, touch, etc.

sense - 1) a function of the body by which one is made aware of the world outside, as sight, hearing, touch, smell or taste, or of conditions inside the body, as pain or hunger; 2) a feeling or awareness; 3) to become aware of

sense organ - body part specialized to receive sensory information, such as the eye, ear, nose, tongue or skin

somatosensory cortex - thin layer across the top of the cerebrum dedicated to receiving information from the

skin senses (touch), located just to the rear of the motor cortex

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

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

sound wave - alternating bands of high and low pressure, detected as sound, produced when an object vibrates in air (or another medium, such as water)

stimulus - an agent that influences the activity of sensory nerves

taste bud - receptor units located on the tongue that are stimulated by chemicals and are responsible for providing information about taste to the brain

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

tympanic membrane - eardrum; thin membrane in the ear canal that transmits sound waves to the inner part of the ear

visual cortex - part of the cortex that receives information from the eyes



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