

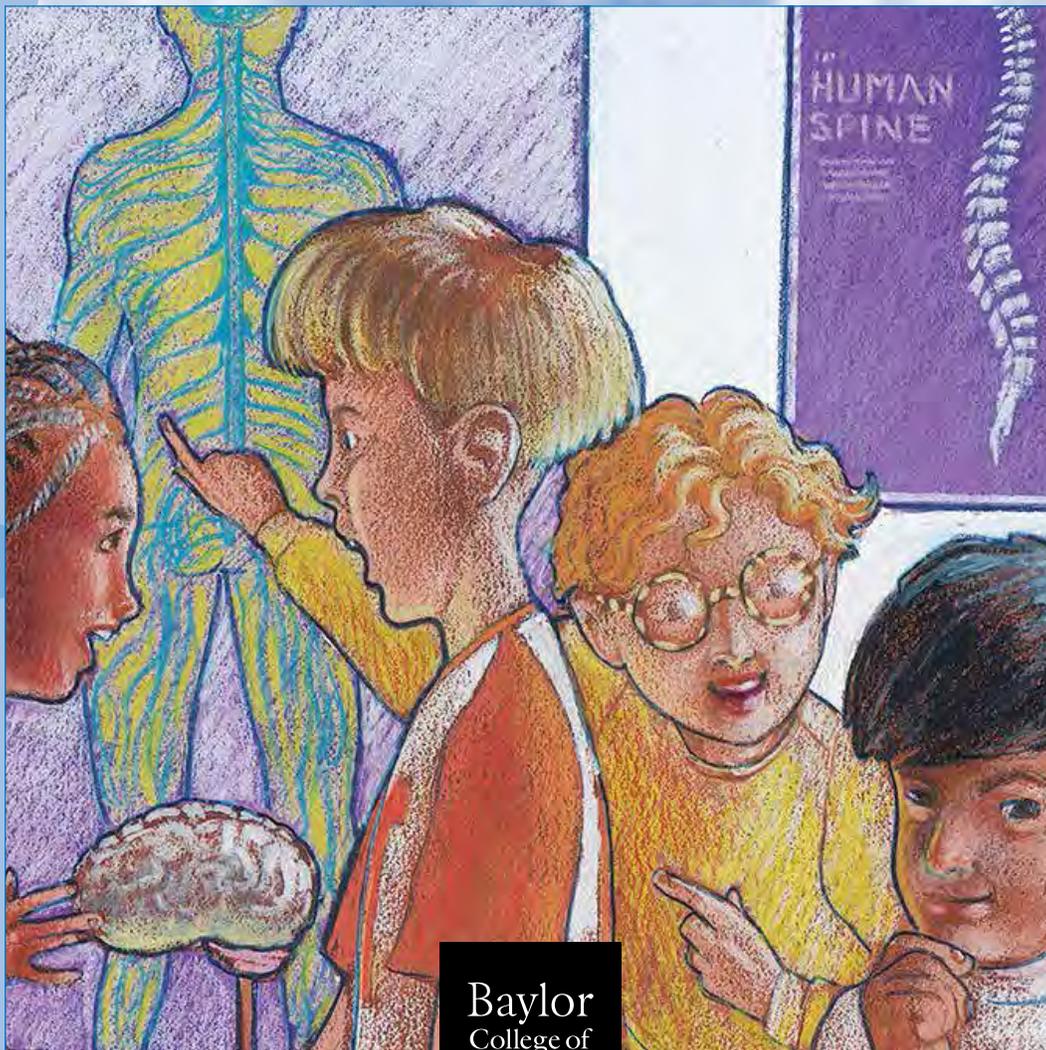


THE MOTOR SYSTEM

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

ISBN: 978-1-944035-15-0
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Fourth edition. First edition published 1992.
Published previously under the title, *Motor Highways Teacher's Guide*.
Printed in the United States of America.

ISBN: 978-1-944035-15-0

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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.

Development of BrainLink[®] educational materials was supported, in part, by funds from the National Institutes of Health, Science Education Partnership Award grant number R25 RR09833. The opinions, findings and conclusions expressed in this publication are solely those of the authors and do not necessarily reflect the views of Baylor College of Medicine, the sponsoring agency, or the publisher.

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THE MOTOR SYSTEM

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

- *Trouble at Tsavo: The Tale of the Black Rhino*
- *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

The BrainLink® project at Baylor College of Medicine has benefited from the vision and expertise of scientists and educators from a wide range of specialties. Our heartfelt appreciation goes to James Patrick, Ph.D., Vice President and Dean of Research, and Head, Division of Neuroscience; Stanley Appel, M.D., Professor and Chairman of Neurology; Carlos Vallbona, M.D., Distinguished Service Professor of Family and Community Medicine; and William A. Thomson, Ph.D., Professor of Family and Community Medicine at Baylor College of Medicine, who have lent their support and expertise to the project. We also express our gratitude to Cynthia Bandemer, M.P.H., Director of Education, Houston Museum of Health and Medical Science, who directed BrainLink activities sponsored by the Harris County Medical Society.

Members of the original BrainLink steering committee provided much valued vision and inspiration for shaping the original direction and design of the project: Terry Contant, Ph.D.; Barbara Fouts, M.S.; Anne Hayman, Ph.D.; Judith Livingston, M.Ed.; Christina Meyers, Ph.D.; Kathleen Philbin, Ph.D.; Carolyn Sumners, Ed.D.; and Katherine Taber, Ph.D.

Several colleagues provided guidance during the production of this guide. In particular, we would like to offer our special thanks to: Vickie Appel, B.S.N.; Celia Clay, M.P.H.; Dane Chetkovich, M.D., Ph.D.; Greg Duncan, M.S.; Carol Johnson, H.T.; Ilene Schwarz, M.Ed.; and Ray Warner, Ph.D. We also are grateful to Sara Copeland and Michael Levy of the Division of Neurosciences, Baylor College of Medicine, who helped update the science content of this revised edition.

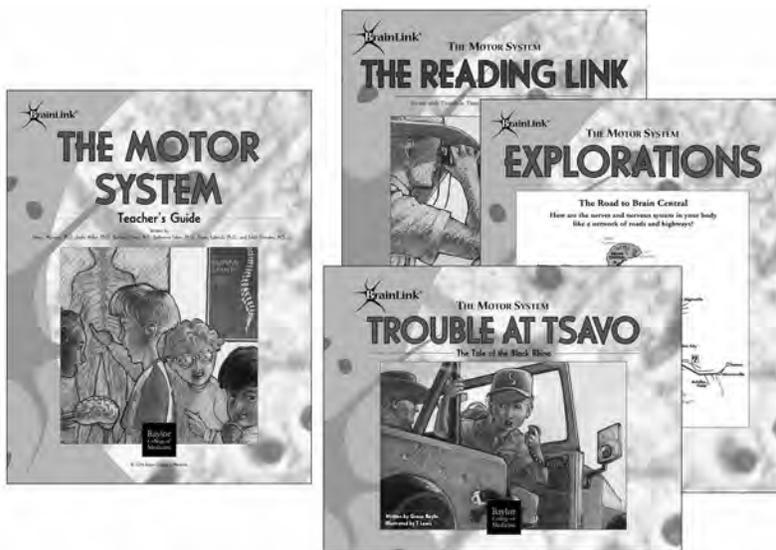
Special thanks go to the National Institutes of Health, Science Education Partnership Award Program for its support of the BrainLink® project.

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 adventure stories “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 integrated components of this BrainLink® unit help students learn why their brains make them special.

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

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 SYTEM

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

BRAIN CHEMISTRY

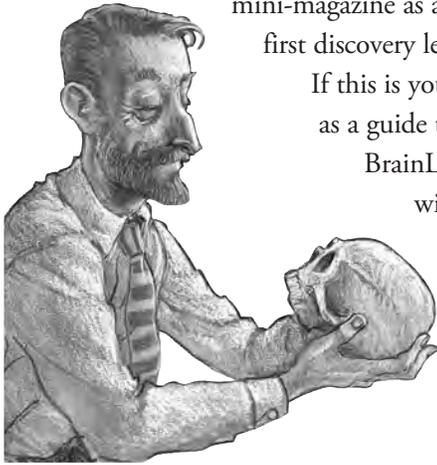
(the brain and neurons, chemical communication in the body, risk perception vs. reality, and how personal choices can affect brain function and performance)

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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 Motor System unit’s adventures story (*Trouble at Tsavo*) 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	
			TROUBLE AT TSAVO	EXPLORATIONS
1. Signals and Synapses	Muscles and the nervous system work together for movement.	1	Story, Chapters 1–3 Science boxes, p. 4 and 5	Cover activity
2. Make a Neuron	The brain is shielded by the skull, which also needs protection.	1	Story, Chapters 4–6 Science box, p. 12	Cover activity “Matter of Fact!” p. 2–3
3. Eye Openers	Involuntary movements such as reflexes, happen without thinking.	1	Story, Chapters 7–8 Science box, p. 15	“Brain Busters!” p. 7 “Faster than Fast!” p. 8
4. Real Knee Jerkers	The knee jerk reflex is processed through the spinal cord.	1	Story, Chapter 9	“Faster than Fast!” p. 8
5. Practice Makes Perfect	Voluntary movements are directed by the motor cortex.	1	Story, Chapter 10 Science box, p. 22	“Now Switching to Auto Pilot...” p. 6
6. Take a Walk	Programs for well-learned movements are stored in the cerebellum.	1	Story, Chapter, 11 Science box, p. 22	“Matter of Fact!” p. 2–3 Brain Busters!, p. 7
7. My Motor Strip	Different areas of the motor cortex direct different muscle groups.	1	Story, Chapter 12 Science boxes, p. 29 and 30	“Matter of Fact!” (drawings), p. 2 and 3
8. Motor System Model	The spine protects the spinal cord. Spinal damage affects movement.	1	Story, Chapter 13 Science boxes, p. 5, 15 and 22	“Not Just Horsing Around” p. 4 “Double Trouble!” p. 5
9. Moving Biographies	Neuron pathways for movement are disrupted in some diseases.	1 or more	Story, Chapter 14; Science boxes, p. 30 and 33	“Did You Know?” p. 5 “Careers for NeuroExplorers,” p. 7
10. Kids on the Move	Summary and assessment activity.	1 or 2	Science boxes: Review all.	Cover activity “Matter of Fact!” p. 2–3



UNIT MATERIALS

Activity 5: Suggested Objects

You will need to obtain 10 different small objects per group of students, such as pieces of uncooked pasta, jacks, erasers, etc.) that students will pickup with the chopsticks.

Activity 8: Make Your Own Modeling Dough

- 2 cups of flour
- 2 cups of water
- 4 tsp cream of tartar
- 1/4 cup of vegetable oil
- 1 cup of salt
- Food coloring (red, blue, yellow)

Combine flour, water and cream of tartar in a large bowl or blender. Mix until lumps disappear.

Add oil and food coloring.

Put mixture in a saucepan and add salt. Stir and cook over low heat until mixture becomes lumpy.

Empty mixture waxed paper covered counter. Knead to smooth out lumps. Let cool.

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 white index cards, 3 in. x 5 in.
- 24 pieces of string, approx. 20-in. length.
- 6 hole punches

ACTIVITY 2 (p. 4)

- 72 pipe cleaners
- Masking tape
- Modeling clay (enough for each student to form a 1- to 2-in. ball)

ACTIVITY 3 (p. 9)

- 12 index cards, 3 in. x 5 in.
- 6 penlights (or small flashlights)

ACTIVITY 4 (p. 12)

- 24 markers (to make 6 sets of black, blue, green and red markers)
- 6 rubber percussion hammers

ACTIVITY 5 (p. 15)

- 120 small objects
- 24 markers (to make 6 marker sets of black, blue, green and red markers)
- 12 pairs of chopsticks
- 12 resealable plastic bags
- 12 stopwatches (or clock with a second hand)
- 2 self-adhesive notepads, two different colors, 3 in. x 3 in.

ACTIVITY 6 (p. 19)

No special materials required.

ACTIVITY 7 (p. 21)

- 24 pipe cleaners
- 6 pairs of scissors
- 6 metric rulers (millimeters)
- Glue or clear tape

ACTIVITY 8 (p. 24)

- 24 sets of red, blue and yellow modeling clay (1.5 cm. dia. each of red and blue; 2.5 cm dia. of yellow)
- 24 sheets of white cardstock, 8.5 in. x 11 in.
- 24 colored plastic drinking straws (any color, not clear)
- 24 pieces of red and black embroidery thread, 12-in. length of each color
- 24 paper clips
- 24 pairs of scissors
- 24 wide-tip markers
- Glue (or clear tape)

ACTIVITY 9 (p. 29)

No special materials required.

ACTIVITY 10 (p. 35)

- 24 sheets of wide kraft paper, approx. 1.5–2 meter in length
- 6 sets of markers in 5 different colors

SIGNALS AND SYNAPSES

The basic building block of the nervous system is the nerve cell, or neuron. Within the body, neurons form vast communications networks in which they are linked with one another, as well as with muscles, sensing organs and other structures.

Billions of neurons form the command center of the body, the brain. The brain connects at the base of the brainstem to the spinal cord—a

thick bundle of nerve fibers that runs inside the spine. Together, the brain and spinal cord make up the central nervous system. The remaining network of nerves throughout the body and head constitutes the peripheral nervous system.

The complete nervous system is made up of the brain, the spinal cord, and all of the neurons and associated cells (see sidebars, p. 2–3).

Only certain portions of the nervous system are involved in producing movement of the body or parts of the body. In this guide, we refer to the parts of the nervous system

that are involved in movement as “motor highways” or “pathways.” All of the motor pathways, from the simplest to the most complex, involve transporting messages along components of the nervous system. Some messages travel from the brain and spinal cord to the muscles. Other messages are transported from sensing organs like ears and skin, as well as from muscles, to the central nervous system.

Two types of neurons carry information necessary for motor function.

- **Motor neurons** conduct signals from the brain or spinal cord to muscles that stimulate muscles to shorten (contract) or lengthen (relax).
- **Sensory neurons** carry information from sensing organs such as eyes, ears, nose, tongue and skin, as well as information about what the muscles are doing, to the spinal cord and brain.

The nervous system and muscles act together to achieve movement of or within the body. Signals that trigger movement are generated in the brain or spinal cord and then travel along motor neurons to the muscles. The



Unit Links

TROUBLE AT TSAVO

Story, Chapters 1–3

Science boxes, p. 4 and 5

(If using BrainLink for the first time, have students read “How the NeuroExplorers Club Began,” and “The NeuroExplorers,” p. iv–vi.)

EXPLORATIONS

Cover activity

OVERVIEW

Using a simple game, students model how signals are sent along nerve cells within the body to achieve movement.

CONCEPTS

- The basic building block of the nervous system is the neuron.
- Neurons transport messages within the body.
- The muscles and the nervous system work together to achieve movement.

SCIENCE AND MATH SKILLS

Problem solving, modeling and inferring

TIME

Preparation: 10 minutes

Class: 30–45 minutes

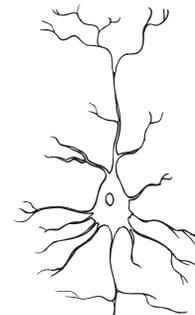
MATERIALS (See Setup)

Per Student Group

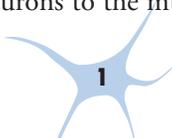
- Hole punch

Per Student

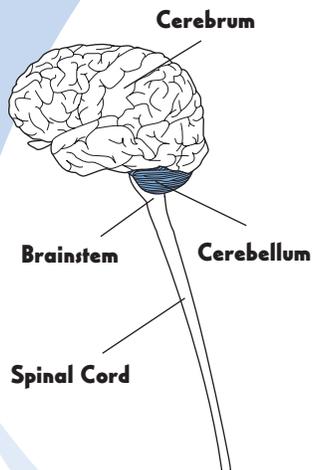
- Piece of string, approx. 20-in.
- White index card, 3 in. x 5 in.



The human nervous system contains approximately 100 billion, or 10^{11} neurons.



The Central Nervous System



The brain and spinal cord make up the central nervous system. The brain is composed of the cerebrum, cerebellum and brainstem.

The brainstem controls automatic activities of the body, such as heart-beat and swallowing. The cerebellum helps muscles work together for coordination and learning of rote movements.

The cerebrum is responsible for thinking, learning, remembering, feeling sensations and emotions, and moving muscles voluntarily.

signals travel very rapidly along the nerve cells and are transmitted chemically or electrically from one neuron to another across tiny gaps, called synapses. Signals also are sent along sensory neurons from muscles and sensing organs to the spinal cord or brain.

In this activity, students will model the simplest kind of interaction among the brain, motor and sensory neurons, and the muscles. Working in teams, students will devise a message-sending system that will allow the “brain” to send a message along “motor neurons” to a “muscle.” “Sensory neurons” will respond by sending a message back to the “brain” about whether the “muscle” carried out the instructions.

SETUP

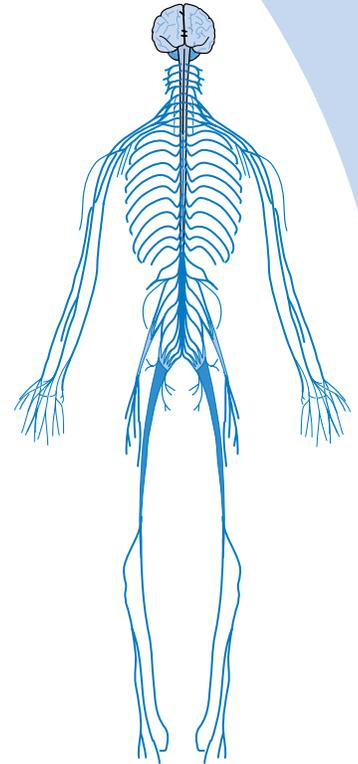
Conduct the initial portion of this activity with the entire class. Then divide the class into groups of four students.

As an alternative to index cards and string, paper plates or construction paper and large safety pins may be used.

PROCEDURE

1. Before beginning any discussion, have the students sit very quietly in their seats. Ask, *Is anyone moving?* After students have had a chance to reply, ask, *Is any part of your body moving?* Give students time to think about their answers. They might mention that their ribcages are moving as they breathe or that someone’s eyelid moved as he or she blinked, etc.
2. Now, ask everyone to stand and jump or turn around. Ask, *What is moving now?* List on the board all the different parts of the body mentioned by students. Explain that all of the movements they have mentioned, including the automatic ones they noticed while sitting quietly, are directed and controlled by the nervous system. Mention that they will now begin to explore how the brain and rest of the nervous system direct movement by sending signals to the muscles of the body.
3. Ask the students if they have ever played a game in which they pass a message around a circle. Let them discuss the different ways in which they have played games of this type.
4. Explain that the body also has ways to send messages from one part to another and that the message carriers are cells called “neurons.” Tell students that the brain is made up of billions of interlinked neurons and that neurons communicate with one another, with muscles, with sensing organs like eyes and ears, and with other organs in the body. Point out that neurons manage to pass signals from one to another without actually touching.

The Central Nervous System



The human nervous system is made up of the brain, the spinal cord, and all of the neurons and associated cells in the body.

5. Divide the class into groups. Each group will have one student represent the following: the “brain,” a “brain-to-muscle motor neuron,” a “muscle,” and a “muscle-to-brain sensory neuron.” Each student should create a badge identifying his or her role, using an index card, string and marker or pen.
6. Let the members of each group wear their respective badges as they brainstorm ways in which a message could be sent from brain to muscle and back without physical contact between students. Talk about the basic sequence of events that occurs when a movement is initiated. The brain sends a signal along one or more motor neurons to a muscle. The muscle reacts as instructed, and sensors within the muscle send a new signal back to the brain along sensory neurons. The return signal lets the brain know that the action has taken place.
7. Each group should devise its own message-sending system between the muscle and the brain (speaking not allowed). An example would be for students to pass a written note from “brain” to “motor neuron” to “muscle” calling for the muscle to perform a particular action (stand up, raise hand, etc.). After reacting, the muscle would send its own message back to the brain through the sensory neuron.
8. Allow time for each group to present its message-sending system to the rest of the class.

BRAIN JOGGING

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

- Why is it important for one part of the body to communicate with another? What would happen if your stomach could not tell your brain that it was full, or your hand could not signal that it was touching something hot?
- The word “neuron” comes from the Greek language. After reading the introduction to *Trouble at Tsavo*, how many words could you find that are made from the same root as neuron. Try creating your own “neuro-” words!

OVERVIEW

Students create three-dimensional models of neurons (nerve cells).

CONCEPTS

- Neurons have special parts that are important for sending and receiving messages or signals.
- There are many different kinds of neurons.

SCIENCE AND MATH SKILLS

Modeling and inferring

TIME

Preparation: 10 minutes

Class: 30-45 minutes

MATERIALS (See Setup)**Per Student**

- 3 pipe cleaners
- Masking tape
- Modeling clay, enough to form a 1- to 2-in. ball
- Copy “Brain Diagram,” “Know Your Neurons” and “Neurons and More Neurons” pages

Within the nervous system, each neuron transmits messages along tail-like branches known as axons. Messages are received on the cell body and on tree-like branches known as dendrites.

Although neurons are microscopic, the dendrites and axons (also known as nerve fibers) can be very long. Some axons exceed one meter in length and extend from the brain into the lower part of the spinal cord or from the spinal cord into the arms or legs. The word nerve is used in a general sense to describe a bundle of nerve fibers and associated cells.

Messages can travel in only one direction along a neuron or series of neurons, such as those shown in “Message Carriers” (sidebar, p. 5).

Other types of cells in the nervous system include specialized receptors (like those in the eye or ear), cells that supply nutrients to neurons, and cells that insulate nerve fibers. The insulating cells form a segmented fatty shield, called a myelin sheath, that allows signals to travel faster along axons (nerve fibers).

Gray matter refers to nervous system tissue that is composed primarily of cell bodies and axons without a myelin sheath. Gray matter makes up much of the surface of the brain and the central core of the spinal cord. Axons covered with a myelin sheath, described as white matter, are present in the inner brain, outer spinal cord and nerves.

SETUP

Conduct this activity with the entire class. Place materials in a central location. Students should work in teams or small groups.

As an alternative, you may use styrofoam spheres instead of modeling clay. Make several holes in each sphere with a knitting needle or with a skewer prior to class. Or, make your own modeling clay (see “Make Your Own Modeling Dough,” p. vi).

PROCEDURE

1. Distribute copies of the “Brain Diagram” page and review the major parts of the brain, if necessary. Next, distribute the “Know Your Neurons” page. Mention that neurons send messages along long branches called axons. Help students find the longest branch on each

**TROUBLE AT TSAVO**

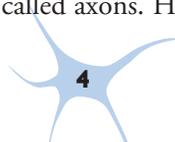
Story, Chapters 4-6

Science box, p. 12

EXPLORATIONS

Cover activity

“Matter of Fact!” p. 2-3



Message Carriers

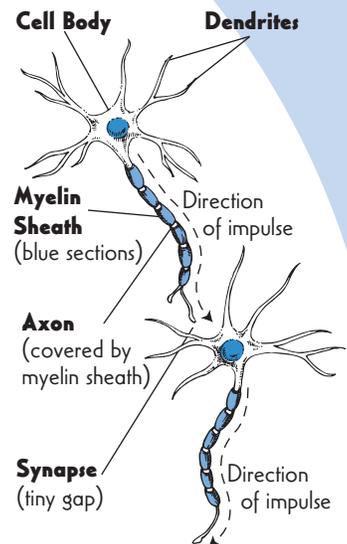
neuron. These are the axons. Next, have students find the shorter branches. These are called dendrites. Messages from other neurons are received on the dendrites and sometimes on the cell body. Point out the myelin sheath surrounding the axon (looks like a string of beads) and the synapse (tiny gap between neurons). Have students label the parts.

2. Tell students that they will create their own neuron models. Distribute copies of the “Neurons and More Neurons” page at this point to give students some ideas about the variety of neurons that exist in the body. Point out the axons, dendrites and cell bodies on the different types of neurons.
3. Have Materials Managers pick up supplies for their groups. Instruct students to roll the clay into a 1- to 2-inch ball (cell body of the nerve cell). Direct students to fold and insert pipe cleaners through the cell bodies of their models to create branches (dendrites—see illustration, right sidebar).
4. Tell the students to create an axon on each of their models by attaching an unfolded, long pipe cleaner to one of the branches.
5. Have students wrap 1-in. pieces of masking tape at 1/8-in. to 1/4-in. intervals along the “axon” to represent the myelin sheath.
6. Let students share their neuron models with the rest of the class or display them in the classroom or on a bulletin board.

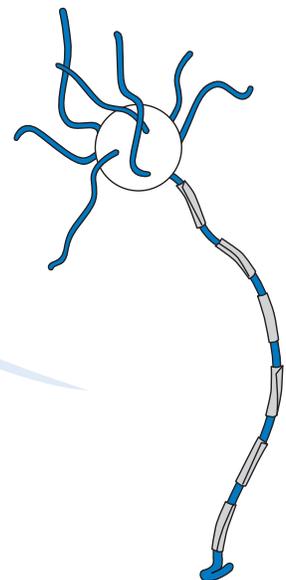
BRAIN JOGGING

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

- Someone might say, “Her synapses are really firing today.” What might such a statement mean? What would happen if synapses were not firing? (Synapse “firing” refers to the chemical or electrical transmission of signals from one neuron to another across the synapses, or tiny gaps between cells.)
- Neurons are connected within vast networks to allow the brain to communicate with the rest of the body. Have students in groups or as a class figure out ways to link their neurons in a communications network—remembering that axons usually lead to dendrites or cell bodies on other neurons.



Messages are received by the dendrites or the cell body, passed down the axon and sent across the synaptic gap to the next neuron or series of neurons. Neurons do not touch as they pass messages across the synaptic gap.

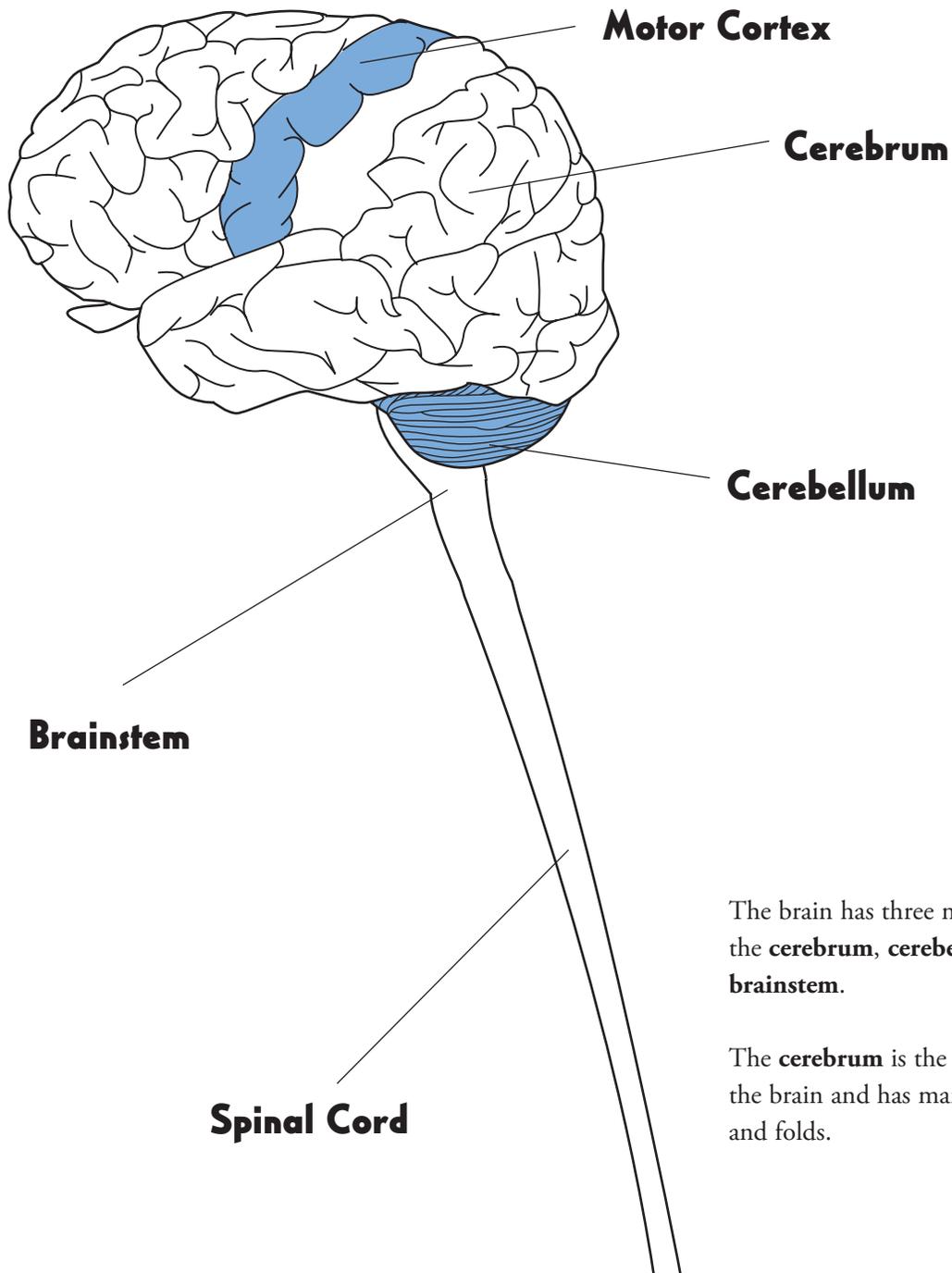


Students create their own neuron models.



BRAIN DIAGRAM

The central nervous system consists of the brain and spinal cord.



The brain has three major parts: the **cerebrum**, **cerebellum** and **brainstem**.

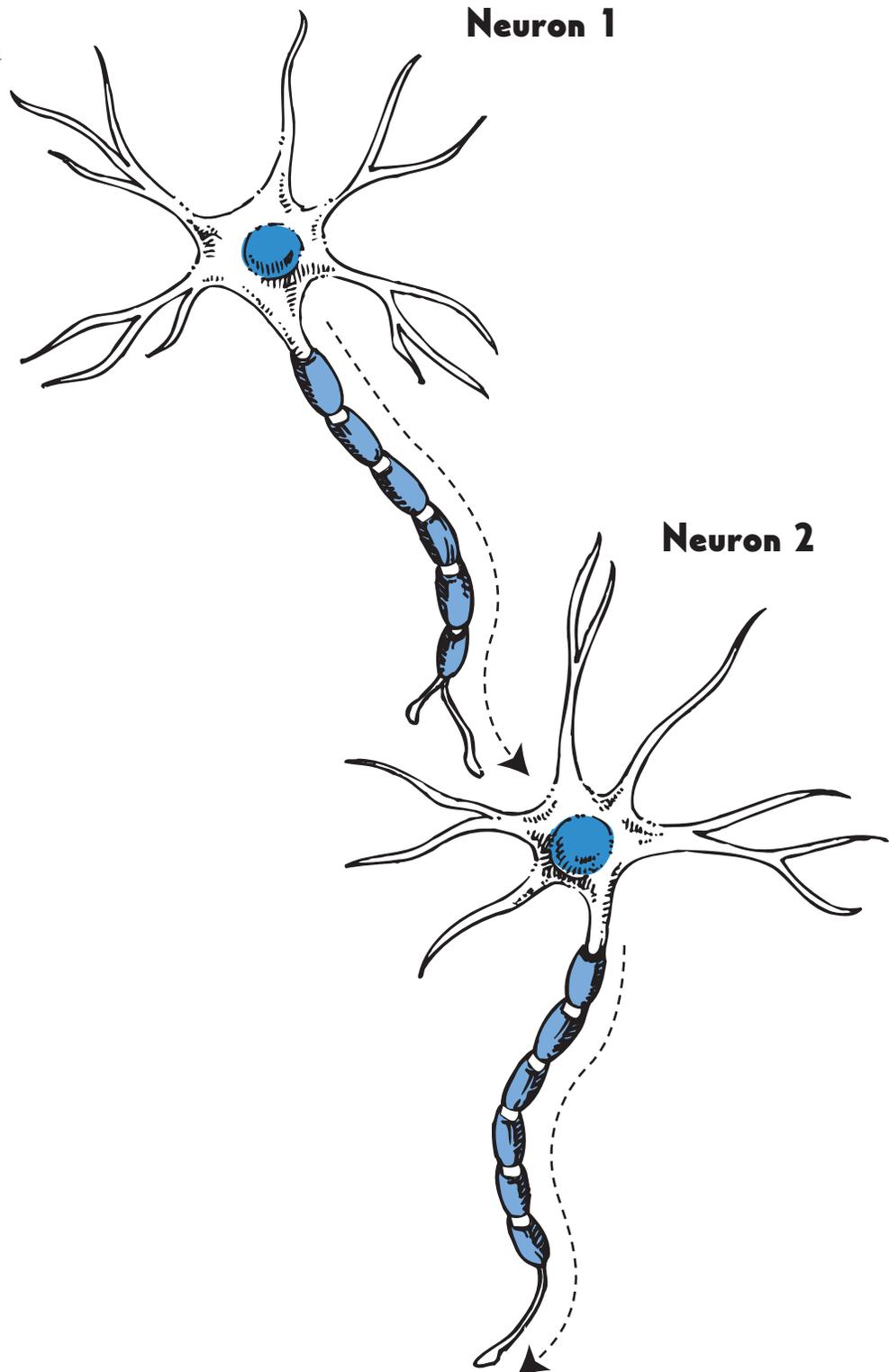
The **cerebrum** is the largest part of the brain and has many wrinkles and folds.



KNOW YOUR NEURONS



1. Find the **axons** (long branches) that lead from one neuron to the next.
2. Locate the **dendrites** (short branches) on the neurons.
3. Find the **myelin sheath** that covers each axon.
4. Find the **cell body** of each neuron.
5. Locate the **synapse** (tiny gap between the neurons, over which messages pass). Draw a circle around it.
6. Label the parts of the neurons.

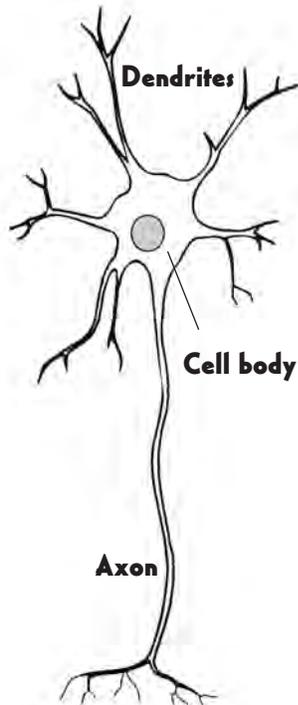




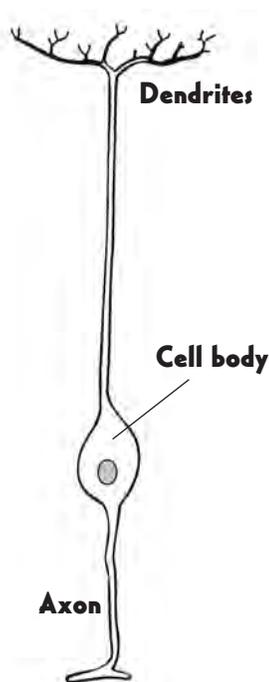
2 NEURONS AND MORE NEURONS

There are more than 10,000 kinds of neurons in the human body! Pictured below are examples of four different neurons. Some neurons are simple structures in which the axon and dendrites are easily identified. Others are very complicated, with hundreds of tiny branches—such as the neurons found in the hippocampus (important for memory and learning) or cerebellum.

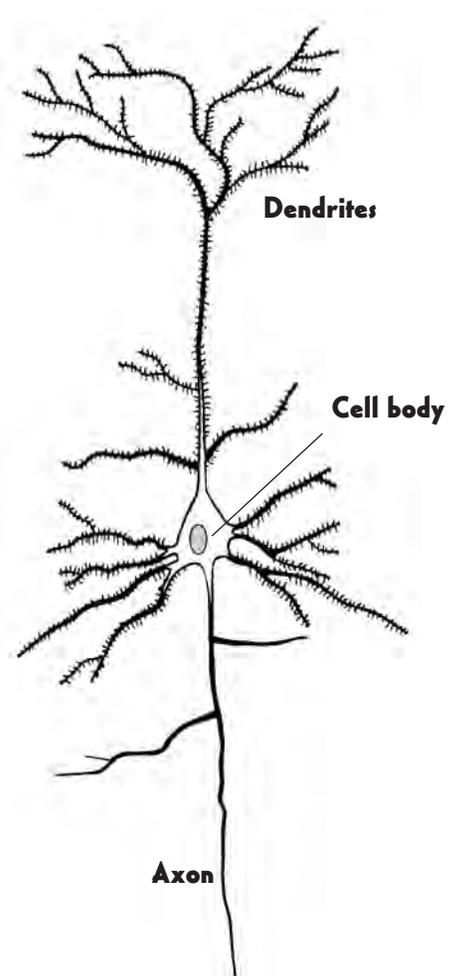
**Motor Neuron
from the Spinal Cord**



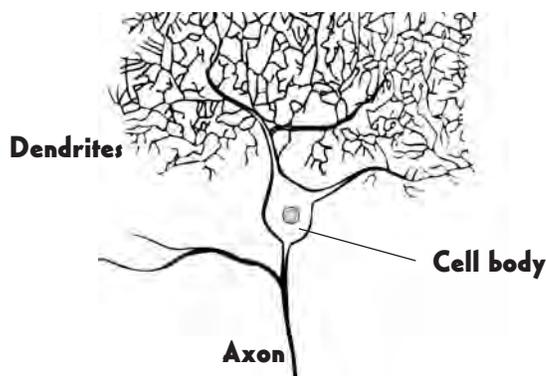
**Sensory Neuron
from the Eye**



**Neuron
from the Hippocampus**



**Neuron
from the Cerebellum**



EYE OPENERS



Many movements of our bodies happen automatically. Some of them, such as breathing, movement of food through the digestive system and beating of the heart, help keep all parts of the body working properly. Automatic functions like these are regulated primarily by the brainstem.

Other automatic movements occur as a response to a stimulus or a sudden change in conditions (such as exposure to a bright light or coming in contact with something very hot or very cold). These movements



TROUBLE AT TSAVO

Story, Chapters 7-8
Science box, p. 15

EXPLORATIONS

"Brain Busters!" p. 7
"Faster than Fast!" p. 8

are called reflexes. Examples of reflexes include pulling away quickly from something hot or sharp, or the adjustment of the pupil of the eye in response to sudden bright light. Reflexes that involve muscles of the face or head are directed through pathways in the brainstem. Other reflexes follow pathways in the spinal cord, as will be examined in Activity 4. Many reflexes, such as the startle reflex or blinking, help protect the body from harm. Others play a role

in the coordination of complex movements involving many muscles. The patellar (knee jerk) reflex, for example, helps to ensure that the legs remain rigid while standing.

Reflex responses are rapid because they follow simple pathways that do not need to include the cerebrum or the cerebellum. In a typical reflex, sensory neurons communicate directly with motor neurons at a central point in the spinal cord or in the brainstem. The motor neurons receive the signals and immediately stimulate the appropriate muscles to respond. The thinking part of the brain does not have to enter into the signal-response loop, which sometimes is referred to as a reflex arc.

Reflexes and automatic body functions are considered involuntary movements. These types of movements, which are essential for survival, are governed by the most primitive parts of the nervous system—the brainstem and the spinal cord. No thinking is required! Even very simple animals show basic reflex responses and have a nervous system that governs essential body functions.

When you look at a bright light, the pupils in both of your eyes automatically become smaller. This is a reflex response triggered by too much light. The light is detected by sensory neurons at the back of the

OVERVIEW

Students learn about reflexes as they investigate the effect of bright light on pupil size.

CONCEPTS

- Involuntary movements happen without us thinking about them.
- Reflexes are a kind of involuntary movement.
- Some reflexes are processed through the brainstem.

SCIENCE AND MATH SKILLS

Predicting, observing and drawing conclusions

TIME

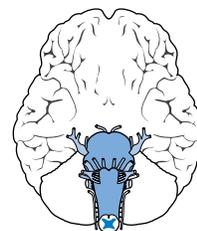
Preparation: 10 minutes

Class: 30 minutes

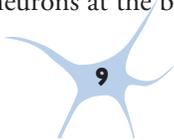
MATERIALS (See Setup)

Per Student Team of Two

- 2 index cards, 3 in. x 5 in.
- Penlight (or small flashlight)



The brainstem (viewed from below) is where automatic functions like breathing, etc., are regulated.



eye that transmit messages to the brainstem region of the brain. There, the message is received by neurons that signal muscles of the iris to reduce the size of the pupil. The thinking part of the brain also receives a message about the presence of potentially harmful bright light. However, by the time you think to shield your eyes, your pupils already have reacted.

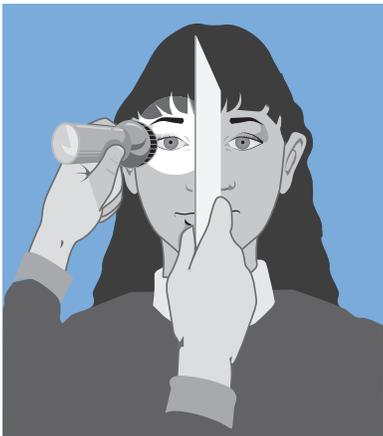
Neurologists (medical doctors specializing in the nervous system) shine a light in the patient's eyes to check pupil contraction. Surprisingly, normal pupils always will contract together, even if only one eye is exposed to bright light. This happens because the sensory neurons that detect light in each eye form synapses in the brainstem with motor neurons for both pupils. In other words, they are “wired” together!

SETUP

After a class discussion, have students work in groups of 2. Place penlights and notecards in a central location for the Materials Managers to collect.

PROCEDURE

1. Introduce the concepts of involuntary movements and reflexes with a class discussion. Ask, *What movements of your body happen even when you are sitting quietly or sleeping? Do you have to think about these movements in order for them to happen? What might happen if you did have to remember to breathe or have your heart beat? How about when you touch something hot? What would happen if you had to think about pulling your hand away?*
2. Mention that many involuntary movements are controlled by the brainstem. Remind students of the brainstem's location at the back of the head above the spinal cord. Mention that they will be exploring one automatic response governed through the brainstem—the pupil reflex.
3. Darken the room as much as possible. Show students a penlight and ask them to predict what might happen if the light is directed toward (not directly into) only one eye of a person. Have them discuss their predictions in small groups and record their observations in their science journals or notebooks.
4. With students working in pairs or small groups, have them observe the pupil reflex. The Materials Manager of each group should be the “subject” and hold an index card between his or her eyes. Have each Principal Investigator shine a penlight toward (not directly into) only one of the subject's eyes. The other members of the group should observe the reactions of both of the subject's eyes. Students should notice that both pupils will contract, even though only one pupil has been exposed to bright light. If time permits, let students take turns.



Students will shine a light toward one of the subject's eyes while observing the size of both pupils.

- 
5. Discuss the mechanism behind the pupil reflex. Ask, *When you go into bright sunlight from a dark room, what happens to your pupils?* (They become smaller.) *How about when you enter a dark room?* (They relax and become larger.) *Why do you think both pupils reacted to the bright light?* Help students understand that the sensory neurons from one eye formed connections, or synapses, with motor neurons for both eyes. Mention that the pupil reflex travels through pathways from the eye to the brainstem and back to the eye, without involving the cerebrum—the thinking part of the brain.
 6. Have students write a paragraph describing the investigation and their results.

BRAIN JOGGING

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

- Why do you think it might be useful for both eyes to respond to bright light, when only one is exposed to it? Can you think of any other times when different parts of the body might react together?
- Is it possible to control the size of the pupils of your eyes by thinking about it? Can you modify any other reflex responses? For example, can you keep yourself from coughing or blinking?

OVERVIEW

Students explore the patellar reflex as they learn about motor responses controlled in the spinal cord.

CONCEPTS

- Some reflexes are processed through the spinal cord.
- The “knee jerk,” or patellar reflex, is an example of a spinal reflex.

SCIENCE AND MATH SKILLS

Predicting, observing and drawing conclusions

TIME

Preparation: 10 minutes

Class: 30–45 minutes

MATERIALS**Per Student Group**

- Rubber percussion hammer
- Set of black, blue, green and red markers

Per Student

- Copy of “Reflex Reactions” page

The Knee Jerk Reflex

The knee jerk reflex is based on sensory information from stretch receptors in the quadriceps muscles.

Reflex reactions that occur below the head follow pathways through the spinal cord. For example, when you step on a sharp piece of glass, a reflex response is triggered in your leg. Sensory neurons detect a change on the surface of the skin and transmit signals, via synapses, to motor and other neurons in the spinal cord. The motor neurons immediately react to the signals and instruct the necessary groups of muscles in the leg to contract. You don’t lose balance, because muscles in the other leg are signaled to compensate for the change in position. A message also is relayed through the spinal cord to the brain, so that the need for further action can be evaluated. The thinking process, however, is much slower than the reflex response. Thus, only after your foot has been removed from the source of pain does the thinking part of the brain react.

Many reflexes help protect the body from harm. When you pull your hand away from something hot, the speed of the reflex response can save you from being burned. Other reflexes play a role in the coordination of complex movements involving many muscles. For example, feedback loops of reflexes through the spinal cord help maintain balance and posture. Reflex responses are similar in all higher animals, including humans, because they are so important for survival.

By observing some of our reflex responses, doctors can evaluate the general status of our nervous systems. One commonly used test involves the knee jerk reflex. In this test, a doctor taps the large tendon just below the kneecap and observes the movement of the lower leg. Usually, the lower leg immediately straightens upward, because a reflex arc that normally helps coordinate muscles of the lower leg is activated. This type of reflex helps muscle groups work together smoothly.

A few reflexes are present only in infants and disappear with age. Doctors look for some of these in the routine examinations of newborn and very young babies. For example, the suckling reflex is triggered in healthy babies when the corner or midpoint of the lip is stroked very gently. This reflex disappears around the age of three or four months. Most babies will close their hands automatically when an object is pressed gently across the palm. This response also disappears after three or four months of age.

**TROUBLE AT TSAVO**

Story, Chapter 9

EXPLORATIONS

“Faster than Fast!” p. 8

SETUP

Photocopy the student page, one per group. Have students conduct this exploration in groups of 2–4.

PROCEDURE

1. Demonstrate how to elicit the knee jerk response before allowing students to begin the activity. Sit or have a student volunteer sit on a stool or table edge with legs dangling or with one leg crossed over the other at the knee. Gently tap the crossed knee (or either knee if not crossed) just below the knee cap. A rubber percussion hammer or the side of the hand may be used. When applied correctly, the tap will cause an abrupt forward movement of the lower leg. (See “Note on the Patellar Reflex,” right sidebar.)
2. Divide the students into pairs or small groups. Let them test each other’s patellar reflex by tapping a knee, as was demonstrated. Ask the students to describe what happened.
3. Next, ask the students to predict whether they can prevent the reflex response by thinking about not letting their legs move. Have students record their predictions.
4. Have students repeat the patellar reflex test. The subjects should try to prevent their legs from moving by thinking about it (but not stiffening their legs). After they have had some time to experiment, ask, *Were you able to stop your leg from jerking by thinking about not letting it move? Why do you think this might be so? Is your brain involved in this kind of reflex?*
5. Discuss the students’ observations and give them an opportunity to discuss or write about their observations. Distribute copies of the “Reflex Reactions” student page. Help students find the pathways followed by signals in a simple reflex that passes through the spinal cord. (This reaction is the pain avoidance reflex.)

BRAIN JOGGING

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

- Can you imagine a reflex you wish you had that, as far as you know, you do not have? What stimulus triggers your imaginary reflex? What is the purpose or protective function of your reflex? Write a paragraph describing your reflex.

Note on the Patellar Reflex

It may take several tries for students to locate the correct spot on the knee to trigger the “knee jerk” reflex. Some students may need to close their eyes, relax or concentrate on something else in order to exhibit the reflex. Expect a range in the magnitude of responses and point out that students should not worry if they are unable to produce a knee jerk response in class. Do not use another type of hammer, other than a rubber percussion hammer, for this activity.

Extension

Another way to elicit reflexes is to have each student lock his or her fingers together and pull. This is termed the Jendrassik maneuver.

For More Information

To learn more about reflexes, visit “Reflex evaluation” at the URL below.

http://www.dartmouth.edu/~dons/part_1/chapter_8.html



REFLEX REACTIONS

Isley I, one of the NeuroExplorers, is standing by a table. Someone bumps into the table, causing a cup of hot liquid to overturn and splash Isley's right hand. Isley's body responds before he can even think about what is happening. How does his body work to protect him from the burning liquid?

1. Locate Isley I's right hand where the liquid is splashing. Sensory neurons in Isley's hand detect something hot. Draw a circle around this spot.
2. **Sensory neurons** flash a message towards Isley's brain. Draw a red line from his hand up the arm and to his spinal cord. Make a small red dot where the message reaches the spinal cord. The message from the sensory neurons says "This is HOT! Do something!"
3. **Motor neurons** in the spinal cord receive the message first and—at great speed—reply with a message commanding a response from Isley's muscles. Start at the red dot on the spinal cord and draw a blue line from the spinal cord back down Isley I's arm and hand. The message to the muscles following this path says, "Pull away! NOW!"
4. At the same time, the **spinal cord** relays information about what is occurring to Isley's **cerebrum** so that his brain learns what has happened. Draw a green line from the red dot on the spinal cord up to Isley I's cerebrum.
5. Isley I already is moving his hand away from the liquid, but hasn't yet made a sound. Why hasn't he said anything, even though his arm is in motion? Has this ever happened to you?



PRACTICE MAKES PERFECT



5

Involuntary movements (automatic functions of the body and reflex responses) happen without first involving the thinking part of the brain. Such movements are essential for basic survival and are governed through the brainstem and/or spinal cord. Of course, they are not all of the movements we carry out in a typical day. Other movements, such as reaching to pick up a pencil, walking across a room or raising a glass for a sip of



TROUBLE AT TSAVO

Story, Chapter 10
Science box, p. 22

EXPLORATIONS

“Now Switching to Auto Pilot...” p. 6

water, require a conscious decision. Movements like these are called voluntary, because we choose to carry them out. Voluntary movements always are initiated in the cerebrum—the thinking part of the brain.

Voluntary movements range from activities you have never done before to movements you perform every day without thinking very much about them. Raising a hand in class, bouncing a basketball and dancing all are examples of voluntary move-

ments. Even actions that eventually become routine, such as walking, are considered voluntary, because they require conscious decisions to start and stop.

Whenever you begin to learn a new movement or sequence of movements, like roller skating or playing a new song on the piano, you must concentrate very hard on what you are doing. As you become skilled at the movements, you no longer need to concentrate as intently. Eventually, the movements become almost automatic, but you still control them by thinking about them. Improving with practice is an important characteristic of voluntary movements.

Many neuroscientists believe that voluntary movements are started in scattered regions of the cerebrum. Neurons from these diverse “thinking areas” communicate with a special area of the cerebrum, known as the motor cortex. This strip of cerebrum, located across the top of the head (about where you might wear headphones), formulates a plan of action and sends it to the muscles. Messages travel from the motor cortex to muscles in the head (for talking, for example) along neurons in the brainstem. For muscles in the rest of the body, messages travel from the motor cortex along neurons in the brainstem and spinal cord. At appropriate places in

OVERVIEW

Students learn about voluntary movements and experience the effect of practice on new voluntary motor skills.

CONCEPTS

- Voluntary movements require conscious thought or planning.
- Voluntary movements improve with practice.
- A special part of the cerebral cortex initiates voluntary movement.
- Programs for movements that are learned and practiced are transferred to the cerebellum.

SCIENCE AND MATH SKILLS

Predicting, making quantitative observations, graphing and drawing conclusions

TIME

Preparation: 10 minutes

Class: 45 minutes

MATERIALS

Teacher

- 12 resealable plastic bags
- 2 self-adhesive notepads in two different colors, 3 in. x 3 in.

Per Team of Two Students

- 10 small objects
- Set of black, blue, green and red markers
- Pair of chopsticks
- Stopwatch (or clock with a second hand)

Per Student

- Copy of the student page

the brainstem or spinal cord, the signals connect with motor neurons and trigger contraction (or relaxation) of the needed groups of muscles.

The motor highways traveled by neuron signals change as you become proficient at a motor task. If you are performing an action that is new to you (for example, when you first learn to ride a skateboard, to type on a keyboard, or perform the exercises in this activity), all of the movements will be controlled by the cerebrum. At first, you might be slow and awkward. However, as you become skilled at the movements, the instructions to the motor cortex will come from the cerebellum instead of from the cerebrum. Your cerebellum “learns” new tasks as you repeat them over and over. Practice does make perfect!

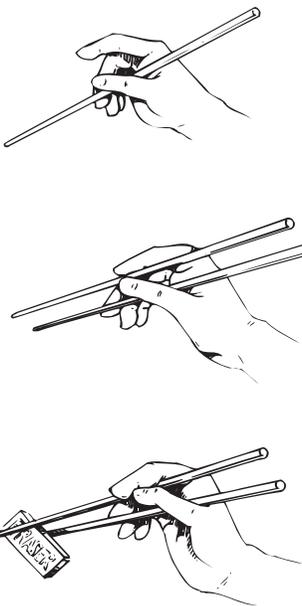
In this activity, students will be asked to perform a movement that they probably never have done before. They will find that, as they practice, they will be able to perform the movement more rapidly and with greater ease.

SETUP

Fill each resealable bag with 10 different small objects (pieces of uncooked pasta, jacks, erasers, etc.) that students will pick up with the chopsticks. Place the bags and other materials in a central location. Have students work in teams of two.

PROCEDURE

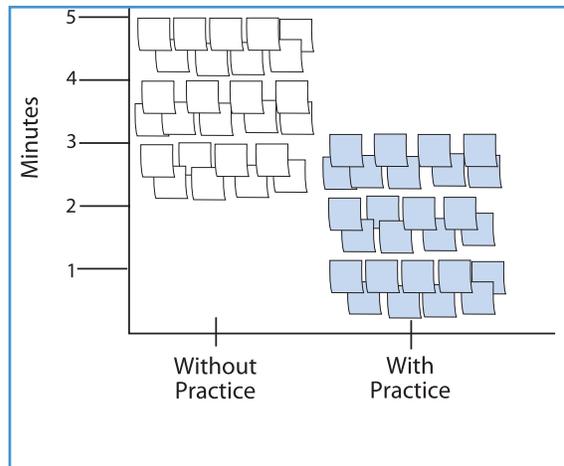
1. Have one member from each team collect a set of chopsticks, a stopwatch and 10 small objects from a central area in the classroom.
2. Determine whether individual students are proficient in the use of chopsticks. If a student is unfamiliar with using chopsticks, he or she should place the chopsticks in his or her dominant hand (used for writing). If necessary, demonstrate how to hold chopsticks for the class.
If a student already is proficient in the use of chopsticks, he or she should place the chopsticks in his or her non-dominant hand.
3. Without allowing any time for practice, have one student in each team measure and record the amount of time it takes for the other student to move 10 objects into a pile using the chopsticks.
4. Ask students, *What do you think will happen if you practice using the chopsticks? Will it take more or less time to move the objects?* Let the students practice using chopsticks for about five minutes.
5. Now, have the timekeepers measure and record how much time it takes for the students with chopsticks to move the 10 objects.



How to hold and use chopsticks.

6. Have the students switch roles and perform the tests again.
7. Create a graph of the class's results, using one color of paper or "sticky" notes

for the times without practice and a second color for the times after practice. Or, have students calculate class averages of their times before and after practicing.



8. Ask, *What happened after you practiced using the chopsticks? How much more practice might you need to be able to eat efficiently using chopsticks?* Mention that different parts of the brain have been involved in the learning process students have just experienced. Distribute the "Voluntary Movement" student page. Help students find the motor cortex and the cerebellum. Then, ask them to find the pathways that messages followed in the nervous system as they learned how to use the chopsticks.

BRAIN JOGGING

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

- Can you move your ear without touching it? Would you consider this voluntary or involuntary?
- Why do you think you can run faster and more smoothly than a two year old? Do you think practice is the most important way to become a good runner?



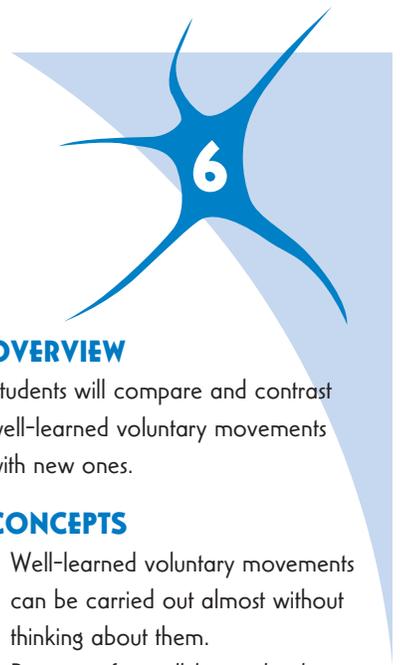
VOLUNTARY MOVEMENT

B.J., one of the NeuroExplorers, loves playing the drums. Though she knows how to use drumsticks, B.J. wants to perform a song that she's never played before. To do so, she must make and learn new movements. How does her body know how to make the drumsticks move in a specific way?

1. Locate B.J.'s **cerebrum**. The thought of learning a new rhythmic pattern and how to play it starts here. Color the cerebrum yellow.
2. Find the **motor cortex** within the cerebrum. Once B.J. starts thinking of how to play the new rhythm, command messages that tell her muscles how to move form here. Color the motor cortex black.
3. The command messages in the motor cortex travel into B.J.'s **spinal cord**. Draw a red line from the motor cortex to the spinal cord. Make a small red dot on this location. (The dashed lines indicate part of the spinal cord that is hidden behind B.J.'s arm.)
4. Next, the command messages move from B.J.'s spinal cord out to the muscles in her arm and hand, telling them to contract or relax. Draw a blue line from the red dot on the spinal cord out to the muscles in B.J.'s arm and hand.
5. Once B.J. has practiced the song many times, will she continue to think about every movement while she performs it? Why or why not?



TAKE A WALK



Voluntary movements that you need to think about occur much more slowly than other movements, like reflexes. The thinking part of the brain (cerebral cortex) must make a decision to begin. It also must choose how to proceed. These decisions take time. As you become skilled at a motor activity, you gradually perform the movements more rapidly than



Unit Links

TROUBLE AT TSAVO

Story, Chapter 11
Science box, p. 22

EXPLORATIONS

“Matter of Fact!” p. 2-3
“Brain Busters!” p. 7

when you first attempted them. The cerebellum “learns” and “stores” motor programs for such movements.

Once initiated, certain well-learned voluntary movements that are repetitive and rhythmic can be carried out without thinking about them at all. Examples include walking, running, chewing, bicycling, jogging and skating. Aside from the voluntary aspect of deciding to start and stop these actions, the pattern of movement takes place repetitively, in a reflex-like

manner. In fact, repetitive actions like these take advantage of feedback loops through the spinal cord to make minute adjustments in muscle movements and to coordinate groups of muscles.

We are able to perform more than one activity at a time because the control of well-learned and rhythmic movements is transferred from the cerebrum to the cerebellum. The cerebellum already knows all of the instructions to send to the motor cortex. It has stored a “motor program.” The thinking part of the brain no longer needs to be involved in supervising routine movements like walking, and thus becomes free to pay attention to other things.

In this activity, students will be able to experience the differences between well-learned voluntary movements and new movements.

SETUP

Have students conduct this activity in pairs, as you direct the entire class.

PROCEDURE

1. Ask students to walk quietly next to their partners around the

OVERVIEW

Students will compare and contrast well-learned voluntary movements with new ones.

CONCEPTS

- Well-learned voluntary movements can be carried out almost without thinking about them.
- Programs for well-learned voluntary movements are stored in the cerebellum.

SCIENCE & MATH SKILLS

Predicting, observing and drawing conclusions

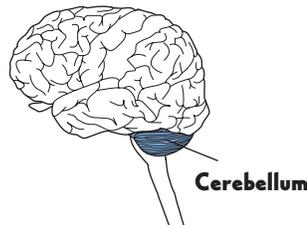
TIME

Preparation: 5 minutes

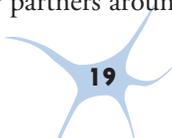
Class: 30 minutes

MATERIALS

No special materials required.



Well-learned voluntary movements are stored in the cerebellum.



Extension

Have students repeat Step 3 over several days. They should notice that it becomes much easier for them to perform the routine.

- perimeter of the room (or any other designated short route). After a few moments, ask, *Did anyone have to stop and think about how to walk? Did you think about lifting and putting down one foot and then the other as you walked? Did you have to practice today before you could walk?*
2. Now, ask one member of each pair of students to tell a story or recite a poem to his or her partner as they walk together. Ask, *Was it difficult to walk and talk at the same time?*
 3. Next, tell the walkers that they must walk in a straight line, putting one foot directly in front of the toe of the other foot. They should walk two steps forward and one step backward in this fashion. At the same time, have them tell the same story or poem to their partners while they perform this heel-to-toe walk.
 4. Ask, *Did you have to think about what you were doing as you walked? Could you talk at the same? Was it easy or hard? Would practicing make a difference?*
 5. Lead a class discussion about the differences between the walking activities. Emphasize that simple walking is a programmed motor pattern governed by the cerebellum. This allows the thinking part of the brain to do something else while you walk, such as concentrate on telling the story. Walking in a new way, however, is directed by the cerebrum—which makes it much harder to conduct another activity that also requires thinking at the same time. Ask, *Why do you think it is useful for us to have programmed motor patterns for some voluntary movements?*

BRAIN JOGGING

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

- What situations can you think of in which it would be very important for you to be able to walk, run, ride a bicycle, etc., without having to pay attention to those movements? Write a short paragraph describing one of the scenarios.

MY MOTOR STRIP



Scientists have mapped the motor cortex of humans and other animals, and have identified the regions responsible for instructing each of the voluntary muscles of the body. They found that the more important a set of muscles is to a particular animal, the more space the control area for those muscles occupies on the motor cortex. By looking at a map of the motor cortex, such as the one given below, one can see which muscles are

dominant. The motor cortex map for each animal is different, because each species uses different special movements, depending on its habitat and lifestyle.

In this activity, students will construct a “headband” that shows the relative sizes and approximate positions of the main areas of muscle control on the motor cortex.

SETUP

Divide the class into small groups of

2–4 students to share materials. Each student will make a Motor Strip headband to wear.



Unit Links

TROUBLE AT TSAVO
Story, Chapter 12
Science boxes, p. 29 and 30

EXPLORATIONS
“Matter of Fact!” (drawings),
p. 2 and 3

OVERVIEW

Students make a model of the motor cortex that they can wear, and they investigate which muscle groups correspond to the largest areas on the motor cortex.

CONCEPTS

- The motor cortex has specific areas that coordinate each group of muscles in the body.
- Important muscle groups occupy proportionately larger areas of the motor cortex.

SCIENCE AND MATH SKILLS

Predicting, measuring, interpreting data and drawing conclusions

TIME

Preparation: 5 minutes

Class: 45 minutes

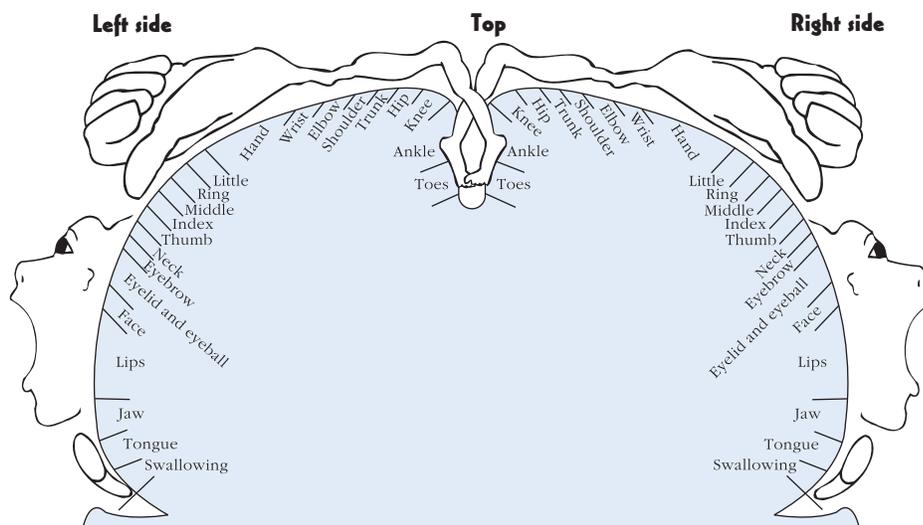
MATERIALS

Per Student Group of Four

- Glue or clear tape
- Metric ruler (millimeters)
- Pair of scissors

Per Student

- Pipe cleaner
- Copy of the “Motor Strip” page



Motor Cortex. The diagram above illustrates where motor commands for the body begin in the motor 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 sending particular motor commands to each body part. Traditionally, this representation is called a homunculus, which means “little human.”

Facial Muscle Commands

Areas in the motor cortex devoted to sending messages to specific muscle groups in the face often overlap in function. For example, the area of the motor cortex that directs the muscles of the face, lips and jaw is used for speech. The area dedicated to muscles in the lips, jaw and tongue is used for salivation, while the area directing swallowing and muscles in the tongue is used for mastication (see “Motor Cortex” diagram, p. 21).

PROCEDURE

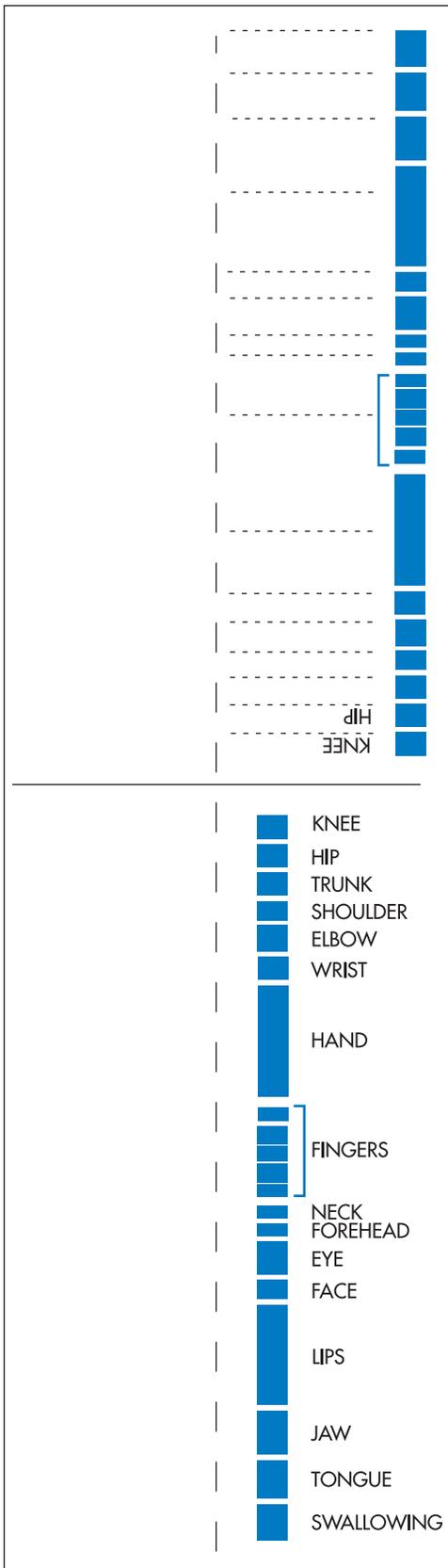
1. Tell students that they will be creating a model of the motor cortex—the part of the brain that directs muscles to carry out voluntary movements. Point out that all voluntary movements are directed through the motor cortex. If they already have created Somatosensory Strips, as described in the BrainLink Sensory Signals unit, mention that the motor cortex is similar to the somatosensory cortex. In fact, it sits directly in front of the somatosensory cortex, across the top of the brain.
2. Have the Materials Managers pick up materials and copies of the “Motor Strip” page.
3. Explain that the areas marked on the Motor Strip represent the approximate lengths of motor cortex dedicated to controlling particular groups of muscles in the body. Larger areas of the motor cortex correspond to groups of muscles that are more important for human movement.
4. Have students measure the lengths of areas on the Motor Cortex strip corresponding to the hand and the elbow. Write the numbers on the board or make a bar graph to compare them. Ask, *Which area is longer? Which makes more complicated movements—your hand or your elbow?* Next, have students measure the areas corresponding to the lips and the forehead. Ask them to identify which is longer and which area must make more kinds of movements. Help students understand that areas of the motor cortex controlling complex and important muscle groups are larger than other areas of the motor cortex.
5. Have students locate the longest and shortest bars on the Motor Strip. Ask for each, *Which part of the body corresponds to this bar?* Make a list on the board of different movements carried out by the corresponding part of the body.
6. Let students make their Motor Strips by following the instructions on the Motor Strip student page.

BRAIN JOGGING

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

- Do you think that a cubic centimeter in the trunk of your body has the same number of motor neurons as a cubic centimeter of your hand? Why?
- The hand and individual fingers are represented by separate sections of the motor cortex. How much of the total length of the motor cortex is given over to controlling movement of the hands and fingers?

MOTOR STRIP



The motor cortex 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 in front of the somatosensory cortex (touch area). Different parts of the motor cortex direct voluntary movement in different areas of the body.

You can see where the motor cortex of your brain is located by making a Motor Strip that you can wear. Each area of the strip will sit about where the actual area of motor cortex for these body parts is located 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 which area of your brain controls the muscles in your fingers? Can you find where your brain controls the muscles in your shoulder? Which area takes up more space on the motor cortex? Why do you think this is so?



MOTOR SYSTEM MODEL

OVERVIEW

Students construct a model of the nervous system that highlights the most important structures involved in the control of movement.

CONCEPTS

- The central nervous system helps to direct and coordinate movements.
- Damage to the spinal cord can affect the transmission of signals through the nervous system below the point of injury to the spinal cord.
- The backbone, or spine, protects the spinal cord.

SCIENCE AND MATH SKILLS

Measuring, modeling and drawing conclusions

TIME

Preparation: 15 minutes

Class: 45 minutes

MATERIALS (See Setup)

Per Student

- Black and red embroidery thread, at least 12-in. length of each color
- Glue or clear tape
- Modeling clay (1.5 cm. dia. each of red and blue; 2.5 cm dia. of yellow)
- Pair of scissors
- Paper clip, standard
- Plastic colored plastic drinking straw (any color, not clear)
- Sheet of white cardstock, 8.5 in. x 11-in.
- Wide-tip marker
- Copy of both student pages

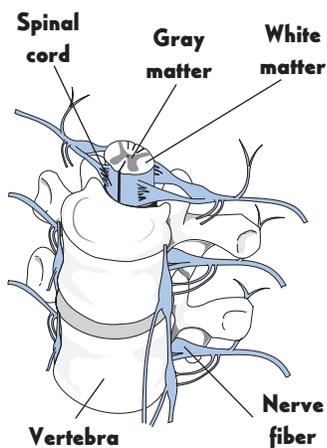
Most movements are the result of finely tuned interactions between muscles and the nervous system. Movement can be initiated by the thinking part of the brain (cerebrum), or it can represent an automatic response to information relayed along sensory neurons to the central nervous system. Generally, movements are classified as voluntary or involuntary, depending upon whether or not a conscious decision is made to initiate the necessary sequence of actions among muscles.

The central nervous system, consisting of the brain and the spinal cord, is so important for survival that each element is protected by a bony structure. The brain is shielded by the cranium, as explored in the Brain Comparisons unit. The spinal cord, which consists mostly of nerve fibers, is protected by the spine, or backbone. The spine must allow for movement of the back and body,

while maintaining its protective function. Consequently, it is comprised of a series of small bones called vertebrae (singular: vertebra). The flexible backbone distinguishes vertebrates from all other forms of animal life. Vertebrates are animals with backbones, and include reptiles, fish, birds and mammals.

Nerve fibers extend from the spinal cord into other parts of the body through the gaps between vertebrae. Injury to a particular part of the spinal cord will affect communication to and from all parts of the body located below that point.

Neurologists frequently are able to localize specific areas of injury to the nervous system by observing which parts of the body have lost the capacity for movement. While damage to the spinal cord often will affect all of the body below the point of injury, damage to one side of the brain



The soft tissue of the spinal cord is protected by the bones of the spine. The spinal cord is quite small, about as big in diameter as an adult human's little finger. Gray and white matter are present in the brain, spinal cord and nerves (see p. 4).



TROUBLE AT TSAVO

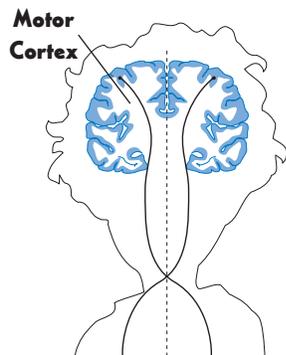
Story, Chapter 13

Science boxes, p. 5, 15 and 22

EXPLORATIONS

"Not Just Horsing Around" p. 4

"Double Trouble!" p. 5



Motor neurons starting on one side of the head cross to the opposite side of the spinal cord to control movement on that side of the body. Humans are cross-wired!

will sometimes affect only the opposite side of the body. This is because motor neurons leading from the brain to the spinal cord cross to the other side of the body in the brainstem (see illustration, left).

Motor neurons that start on the right side of the head cross to the left side of the spinal cord to control the left side of the body. Likewise, motor neurons originating in the left side of the brain cross to the right side of the body. Since our nervous system is “cross-wired,” a physician might diagnose probable damage to the left side of the brain in an accident victim with motor and/or sensory loss on the right side of the body.

SETUP

Photocopy the “Motor Instructions,” page onto 8.5-in. x 11-in. paper, and the “Motor Model” page onto white card stock (or glue paper photocopies onto heavy construction paper).

Each student will need three colors of modeling clay (one piece of yellow, approximately 2.5 cm in diameter, and one piece each of red and blue, about 1.5 cm in diameter).

Cut the embroidery thread into 12-in. lengths, separating by color.

As an alternative to using modeling clay, make modeling dough (see “Make Your Own Modeling Dough,” right sidebar, for instructions).

Distribute the materials or have the Materials Manager from each group pick up the supplies. Students should work in groups of two.

PROCEDURE

1. Distribute the student sheets. Have students create a yellow cerebrum, a red cerebellum, and a blue brainstem. Show the students how to assemble the three parts into a model of the brain. Finished models should fit within the confines of the head on the “Motor Model” sheet. (For more detailed information on the structure and function of the brain, including wrinkles and folds, see the *Brain Comparisons* unit of this series.)
2. Demonstrate how to create the spinal column, using short pieces of straw for vertebrae, and embroidery thread for the nerve fibers going through the spinal cord. One color of thread should be used to represent motor neurons and another to represent sensory neurons. Detailed

Make Your Own Modeling Dough

- 2 cups of flour
- 2 cups of water
- 4 tsp cream of tartar
- 1/4 cup of vegetable oil
- 1 cup of salt
- Food coloring (red, blue, yellow)

Combine flour, water and cream of tartar in a large bowl or blender. Mix until lumps disappear.

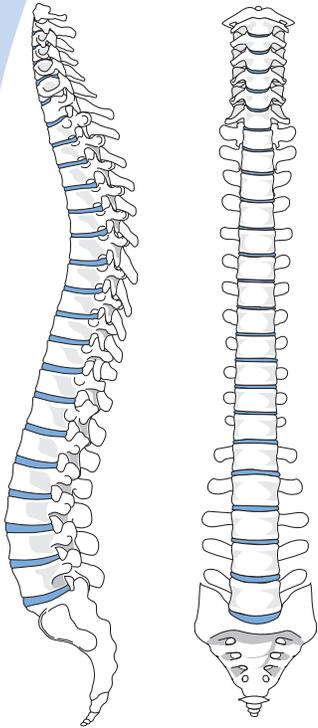
Add oil and food coloring.

Put mixture in a saucepan and add salt. Stir and cook over low heat until mixture becomes lumpy.

Empty mixture waxed paper covered counter. Knead to smooth out lumps. Let cool.

Flexible and Strong

The spine must protect the spinal cord, but at the same time, remain flexible to allow for movement of the back and body.



instructions are given on the “Model Instructions” student sheet. (You may prefer to simplify the model for students by using only one color of thread or yarn.)

3. When students have completed their models, discuss how the brain communicates with muscles by way of spinal cord neurons. Point out the flexible nature of the straw “spine.” Ask, *Why do you think this flexibility is necessary?*
4. Discuss the consequences of injury to the spinal cord. Ask, *What would happen to a person if his/her spinal cord were cut at the point that corresponds to the area just above the first straw vertebra in your model? What would happen if the spinal cord were cut or damaged between the third and fourth straw vertebrae?* If your students have read or are reading *Trouble at Tsavo*, mention Shiloh Nimbus’ paralysis. Ask, *How do you think this might have happened? Where on Shiloh’s spine do you think her injury occurred?*
5. Some of the students may know a person who is paralyzed on only one side of the body. Help them to understand that paralysis on one side may indicate some type of brain injury (trauma, stroke, tumor, etc.) on the opposite side of the brain (“cross-wiring”), while paralysis of both sides is more likely due to spinal cord injury.

BRAIN JOGGING

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

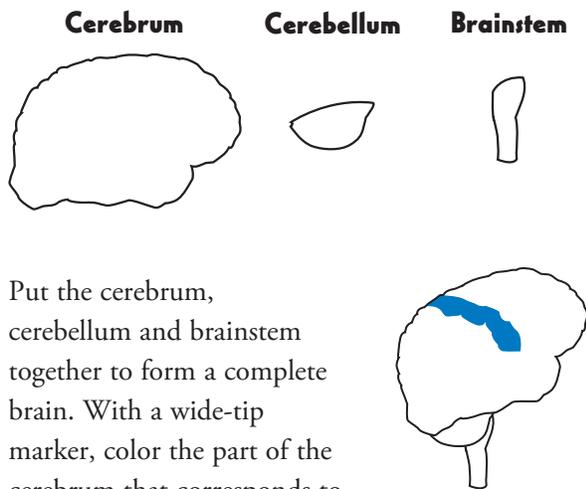
- Is it absolutely necessary for an animal to have a spinal cord? A backbone?
- Think of animals that have backbones. Are all of them capable of flexible movement? Are there any large animals without backbones? If so, where do they live?

MODEL INSTRUCTIONS



Before you begin making the model, read all the instructions below. The brain made of clay should fit within the drawing of the head on the “Motor Model” page.

1. Mold the clay to form shapes similar to those below. Use yellow for the cerebrum, red for the cerebellum and blue for the brainstem.



2. Put the cerebrum, cerebellum and brainstem together to form a complete brain. With a wide-tip marker, color the part of the cerebrum that corresponds to the motor cortex.
3. Cut the straw into five 1-cm (1/2 in.) pieces. The straw pieces represent the vertebrae.
4. If needed, cut both pieces of embroidery thread into 20-cm (12 in.) pieces. The thread represents



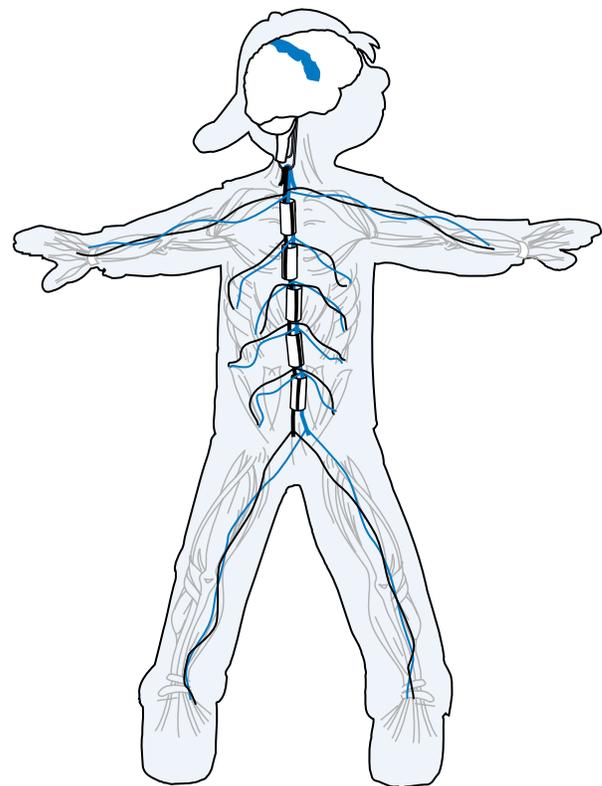
the spinal cord (nerve fibers). Tie both pieces of embroidery thread to the small end of the paper clip. Unravel each thread into several strands.

5. Working with a partner, thread the paper clip and attached threads through each piece of straw.



Be careful that the straw pieces do not fall off the threads.

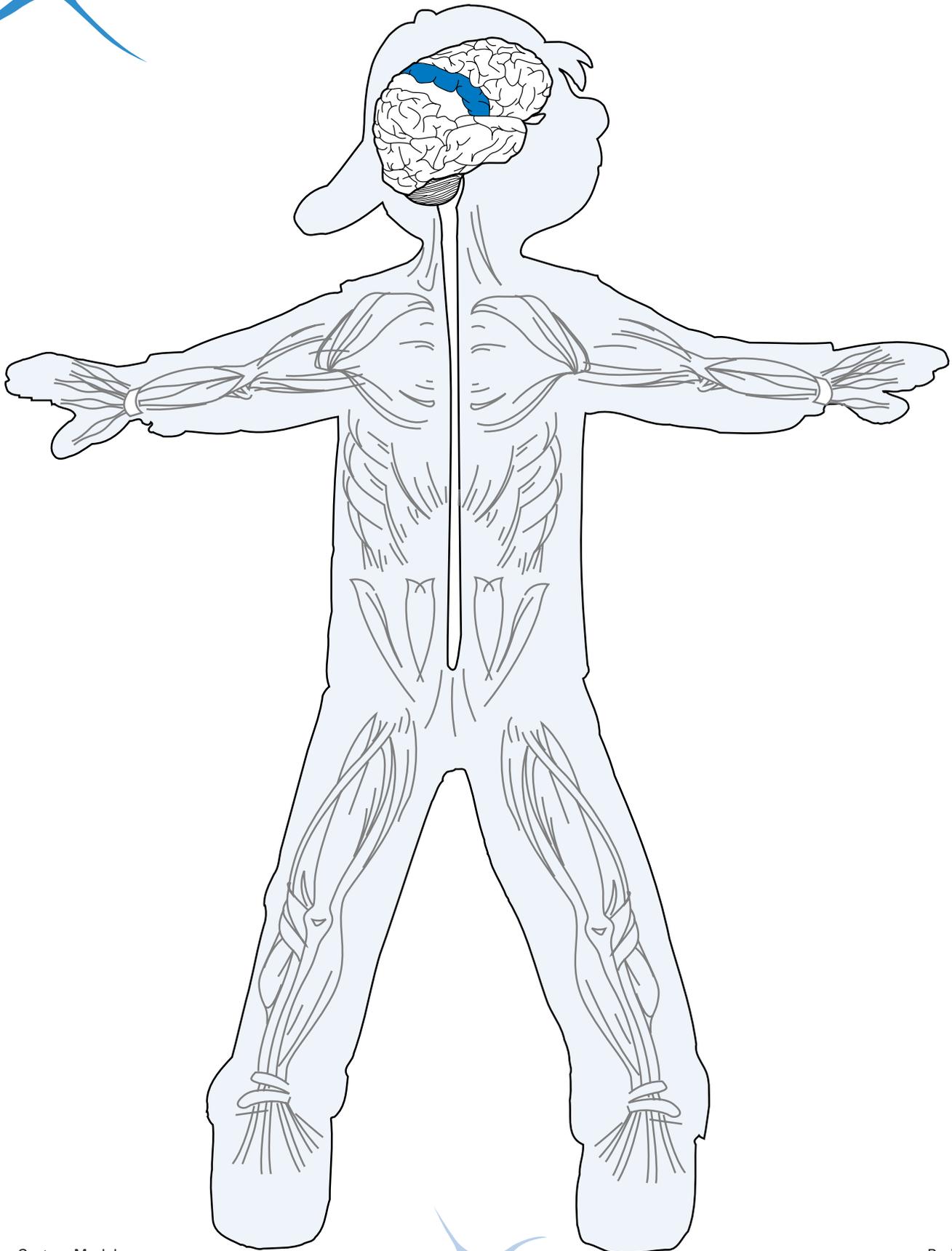
6. Push the large end of the paper clip into the brainstem of the clay brain. Shape the clay around the paper clip.
7. With a partner, glue the brain and spinal cord (straw) onto the “Motor Model” sheet. Be careful to keep the threads free of glue or tape.
8. Using a pencil tip, pull two strands of each color of thread out between each straw piece.



9. Fasten the thread ends to muscles of the arms, legs, or body of the “Motor Model” with glue or tape. Trim the threads if they are too long.



MOTOR MODEL



MOVING BIOGRAPHIES



In motor system diseases, the neuron pathways that control movement are disrupted. This can result from damage to portions of motor neurons or from the death of whole neurons. Perhaps the most well-known motor system diseases are polio, amyotrophic lateral sclerosis (ALS) and multiple sclerosis (MS).

Many motor system diseases progress gradually. In the beginning, affected persons often notice weakness in a particular part of the body, or find that they are becoming clumsy or that they tire more easily. It may be more difficult for them to speak clearly because the muscles controlling speech have been affected. Weakness occurs because the muscles no longer receive orders to move. In many cases, weakness progresses to complete paralysis as more motor neurons become damaged. Accidents also can cause damage to the spinal cord or parts of the brain responsible for movement.

Currently, there are no cures for motor system diseases or to cure damage to the spinal cord as a result of accident. Once a neuron is destroyed, the nervous system is not able to replace it. Some motor system diseases can be prevented. Polio, a disease caused by a virus that destroys neurons, once affected thousands of children every year. Now people can be vaccinated to protect against this disease. For other motor system diseases, like MS, the initial causes still are not known, so there is no known way to prevent them. In these cases, the only way to help the patient is to try to slow the progression of the disease once it has started. The search for effective treatments is an active and exciting area of research in neuroscience.

It is important to remember that the ability to move is the primary loss associated with most of these diseases. People with ALS and polio do not lose input from the senses or the ability to think. On the other hand, MS affects movement and also can affect sensory pathways and the thinking part of the brain.

About 250,000 Americans have spinal cord injuries. These injuries can result in an inability to move or a loss of sensation (touch). Following an injury, neurons in the central nervous system (brain and spinal cord) are not able to rebuild damaged connections. However, researchers are working to uncover ways to regenerate lost connections.



Unit Links

TROUBLE AT TSAVO

Story, Chapters 14
Science boxes, pp. 30 and 33

EXPLORATIONS

"Did You Know?" p. 5, "Careers for NeuroExplorers" p. 7

OVERVIEW

Readings about four famous people with different motor system diseases or injuries are provided to stimulate discussion and further exploration.

CONCEPTS

- Neuron pathways that control movement are disrupted in motor system diseases.
- People with motor system diseases or damage to the motor system from accidents often are able to lead productive lives.

SCIENCE AND MATH SKILLS

Using resources to gather information; drawing and presenting conclusions

TIME

Preparation: 10 minutes

Class: 45 minutes

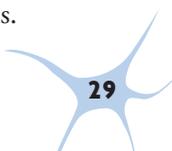
MATERIALS (See Setup)

Per Student

- Copy of each student page

Neuron Growth

Neuroscientists are investigating whether cells transplanted from other parts of the nervous system can aid neuron growth in the spinal cord. This research could help persons with spinal cord injuries.



Robotic Limbs

After years of research, scientists are beginning to figure out ways to interpret brain signals and launch movement of robotic limbs. Even though much more research is needed, someday robotic arms or legs may be developed to help some disabled persons regain mobility.

Did You Know?

People of all ages and with different careers have motor system diseases. Listed below are just a few of them.

Donna Fargo: Singer/MS
Annette Funicello: Actress/MS
Judy Holliday: Actress/Polio
Jacob Javits: Senator/ALS
Ida Lupino: Actress/Polio
David Niven: Actor/ALS
Richard Pryor: Comedian/MS

Resources

For more information on motor system diseases or injury, look for these organizations on the Internet or at your library.

- American Academy of Neurology
- ALS Association
- March of Dimes Foundation
- National Multiple Sclerosis Society
- Christopher Reeve Paralysis Foundation

Also contact local schools and organizations specializing in movement disorders.

People with motor system diseases or injuries often are able to continue to work throughout their lives. Many of them, like the people profiled in this activity, have contributed and will continue to contribute great things to society.

SETUP

This activity may begin with a class discussion, followed by reading of the biographical essays, or vice versa. With younger students, you may want to read the individual biographies to the class and then conduct a discussion. Otherwise, individuals or groups can be given reading assignments and then asked to find further information about the featured people, motor system diseases, or other forms of disabilities from the library or the suggested source organizations (see sidebar, Resources).

PROCEDURE

1. Ask students if they have heard of Christopher Reeve, Barbara Jordan, Stephen Hawking or Franklin Roosevelt. Discuss what the students already know about each of these famous individuals.
2. Tell students that these persons have something in common. Ask if they can guess what it is.
3. Distribute the readings and use them in whatever way you think best. You might divide the class into four groups and assign one of the readings to each group. Let the members of each group read, share and discuss their reading, and report their findings to the class.
4. Encourage students to learn more about motor system diseases and injuries by studying these people or others with difficulties—including people they may know (see sidebar, Did You Know?).

BRAIN JOGGING

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

- Write a short story or diary from the point of view of a person who has a motor system disease.
- If you were a new kid at your school who had a motor system disease and had to use a wheelchair or braces, what would you tell your friends?

THERE'S NO STOPPING HIM!



When people think of Superman, many think of Christopher Reeve. He was the actor who portrayed the super hero in the 1978 movie, *Superman*, and in several sequels that followed. Today, Christopher Reeve is paralyzed from the neck down due to a **spinal cord injury** (SCI).

In May 1995, Christopher Reeve was competing in a horse show when his horse stopped short at a jump, throwing him forward. Mr. Reeve's hands tangled in the reins and he landed head first—fracturing the uppermost vertebrae in his spine. Instantly, Christopher Reeve was paralyzed from the neck down and unable to breathe. Prompt medical attention saved his life, and delicate surgery stabilized his shattered first two vertebrae.

After six months at Kessler Rehabilitation Institute in New Jersey, Mr. Reeve returned to his home in Bedford, New York. His wife, Dana, had made major renovations to their house to accommodate his needs and those of his electric wheelchair, which he operated by sipping or puffing on a straw.

More than 10,000 Americans are paralyzed each year from SCI. The severity of SCI symptoms depends on the seriousness of damage done and the part of the spinal cord that is damaged. The spinal cord is a tightly packed bundle of nerves, about three-quarters of an inch thick. It runs from the base of the brain, down the middle of the back, and ends at the waist. The spinal

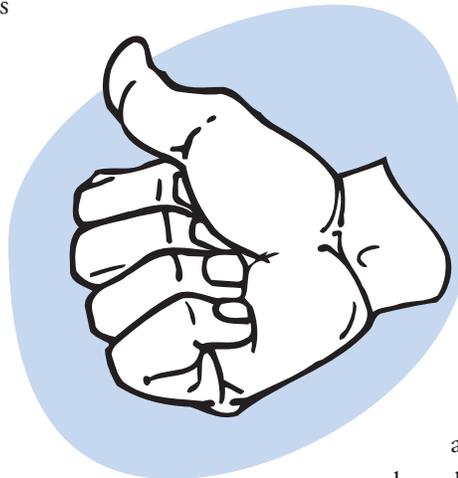
column, consisting of 33 bony vertebrae, houses and protects the spinal cord.

Different sets of neurons carry instructions from the brain to the rest of the body and signals from the body back to the brain. Injuries to the spinal cord in the neck above the level of the third vertebra prevent all of the signals from the body from getting through. These injuries leave a person dependent on a mechanical

respirator and with **quadriplegia**. This means that not all body functions happen automatically anymore and that the arms and legs are paralyzed (like Mr. Reeve). These injuries happen in more than 50% of all SCI cases. More than 90% of those are caused by sports trauma.

In spite of his life-changing injuries, Christopher Reeve continued working as an actor and director and wrote a best-selling autobiography about his life and the effects of his injury. He also continued rigorous physical therapy to keep his body in the best shape possible for as long as possible.

In addition to his career in the entertainment industry, Mr. Reeve was a political activist. As such, he worked tirelessly to raise public awareness about the significance of medical research and about improving the quality of life for all disabled people. He also helped establish the Christopher Reeve Paralysis Foundation, a national, nonprofit organization that supports research to develop effective treatments and a cure for paralysis caused by spinal cord injury and other central nervous system disorders.





LEARNING AND LEADING

Barbara Charline Jordan was born in 1936. She grew up in a nice, neat house in a poor area of Houston, Texas. Her parents taught her the value of study and hard work. Her father, a Baptist minister, told her she could do anything if she worked hard enough. Barbara listened. She made it through high school, college and law school, and went on to become a lawyer by the age of 24.

Barbara knew that she wanted to help change the way America was governed. She wanted to make things better for all people. She saw that she might be able to do this by going into politics. She worked for changes that helped lead to the Civil Rights Act. President Lyndon Baines Johnson signed this act into law in 1964. It made certain that the laws of the country would be equal for everyone.

In 1967, Ms. Jordan became the first African-American woman elected to the Texas Legislature. Five years later, she became the first African-American woman from the South ever elected to the U.S. House of Representatives (part of the U.S. Congress). There she worked very hard to do things that would help people.

After serving six years in the U.S. Congress, Representative Jordan retired in 1978 from elected office. She became a professor at the Lyndon Baines Johnson School of Public Affairs at The University of

Texas. She was a very popular and inspiring teacher. Everyone wanted to be in her classes.

When Barbara Jordan left the U.S. Congress, she was having trouble walking. By the time she began teaching in 1979, she was in a wheelchair. Professor Jordan had **multiple sclerosis**.

Multiple sclerosis (sklah-RO-sis), sometimes called MS, is a disease that breaks down the covering that protects many neurons. This covering, called **myelin** (MY-uh-lin), helps to conduct messages through the body. When myelin is destroyed it is replaced by scars. (Multiple sclerosis means “many scars.”) Messages cannot travel along the neurons, so messages from the brain that tell the body to move do not get through.

The spinal cord is one place where the scars often are found. They cause weakness and stiffness of the legs and arms.

They can cause numbness in these limbs, like the tingling you feel when your leg or foot goes to sleep. MS affects each person who has it differently. It is a condition that is likely to last a person’s lifetime.

MS may have played a part in Professor Jordan’s decision to leave the U.S. Congress. It certainly did not keep her from being an outstanding teacher. She was greatly respected for what she accomplished. People throughout the nation will always remember her words of wisdom and her leadership.



HIS WORLD/OUR UNIVERSE



Stephen W. Hawking is no ordinary man. He is one of the greatest thinkers of our time. His mind has explored distant galaxies and black holes. He has asked the questions, “Was there a beginning of time? Will there be an end of time? Is the universe boundless?” His search for answers has brought us closer to the secrets of time, space and the universe. Remarkably, he has done all of these things for more than 25 years from a wheelchair.

Professor Hawking has motor neuron disease, or **amyotrophic lateral sclerosis**, or ALS for short. It also is known as “Lou Gehrig’s disease” after the famous baseball player who also had ALS. The word **amyotrophic** (a-my-o-TRO-fik) means a withering or weakening of muscles. **Lateral** means “to the side” and **sclerosis** (sklah-RO-sis) means “scar.” So together, these words mean muscle weakening that is caused by scarring in the lateral (side) part of the spinal cord (which contains critical motor pathways).

ALS destroys the motor nerve cells (neurons) in the nervous system that directly control the muscles. Without motor neurons there is no way for the brain and spinal cord to get messages out to the muscles. It is as if the wire between two telephones had been cut. There is no pathway to get a message through. Right now, doctors do not have a cure for this disease, but

many people are working to discover one.

ALS may prevent a person from moving, but it does not damage a person’s thinking. Professor Hawking, for example, has an active mind and, from his wheelchair, is helping us understand how the universe works.

When he caught pneumonia in 1985, he had to have an operation that took away his ability to speak. Yet it has not stopped him from communicating.

Professor Hawking is a published author and has appeared on

television in a series about his work and appeared as himself in a role on the science fiction series, *Star Trek: The Next Generation*.

With the help of a small computer, a voice synthesizer (a machine that makes speech sounds), his friends and health care givers, he continues to tell the world about the physical universe. In fact, he says that he can communicate better than before he lost his voice! In spite of the challenges of living with ALS, Dr. Hawking does not view it as a serious handicap. He says he was lucky to have chosen a career that is “all in the mind.”

He does have one complaint. In a recent radio interview using his voice synthesizer, he complained that the machine made him sound too much like an American. Professor Hawking is very proud to be an Englishman!





PRESIDENTIAL STRENGTH

James Roosevelt snapped his father's leg braces into place. Using crutches, Mr. Roosevelt walked slowly to the platform. His son, James, was at his side. The crowd grew silent. Franklin Delano Roosevelt, known as FDR, began his speech. He was the respected Governor of New York, and he was nominating someone for the presidency of the United States. People would remember his speech, and they would remember FDR.

As a young man, Roosevelt had caught the virus that causes **polio**, a disease that can spread from one person to another. Long ago, polio killed or paralyzed many people, mostly children.

When the polio virus reaches the brain and spinal cord, it destroys nerve cells. When the nerve cells are destroyed, messages that normally would travel to and from the brain along the spinal cord cannot reach the muscles. Arms and legs cannot move. The most serious kind of polio results when the virus attacks the nerve cells in the brainstem or the spinal cord that control breathing. When this happens, the person cannot breathe without the help of a machine.

Although his legs were paralyzed and could not move, FDR exercised to strengthen other muscles in his body. These muscles could help support his legs. Over time, his control improved until he only needed braces for his lower legs and knees. Having polio did not keep FDR

from facing his future. FDR continued in politics and became the 32nd President of the United States. He served three terms as president and led the country during World War II.

One important thing FDR did as President was to help form the March of Dimes, an organization created to help stop the spread of polio. During the financial depression of the 1930s, many people in America were very poor. Even so, they sent their dimes to

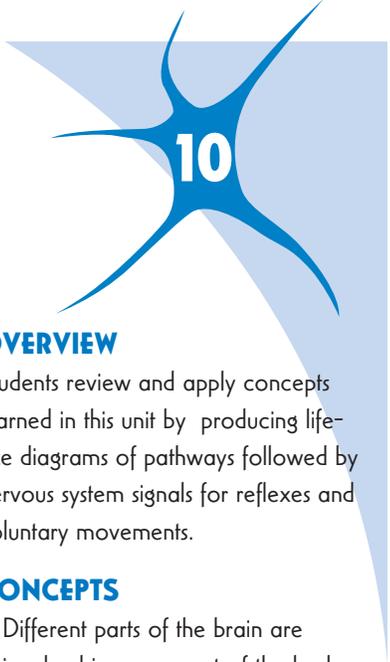
the March of Dimes to help find a cure or treatment for polio. Some of this money went to scientists who studied polio. It was through scientific study that Dr. Jonas Salk was able to make the first vaccine, a shot to prevent polio.

The vaccine against polio was first used in the early 1950s. Since that time, children in America and the rest of the world get vaccines that protect them from polio. These vaccines help the human body develop defenses, called antibodies, against the germs that cause polio. That is why you do not hear very much about people having polio today.

Though President Roosevelt suffered life-long effects from his battle with polio, he would not let it stop him from pursuing his dreams and fulfilling the demands of his work. He is remembered not only for his courage, intelligence and leadership, but for his strength of will over mind and body.



KIDS ON THE MOVE



10

Most movements are the result of finely tuned interactions between muscles and the nervous system. Movement can be initiated by the thinking part of the brain (cerebral cortex and associated areas), or it can represent an automatic response to information relayed along sensory neurons to the central nervous system. Generally, movements are classified as voluntary or involuntary, depending upon whether a conscious decision is made to initiate the necessary muscle sequences.



TROUBLE AT TSAVO

Science boxes: Review all.

EXPLORATIONS

Cover activity

“Matter of Fact!” p. 2-3

Involuntary movements are those that are initiated without any thought or concentration. Some involuntary movements keep the body running smoothly. Others, called reflexes, occur as a direct response to changes in conditions (inside or outside the body). Reflexes follow very simple

pathways that do not include the thinking part of the brain in the path between sensory input and motor output. As a result, the reaction time for reflexes is relatively short.

Voluntary movements are those that are undertaken “on purpose.” They are controlled by a particular part of the cerebrum—the motor cortex. As voluntary movements are practiced, they become easier to perform. Control of such movements is gradually passed to the cerebellum, which coordinates instructions to the motor cortex. Eventually, very well learned voluntary movements become almost automatic, but they still are directed by the brain.

SETUP

Divide the class into small groups of 2–4. Each group will work independently to produce a graphic model of a nervous system pathway. This activity can be used to assess understanding of basic concepts covered in this unit.

The production of one or more drawings also may be undertaken as a whole class activity.

PROCEDURE

1. Review pathways for reflexes and voluntary movements using the students’ motor system models (or student pages from Activity 4, “Reflex Reactions” and Activity 5, “Voluntary Movement”). Encourage

OVERVIEW

Students review and apply concepts learned in this unit by producing life-size diagrams of pathways followed by nervous system signals for reflexes and voluntary movements.

CONCEPTS

- Different parts of the brain are involved in movement of the body.
- Messages to and from muscles are transmitted by different kinds of neurons.
- Involuntary movements happen without thought.
- Voluntary movements require conscious thought or planning.
- The backbone, or spine, protects the spinal cord.
- Neuron pathways that control movement can be disrupted by disease or injury.

SCIENCE AND MATH SKILLS

Modeling, problem solving, and applying prior knowledge to new situations

TIME

Preparation: 15 minutes

Class: 45-60 minutes, in one or two sessions

MATERIALS (See Setup)

Per Student Group

- 4 sheets of wide kraft paper, approx. 1.5-m to 2-m length sheets
- Set of markers or crayons in 5 different colors
- Completed Motor Models
- Copies of the student page



Students will create life-size drawings of the pathways followed by signals in the nervous system for movement.

students to suggest different examples of involuntary and voluntary movements.

2. Tell students they will create NeuroKid drawings to show the pathways followed by signals in the nervous system for movement. Distribute the student page. Point out the list of possible movements provided. Ask each group to select one kind of movement they would like to represent and to select one team member to serve as a model. (Groups also may illustrate movements that do not appear on the list.)
3. Have students spread the large sheets of paper on the floor. Each model should assume a position on the paper appropriate to the movement being illustrated (does not have to be the entire body). Group members should first draw a pencil outline of the model. After the pencil outline is complete, have students adjust irregularities in the outlines as they trace over the pencil lines with a black marker.
4. Have group members draw the central nervous system (the brain—showing cerebrum with motor cortex, cerebellum, brainstem and spinal cord) on their outline.
5. Ask students to think about the nervous system pathways that will be followed when the movement that they have selected is carried out. After they have decided on the pathways, have students create the following parts of the nervous system involved in the movement, as described below.
 - Have students make a red circle on the place where the sequence for movement begins. Reflexes begin at the point of sensory stimulus (hand, foot or knee, for example). Other movements begin in the cerebrum (the decision to move).
 - Next, they should draw a pathway from the place where movement begins to a point on the appropriate level in the spinal cord and make a dot on that spot. In a reflex response, the pathway will lead from the arm or leg to the spinal cord. In a new voluntary movement, the pathway will lead from the cerebrum, where the thought begins, to the motor cortex, through the brainstem and into the spinal cord. For a well-learned voluntary movement, the pathway will lead from the cerebrum to the cerebellum before passing to the motor cortex and into the spinal cord.
 - Next, using a second color, have students draw a pathway from the dot on the spinal cord to the muscle(s) involved in the movement.
 - Finally, have students draw a pathway back to the brain from



the muscles or spinal cord. Have them use a third color or draw a dotted line.

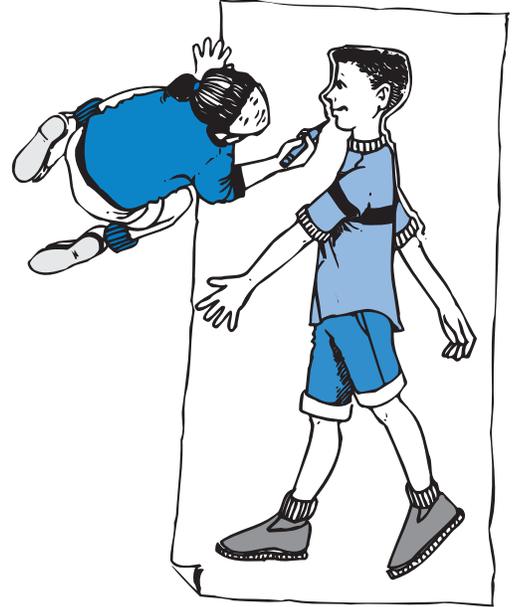
6. Encourage students to use their imaginations and add names, props or other decorations to their drawings.
7. Have each group present and describe its NeuroKid to the rest of the class. Encourage students to think about the pathways being followed by asking questions such as, *Is this an example of a voluntary or an involuntary movement? Would this movement improve with practice? How is this movement different from the movement presented by the previous group?*

BRAIN JOGGING

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

- Coughing usually is a reflex response. Chewing is a well-learned voluntary movement or habit. In what ways are coughing and chewing similar? In what ways are coughing and chewing different?
- The “knee jerk” is an example of a reflex response. Can you move your leg in the same way as a knee jerk by just deciding to do it? Was your voluntary leg movement identical to the knee jerk? Why or why not?
- We often do not think about the small movements that are part of a very well-learned voluntary activity that has become automatic. Try to describe in detail how you carry out a routine activity such as tying your shoes or buttoning your shirt.

1. Look at the list of suggested movements below. Decide which movements you would like to represent in your life-size drawings—or you may illustrate a movement that does not appear in the list.
2. Spread the large sheet of paper on the floor. Have the model lie on the paper and assume a position appropriate to the movement being illustrated (does not have to be full body). Trace the model's outline in pencil. Trace the model's outline in pencil.
3. After the pencil outline is complete, adjust irregularities in the drawing as you trace over the pencil lines with a black marker.
4. Complete the drawing by adding the central nervous system (brain and spinal cord). Color the parts. Do not use red.
5. Make a red circle on the place where the sequence for movement begins. Is the movement a reflex, a new voluntary movement or a well-learned voluntary movement?
6. The message for movement travels to a central location in the body before being passed on to the muscles. Where does the message travel to? Draw this pathway and mark the spot with a small dot.
7. The message now goes to the muscle(s) involved in the movement. Draw the pathway(s) in another color and mark the ending spot with a small dot.
8. Does the brain find out about the movement? If so, draw a pathway from the muscles or spinal cord back to the brain.



Reflex Responses

- Knee jerk reflex test
- Pulling hand, arm or finger away from a hot object
- Hunching down or jumping at a loud noise
- Jerking foot away from a sharp object (thumbtack, etc.)

New Voluntary Movements

- Throwing a baseball for the first time
- Performing a new dance step
- Learning to play the guitar
- Learning to walk on a balance beam

Well-learned Voluntary Movements

- Running to home plate
- Kicking a soccer ball
- Playing a familiar video game
- Writing your name

GLOSSARY



amyotrophic lateral sclerosis - nervous system disease that destroys motor neurons and results in a loss of muscle control

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

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

brainstem or brain stem - structure that connects the rest of the brain to the spinal cord and controls basic survival activities such as breathing, heartbeat, body temperature, and digestion

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 is started

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

gray matter - nervous system tissue that is composed primarily of cell bodies and nerve fibers without a myelin sheath

involuntary movement - movements that are started without any thought or concentration, and that happen without any input from the cerebrum

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

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

myelin - fatty substance that forms a thick sheath around the axons of some nerve cells; a bundle of nerve fibers and associated cells

nerve fiber - any of the branches of a neuron including dendrites and axons

neurologist - a medical doctor specializing in the diagnosis and treatment of disease and injury in the nervous system

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

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

polio - infectious nervous system disease caused by a virus that affects nerve cells in the brain or spinal cord and leads to loss of motor function

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

reflex arc - the complete nervous path that is involved in a reflex, usually consisting of detection of a stimulus by sensory neurons, communication with motor neurons in the spinal cord or brainstem, and stimulation of muscles by motor neurons

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

spinal cord - bundle of nerve fibers that runs inside the spine

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



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

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

vertebra - any of the bony segments that make up the spine (plural: vertebrae); **vertebrate** - animal that has a spine

voluntary movement - movement that is done on purpose or involves a choice; always requires input from the cerebrum

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



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

ISBN: 978-1-944035-15-0
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