The Brain: Our Sense of Self

under a contract from the
National Institutes of Health

National Institute of Neurological Disorders and Stroke

BSCS

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Please contact the NIH Office of Science Education with questions about this supplement, at *supplements@science.education.nih.gov.*

Contents

Foreword

This curriculum supplement, from *The NIH Curriculum Supplement Series*, brings cutting-edge medical science and basic research discoveries from the laboratories of the National Institutes of Health (NIH) into classrooms. As the largest medical research institution in the United States, NIH plays a vital role in the health of all Americans and seeks to foster interest in research, science, and medicine-related careers for future generations. NIH's Office of Science Education (OSE) is dedicated to promoting science education and scientific literacy.

We designed this curriculum supplement to complement existing life science curricula at both the state and local levels and to be consistent with *National Science Education Standards*.[1] It was developed and tested by a team composed of teachers, scientists, medical experts, and other professionals with relevant subject-area expertise from institutes and medical schools across the country; representatives from the National Institute of Neurological Disorders and Stroke; and curriculum-design experts from Biological Sciences Curriculum Study (BSCS), SAIC, and Edge Interactive. The authors incorporated real scientific data and actual case studies into classroom activities. A three-year development process included geographically dispersed field tests by teachers and students.

The structure of this module enables teachers to effectively facilitate learning and stimulate student interest by applying scientific concepts to real-life scenarios. Design elements include a conceptual flow of lessons based on BSCS's 5E Instructional Model of Learning, multisubject integration emphasizing cutting-edge science content, and built-in assessment tools. Activities promote active and collaborative learning and are inquiry-based to help students develop problem-solving strategies and critical thinking.

Each curriculum supplement comes with a complete set of materials for both teachers and students, including printed materials, extensive background and resource information, and a Web site with interactive activities. The supplements are distributed at no cost to teachers across the United States. All materials may be copied for classroom use but may not be sold. We welcome feedback from our users. For a complete list of curriculum supplements, updates, availability, and ordering information, or to submit feedback, please visit our Web site at *http://science.education.nih.gov* or write to

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We appreciate the valuable contributions of the talented staff at BSCS, SAIC, and Edge Interactive. We are also grateful to the NIH scientists, advisors, and all other participating professionals for their work and dedication. Finally, we thank the teachers and students who participated in focus groups and field tests to ensure that these supplements are both engaging and effective. I hope you find our series a valuable addition to your classroom and wish you a productive school year.

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1 In 1996, the National Academy of Sciences released the *National Science Education Standards*, which outlines what all citizens should understand about science by the time they graduate from high school. The *Standards* encourages teachers to select major science concepts that empower students to use information to solve problems rather than stressing memorization of unrelated information.

About the National Institutes of Health

Begun as the one-room Laboratory of Hygiene in 1887, the National Institutes of Health (NIH) today is one of the world's foremost medical research centers and the federal focal point for health research in the United States.

Mission and Goals

The NIH mission is science in pursuit of fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to extend healthy life and reduce the burdens of illness and disability. The goals of the agency are to

- foster fundamental creative discoveries, innovative research strategies, and their applications as a basis for advancing significantly the nation's capacity to protect and improve health;
- develop, maintain, and renew scientific resources—both human and physical—that will ensure the nation's ability to prevent disease;
- expand the knowledge base in medical and associated sciences in order to enhance the nation's economic well-being and ensure a continued high return on the public investment in research; and
- exemplify and promote the highest level of scientific integrity, public accountability, and social responsibility in the conduct of science.

NIH works toward meeting those goals by providing leadership, direction, and grant support to programs designed to improve the health of the nation through research in the

- causes, diagnosis, prevention, and cure of human diseases;
- processes of human growth and development;
- biological effects of environmental contaminants;
- understanding of mental, addictive, and physical disorders; and
- collection, dissemination, and exchange of information in medicine and health, including the development and support of medical libraries and the training of medical librarians and other health information specialists.

Organization

Composed of 27 separate institutes and centers, NIH is one of eight health agencies of the Public Health Service within the U.S. Department of Health and Human Services. NIH encompasses 75 buildings on more than 300 acres in Bethesda, Md., as well as facilities at several other sites in the United States. The NIH budget has grown from about $300 in 1887 to more than $27.8 billion in 2004.

Research Programs

One of NIH's principal concerns is to invest wisely the tax dollars entrusted to it for the support and conduct of this research. Approximately 82 percent of the investment is made through grants and contracts supporting research and training in more than 2,000 research institutions throughout the United States and abroad. In fact, NIH grantees are located in every state in the country. These grants and contracts make up the NIH Extramural Research Program.

Approximately 10 percent of the budget goes to NIH's Intramural Research Programs, the more than 2,000 projects conducted mainly in its own laboratories. These projects are central to the NIH scientific effort. First-rate intramural scientists collaborate with one another regardless of institute affiliation or scientific discipline and have the intellectual freedom to pursue their research leads in NIH's own laboratories. These explorations range from basic biology to behavioral research to studies on treatment of major diseases.

Grant-Making Process

The grant-making process begins with an idea that an individual scientist describes in a written application for a research grant. The project might be small, or it might involve millions of dollars. The project might become useful immediately as a diagnostic test or new treatment, or it might involve studies of basic biological processes whose clinical value may not be apparent for many years.

Each research grant application undergoes peer review. A panel of scientific experts, primarily from outside the government, who are active and productive researchers in the biomedical sciences, first evaluates the scientific merit of the application. Then, a national advisory council or board, composed of eminent scientists as well as members of the public who are interested in health issues or the biomedical sciences, determines the project's overall merit and priority in advancing the research agenda of the particular NIH funding institutes.

About 38,500 research and training applications are reviewed annually through the NIH peer-review system. At any given time, NIH supports 35,000 grants in universities, medical schools, and other research and research training institutions, both nationally and internationally.

NIH Nobelists

The roster of people who have conducted NIH research or who have received NIH support over the years includes some of the world's most illustrious scientists and physicians. Among them are 115 winners of Nobel Prizes for achievements as diverse as deciphering the genetic code and identifying the causes of hepatitis.

Five Nobelists made their prize-winning discoveries in NIH laboratories. You can learn more about Nobelists who have received NIH support at *http://www.nih.gov/about/almanac/nobel/index.htm*.

Impact on the Nation's Health

Through its research, NIH has played a major role in making possible many achievements over the past few decades, including

- Mortality from heart disease, the number one killer in the United States, dropped by 36 percent between 1977 and 1999.
- Improved treatments and detection methods increased the relative five-year survival rate for people with cancer to 60 percent.
- With effective medications and psychotherapy, the 19 million Americans who suffer from depression can now look forward to a better, more productive future.
- Vaccines are now available that protect against infectious diseases that once killed and disabled millions of children and adults.
- In 1990, NIH researchers performed the first trial of gene therapy in humans. Scientists are increasingly able to locate, identify, and describe the functions of many of the genes in the human genome. The ultimate goal is to develop screening tools and gene therapies for the general population for cancer and many other diseases.

For more information about NIH, visit http://www.nih.gov.

About the National Institute of Neurological Disorders and Stroke

NINDS Vision

The vision of the National Institute of Neurological Disorders and Stroke (NINDS) is to

1. Lead the neuroscience community in shaping the future of research and its relationship to brain diseases.
2. Build an intramural program that is the model for modern collaborative neuroscience research.
3. Develop the next generation of basic and clinical neuroscientists through inspiration and resource support.
4. Seize opportunities to focus our resources to rapidly translate scientific discoveries into prevention, treatment, and cures.
5. Be the first place the public turns to for authoritative neuroscience research information.

NINDS Today

One of the National Institutes of Health's 27 Institutes and Centers (ICs), NINDS has occupied a central position in the world of neuroscience for more than 50 years. Its extramural program supports approximately 2,240 research project grants and 85 research contracts. Institutional training grants and individual fellowships support 585 scientists in training; another 246 "career awards" provide a range of research experience and support for faculty members at various levels. Scientists in the Institute's laboratories and clinics conduct research in most of the major areas of neuroscience and many of the most important and challenging neurological disorders. Currently, 644 staff members support the Institute's efforts.

The Institute's interests, broad as they are, are not limited to NINDS programs. The Institute collaborates widely with other NIH components, almost all of which support neuroscience research in areas of mutual interest. Even broader interest is focused on topics such as genomic analysis and selected research resources. Many collaborations are already in place, and it is our hope that the planning process will inspire more. The Institute has a history of productive collaborations with other agencies such as the Department of Defense, the Department of Veterans Affairs, the National Aeronautics and Space Administration, the Centers for Disease Control and Prevention, and the Food and Drug Administration, as well as nonprofit organizations and industry. We shall strive to maintain and expand these relationships.

NINDS Mission

The mission of NINDS is to reduce the burden of neurological disease—a burden borne by every age group, by every segment of society, by people all over the world.

To support this mission, NINDS

- Conducts, fosters, coordinates, and guides research on the causes, prevention, diagnosis, and treatment of neurological disorders and stroke, and supports basic research in related scientific areas.
- Provides grants-in-aid to public and private institutions and individuals in fields related to the Institute's areas of interest, including research project, program project, and research center grants.
- Operates a program of contracts for the funding of research and research support

efforts in selected areas of NINDS's need.

- Provides individual and institutional fellowships to increase scientific expertise in neurological fields.
- Conducts a diversified program of intramural and collaborative research in its own laboratories, branches, and clinics.
- Collects and disseminates research information related to neurological disorders.

For information on neurological disorders, including brochures that might be of interest to your students, please go to *http://www.ninds.nih.gov*.

Introduction to *The Brain: Our Sense of Self*

The **brain** is vital to our existence. It controls our voluntary movements, and it regulates involuntary activities such as breathing and heartbeat. The brain serves as the seat of human consciousness: it stores our memories, enables us to feel emotions, and gives us our personalities. In short, the brain dictates the behaviors that allow us to survive and makes us who we are. Scientists have worked for many years to unravel the complex workings of the brain. Their research efforts have greatly improved our understanding of brain function.

The American public has the opportunity to learn of new research findings about the brain regularly through media reports of scientific breakthroughs and discoveries. However, not all of the information we receive is accurate. As a result of misinformation presented by various media, many people maintain misconceptions about the brain and brain function. This problem may be compounded by textbooks for middle school students that present little, if any, scientific information on the brain as the organ that controls human behavior. By providing students with a conceptual framework about the brain, we significantly increase our chances of producing an informed public with the tools needed to correctly interpret brain research findings.

What Are the Objectives of the Module?

The Brain: Our Sense of Self has several objectives. One is to introduce students to the key concept that the sense of self, our sense of identity, is contained within the brain. Through inquiry-based activities, students investigate brain function and the various roles of the brain within the nervous system. A second objective is to allow students to develop the understanding that brain function is not predetermined; the brain can change with learning throughout life. The lessons in this module help students sharpen their skills in observation, critical thinking, experimental design, and data analysis. They also make connections to other disciplines such as English, history, mathematics, and social science.

A third objective is to convey to students the purpose of scientific research. Ongoing research affects how we understand the world around us and gives us the foundation for improving choices about our personal health and the health of our community. In this module, students experience how science provides evidence that can be used to understand and treat human disease. Because the mission of the National Institute of Neurological Diseases and Stroke includes helping the public understand the importance of brain and nervous system function to their health, education is an important activity for the Institute.

The lessons in this module encourage students to think about the relationships among knowledge, choice, behavior, and human health in this way:

Knowledge (what is known and not known) + Choice = Power

Power + Behavior = Enhanced Human Health

The final objective of this module is to encourage students to think in terms of these relationships now and as they grow older.

Why Teach the Module?

Middle school life science classes offer an ideal setting for integrating many areas of student interest. In this module, students participate in activities that integrate inquiry, science, human health, mathematics, and science-technology-society relationships. The real-life context of the module's classroom lessons is engaging for students, and the knowledge gained can be applied immediately to students' lives.

"The hands-on nature of the module was excellent. It generated student interest and kept learning fun."—Field-Test Teacher

"The inquiry approach of the module was challenging to the students at the right level—it activated the learning process. All students could successfully participate in all activities."—Field-Test Teacher

"I think that the most valuable aspect of the lessons was that they were related to real-life experiences. Also, since the Web activities were hands-on, they were fun and I learned a lot that would have been hard to understand otherwise." —Field-Test Student

"The lessons were interesting, promoted thinking, and allowed me to learn something I didn't know before. Overall, the module inspired me to learn more about the brain and how it functions."—Field-Test Student

What's in It for the Teacher?

The Brain: Our Sense of Self meets many of the criteria by which teachers and their programs are assessed.

- The module is **standards based** and meets science content, teaching, and assessment standards as expressed in the *National Science Education Standards*. It pays particular attention to the standards that describe what students should know and be able to do with respect to **scientific inquiry**.
- As described above, it is an **integrated** module, drawing most heavily from the subjects of science, social science, mathematics, and health.
- The module has a Web-based **technology component** that includes an interactive database and simulations.
- Finally, the module includes built-in **assessment tools**, which are noted in each of the lessons with an assessment icon.

In addition, the module provides a means for **professional development**. Teachers can engage in new and different teaching practices like those described in this module without completely overhauling their entire program. In *Designing Professional Development for Teachers of Science and Mathematics*, Susan Loucks-Horsley et al.[18] write that replacement modules such as this one "offer a window through which teachers get a glimpse of what new teaching strategies look like in action." By experiencing a short-term unit like this one, teachers can "change how they think about teaching and embrace new approaches that stimulate students to problem solve, reason, investigate, and construct their own meaning for the content." The use of supplements like this module can encourage reflection and discussion and stimulate teachers to improve their practices by focusing on student learning through inquiry.

The following table correlates topics often included in the life science curriculum with the major concepts presented in this module. This information is presented to help teachers make decisions about incorporating this material into the curriculum.

Correlation of *The Brain: Our Sense of Self* to Common Middle School Life Science Topics

Topics	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5
Localization of brain function	✔	✔	✔	✔	✔
General functions of specific brain regions		✔			✔
Anatomy of the neuron			✔	✔	
Neurotransmission			✔		✔
Scientific methods		✔	✔	✔	✔
Relationship of science, technology, and society		✔	✔		✔
Organisms sense and respond to environmental stimuli	✔	✔	✔	✔	✔

Implementing the Module

The five lessons in this module are designed to be taught in sequence for approximately seven days as a replacement for a part of the standard curriculum in middle school life science. The following pages offer general suggestions about using these materials in the classroom; you will find specific suggestions in the procedures provided for each lesson.

What Are the Goals of the Module?

The Brain: Our Sense of Self is designed to help students reach these major goals associated with scientific literacy:

- to understand a set of basic scientific principles related to the brain and nervous system;
- to experience the process of scientific inquiry and develop an enhanced understanding of the nature and methods of science; and
- to recognize the role of science in society and the relationship between basic science and human health.

What Are the Science Concepts and How Are They Connected?

We organized the lessons to move students from what they already know about the brain and nervous system, some of which may be incorrect, to having the students gain a scientific perspective of the nature of the brain and nervous system, as well as the importance of the brain and nervous system to their lives. Students are engaged in the topic by exploring various higher brain functions (*A Difference of Mind*). Next, students investigate functional specialization within the brain (*Regional Differences*). Students expand their understanding of the role of the brain within the nervous system by building **neural pathways** for involuntary and voluntary actions (*Inside Information*). Students examine brain **plasticity** and learn about the process of science by exploring the effect of environment on learning in mice (*Outside Influence*). The final lesson (*Our Sense of Self*) allows students to draw on the understandings they have developed over the course of the module to evaluate whether the brain contains our sense of self. The following two tables illustrate the science content and conceptual flow of the classroom lessons and activities.

Science Content of the Lessons

Lesson	Science Content
Lesson 1	Functions of the brain
Lesson 2	Structure and function of the brain
Lesson 3	Neural pathways; reflexes and voluntary actions
Lesson 4	Learning and factors that affect learning
Lesson 5	Pulling it together: our sense of self

Conceptual Flow of the Lessons

Lesson	Learning Focus*	Major Concepts
Lesson 1 *A Difference of Mind*	Engage Explore	• The human brain performs diverse functions. • Each person's brain responds differently from every other person's brain to tasks related to these brain functions.
Lesson 2 *Regional Differences*	Explore Explain	• Specialized regions of the brain process information from specific sources, such as the eyes, ears, or skin. • The location of these specialized regions in the brain is similar between individuals. • Responses by the brain differ between individuals, even though the individuals receive information from the same sources in the same specialized areas of the brain.
Lesson 3 *Inside Information*	Explore Explain	• The body receives and delivers information through the nervous system. • The nervous system is an interconnected set of specialized parts, including the brain, the spinal cord, and nerve cells outside the brain and spinal cord. • Information flows in one direction through a nerve cell. • Reflex pathways lead to rapid, involuntary responses and include only the spinal cord and nerve cells outside the brain and spinal cord. • Voluntary response pathways involve choice and thus include the brain as well as the spinal cord and nerve cells outside the brain and spinal cord.
Lesson 4 *Outside Influence*	Elaborate	• Learning is an important brain function. • There are factors that affect learning. • Laboratory animals can serve as experimental models for investigating learning. • The ability of the brain to learn is not fixed.
Lesson 5 *Our Sense of Self*	Evaluate	• The nervous system can be damaged through injury or disease. • Damage to the spinal cord does not change who we are. • Damage to the brain can change who we are.

* See *How Does the 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?* on page 10.

How Does the Module Correlate to the *National Science Education Standards*?

NSES

The Brain: Our Sense of Self supports you in your efforts to reform science education in the spirit of the National Research Council's 1996 *National Science Education Standards* (*NSES*). The content of the module is explicitly standards based. Each time a standard is addressed in a lesson, an icon appears in the margin and the applicable standard is identified. The following chart lists the specific content standards that this module addresses.

Content Standards: Grades 5–8

Standard A: Science as Inquiry **As a result of activities in grades 5–8, all students should develop**	**Correlation to *The Brain: Our Sense of Self***
Abilities necessary to do scientific inquiry	
• Identify questions and concepts that guide scientific investigations.	Lessons 4, 5
• Design and conduct a scientific investigation.	Lessons 4, 5
• Use appropriate tools and techniques to gather, analyze, and interpret data.	Lessons 4, 5
• Develop descriptions, explanations, predictions, and models using evidence.	Lessons 4, 5
• Think critically and logically to make the relationships between evidence and explanations.	Lessons 4, 5
• Recognize and analyze alternative explanations and predictions.	Lessons 4, 5
• Communicate scientific procedures and explanations.	Lessons 4, 5
Understandings about scientific inquiry	
• Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects; and some involve making models.	Lessons 3, 4, 5
• Current scientific knowledge and understanding guide scientific investigations. Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and understanding.	Lessons 3, 4, 5
• Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.	Lessons 2, 4
• Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.	Lessons 3, 4, 5
• Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations.	Lessons 2, 3, 4, 5
• Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.	Lessons 3, 4, 5

Standard C: Life Science **As a result of their activities in grades 5–8, all students should develop understanding of**	
Structure and function in living systems	
• Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.	Lessons 2, 3, 4, 5
• All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.	Lessons 3, 4
• Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organism needs.	Lessons 3, 4, 5
• Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue, such as muscle. Different tissues are in turn grouped together to form larger functional units, called organs. Each type of cell, tissue, and organ has a distinct structure and set of functions that serve the organism as a whole.	Lessons 2, 3, 4, 5
• The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control, and coordination and for protection from disease. These systems interact with one another.	Lessons 2, 3, 4, 5
• Disease is a breakdown in structures or functions of an organism. Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.	Lesson 5
Reproduction and heredity	
• The characteristics of an organism can be described in terms of a combination of traits. Some are inherited, and others result from interactions with the environment.	Lesson 4
Regulation and behavior	
• Regulation of an organism's internal environment involves sensing the internal environment and changing physiological activities to keep conditions within the range required to survive.	Lessons 2, 3, 4, 5
• Behavior is one kind of response an organism can make to an internal or environmental stimulus. A behavioral response requires coordination and communication at many levels, including cells, organ systems, and whole organisms. Behavioral response is a set of actions determined in part by heredity and in part by experience.	Lessons 2, 3, 4, 5
• An organism's behavior evolves through adaptation to its environment. How a species moves, obtains food, reproduces, and responds to danger is based in the species' evolutionary history.	Lessons 2, 3, 4, 5

Diversity and adaptations of organisms	
• Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry.	Lesson 4
• Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.	Lesson 4
Standard F: Science in Personal and Social Perspectives As a result of their activities in grades 5–8, all students should develop understanding of	
Personal health	
• The potential for accidents and the existence of hazards impose the need for injury prevention. Safe living involves the development and use of safety precautions and the recognition of risk in personal decisions.	Lesson 5
Risks and benefits	
• Risk analysis considers the type of hazard and estimates the number of people who might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risks.	Lessons 2, 3, 4, 5
• Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions), chemical hazards (pollutants in air, water, soil, and food), biological hazards (pollen, viruses, bacterial, and parasites), social hazards (occupational safety and transportation), and personal hazards (smoking, dieting, and drinking).	Lessons 2, 3, 4, 5
• Individuals can use a systematic approach to thinking critically about risks and benefits. Examples include applying probability estimates to risks and comparing them to estimated personal and social benefits.	Lessons 2, 3, 4, 5
• Important personal and social decisions are made based on perceptions of benefits and risks.	Lessons 2, 3, 4, 5
Science and technology in society	
• Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.	Lessons 2, 3, 4, 5

Teaching Standards

The suggested teaching strategies in all the lessons support you as you work to meet the teaching standards outlined in the *National Science Education Standards*. The module helps teachers plan an inquiry-based science program by providing short-term objectives for students. It also includes planning tools such as the Conceptual Flow of the Lessons chart and the Suggested Timeline for teaching the module. Teachers can use this module to update their curriculum in response to their students' interest in this topic.

The focus on active, collaborative, and inquiry-based learning in the lessons helps teachers support the development of student understanding and nurture a community of science learners.

The structure of the lessons in this module enables teachers to guide and facilitate learning. All the activities encourage and support student inquiry, promote discourse among students, and challenge students to accept and share responsibility for their learning. Using the 5E Instructional Model, combined with active, collaborative learning, allows teachers to respond effectively to the diversity of student backgrounds and learning styles. The module is fully annotated, with suggestions for how teachers can encourage and model the skills of scientific inquiry, as well as foster the curiosity, openness to new ideas and data, and skepticism that characterize successful study of science.

Assessment Standards

You can engage in ongoing assessment of your teaching and of student learning using the variety of assessment components embedded within the module's structure. The assessment tasks are authentic; they are similar in form to tasks that students will encounter in their lives outside the classroom or in which scientists participate. Annotations guide teachers to these opportunities for assessment and provide answers to questions that can help teachers analyze student feedback.

How Does the 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?

Because learning does not occur through a process of passive absorption, the lessons in this module promote active learning. Students are involved in more than listening and reading. They are developing skills, analyzing and evaluating evidence, experiencing and discussing, and talking to their peers about their own understandings. Students work collaboratively with others to solve problems and plan investigations. Many students find that they learn better when they work with others in a collaborative environment than they can when they work alone in a competitive environment. When all this active, collaborative learning is directed toward inquiry science, students succeed in making their own discoveries. They ask questions, observe, analyze, explain, draw conclusions, and ask new questions. These inquiry experiences include both those that involve students in direct experimentation and those in which students develop explanations through critical and logical thinking.

This viewpoint that students are active thinkers who construct their own understanding out of interactions with phenomena, the environment, and other individuals is based on the theory of **constructivism**. A constructivist view of learning recognizes that students need time to

- express their current thinking;
- interact with objects, organisms, substances, and equipment to develop a range of experiences on which to base their thinking;
- reflect on their thinking by writing and expressing themselves and comparing what they think with what others think; and
- make connections between their learning experiences and the real world.

This module provides a built-in structure for creating a constructivist classroom: the 5E Instructional Model. This model sequences the learning experiences so that students have the opportunity to construct their understanding of a concept over time. The model takes students through five phases of learning that are easily described using five words that begin with the letter *E*: Engage, Explore, Explain, Elaborate, and Evaluate. The following paragraphs illustrate how the five Es are implemented across the lessons in this module.

Engage

Students come to learning situations with prior knowledge. This knowledge may or may not be congruent with the concepts presented in this module. Engage lessons provide the opportunity for teachers to find out what students already know or what they think they know about the topic and concepts to be developed.

The Engage lesson in this module, Lesson 1: *A Difference of Mind*, is designed to

- pique students' curiosity and generate interest;
- determine students' current understanding about the brain;
- invite students to raise their own questions about the brain and nervous system;
- encourage students to compare their ideas with the ideas of others; and
- enable teachers to assess what students do or do not understand about the stated outcomes of the lesson.

Explore

In the Explore phase of the module, Lesson 2: *Regional Differences* and Lesson 3: *Inside Information*, students investigate how the brain functions as the body's center for information processing. These lessons require students to make observations, evaluate and interpret data, and draw conclusions. Students

- interact with materials and ideas through classroom demonstrations and simulations;
- consider different ways to solve a problem or answer a question;
- acquire a common set of experiences with their classmates so they can compare results and ideas;
- observe, describe, record, compare, and share their ideas and experiences; and
- express their developing understanding of the brain by interpreting models, analyzing simulations, and answering questions.

Explain

The Explain phase provides opportunities for students to connect their previous experiences and to begin to make conceptual sense of the main ideas of the module. This stage also allows for the introduction of formal language, scientific terms, and content information that might make students' previous experiences easier to describe and explain.

In the Explain lessons in this module, Lesson 2: *Regional Differences* and Lesson 3: *Inside Information*, students

- explain concepts and ideas in their own words about how the brain receives, processes, interprets, and generates information;
- listen to and compare others' explanations of their results with their own;
- become involved in student-to-student discourse in which they explain their thinking to others and debate their ideas;
- revise their ideas;
- record their ideas and current understanding;
- use labels, terminology, and formal language; and
- compare their current thinking with what they previously thought.

Elaborate

In Elaborate lessons, students apply or extend the concepts in new situations and relate their previous experiences to new ones. In the Elaborate lesson in this module, Lesson 4: *Outside Influence*, students make conceptual connections between new and former experiences. They draw upon their knowledge about the brain and nervous system to evaluate data related to learning. In these lessons students

- connect ideas, solve problems, and apply their understanding in a new situation;
- use scientific terms and descriptions;
- draw reasonable conclusions from evidence and data;
- add depth to their understanding of concepts and processes; and
- communicate their understanding to others.

Evaluate

The Evaluate lesson is the final stage of the Instructional Model, but it only provides a "snapshot" of what the students understand and how far they have come from where they began. In reality, the evaluation of students' conceptual understanding and ability to use skills begins with the Engage lesson and continues throughout each stage of the model, as described in the following section. However, combined with the students' written work and performance of tasks throughout the module, the Evaluate lesson can serve as a summative assessment of what students know and can do.

The Evaluate lesson in this module, Lesson 5: *Our Sense of Self*, provides an opportunity for students to

- demonstrate what they understand about the brain and nervous system and how well they can apply their knowledge to solve a problem;
- share their current thinking with others;
- assess their own progress by comparing their current understanding with their prior knowledge; and
- ask questions that take them deeper into a concept.

To review the relationship of the 5E Instructional Model to the concepts presented in the module, see the Conceptual Flow of the Lessons chart on page 6.

When a teacher uses the 5E Instructional Model, he or she engages in practices that are very different from those of a traditional teacher. In response, students also participate in their learning in ways that are different from those seen in a traditional classroom. The following charts, What the Teacher Does and What the Students Do, outline these differences.

What the Teacher Does

Stage	That is *consistent* with the 5E Instructional Model	That is *inconsistent* with the 5E Instructional Model
Engage	• Piques students' curiosity and generates interest • Determines students' current understanding (prior knowledge) of a concept or idea • Invites students to express what they think • Invites students to raise their own questions	• Introduces vocabulary • Explains concepts • Provides definitions and answers • Provides closure • Discourages students' ideas and questions
Explore	• Encourages student-to-student interaction • Observes and listens to the students as they interact • Asks probing questions to redirect the students' investigations when necessary • Asks questions to help students make sense of their experiences • Provides time for students to puzzle through problems	• Provides answers • Proceeds too rapidly for students to make sense of their experiences • Provides closure • Tells the students that they are wrong • Gives information and facts that solve the problem • Leads the students step-by-step to a solution

Explain	• Encourages students to use their common experiences and data from the Engage and Explore lessons to develop explanations • Asks questions that help students express understanding and explanations • Requests justification (evidence) for students' explanations • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Introduces terminology and alternative explanations after students express their ideas	• Neglects to solicit students' explanations • Ignores data and information students gathered from previous lessons • Dismisses students' ideas • Accepts explanations that are not supported by evidence • Introduces unrelated concepts or skills
Elaborate	• Focuses students' attention on conceptual connections between new and former experiences • Encourages students to use what they have learned to explain a new event or idea • Reinforces students' use of scientific terms and descriptions previously introduced • Asks questions that help students draw reasonable conclusions from evidence and data	• Neglects to help students connect new and former experiences • Provides definitive answers • Tells students that they are wrong • Leads students step-by-step to a solution
Evaluate	• Observes and records as students demonstrate their understanding of concepts and performance of skills • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Interviews students as a means of assessing their developing understanding • Encourages students to assess their own progress	• Tests vocabulary words, terms, and isolated facts • Introduces new ideas or concepts • Creates ambiguity • Promotes open-ended discussion unrelated to the concept or skill

What the Students Do

Stage	That is *consistent* with the 5E Instructional Model	That is *inconsistent* with the 5E Instructional Model
Engage	• Become interested in and curious about the concept/topic • Express current understanding of a concept or idea • Raise questions such as, What do I already know about this? What do I want to know about this? How could I find out?	• Ask for the "right" answer • Offer the "right" answer • Insist on answers or explanations • Seek closure
Explore	• "Mess around" with materials and ideas • Conduct investigations in which they observe, describe, and record data • Try different ways to solve a problem or answer a question • Acquire a common set of experiences so they can compare results and ideas • Compare their ideas with those of others	• Let others do the thinking and exploring (passive involvement) • Work quietly with little or no interaction with others (only appropriate when exploring ideas or feelings) • Stop with one solution • Demand or seek closure
Explain	• Explain concepts and ideas in their own words • Base their explanations on evidence acquired during previous investigations • Become involved in student-to-student conversations in which they debate their ideas • Record their ideas and current understanding • Reflect on and perhaps revise their ideas • Express their ideas using appropriate scientific language • Compare their ideas with what scientists know and understand	• Propose explanations from "thin air" with no relationship to previous experiences • Bring up irrelevant experiences and examples • Accept explanations without justification • Ignore or dismiss other plausible explanations • Propose explanations without evidence to support their ideas
Elaborate	• Make conceptual connections between new and former experiences • Use what they have learned to explain a new object, event, organism, or idea • Use scientific terms and descriptions • Draw reasonable conclusions from evidence and data • Communicate their understanding to others	• Ignore previous information or evidence • Draw conclusions from "thin air" • Use terminology inappropriately and without understanding

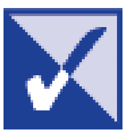
Evaluate	• Demonstrate what they understand about the concepts and how well they can implement skills • Compare their current thinking with that of others and perhaps revise their ideas • Assess their own progress by comparing their current understanding with their prior knowledge • Ask new questions that take them deeper into a concept or topic area	• Disregard evidence or previously accepted explanations in drawing conclusions • Offer only yes-or-no answers or memorized definitions or explanations as answers • Fail to express satisfactory explanations in their own words • Introduce new, irrelevant topics

How Does the Module Support Ongoing Assessment?

Because teachers will use this module in a variety of ways and at a variety of points in their curriculum, the most appropriate mechanism for assessing student learning is one that occurs informally at various points within the five lessons, rather than something that happens more formally just once at the end of the module. Accordingly, integrated within the module's five lessons are specific assessment components. These "embedded" assessment opportunities include one or more of the following strategies:

- performance-based activities, such as developing graphs or participating in a discussion of health effects or social policies;
- oral presentations to the class, such as presenting experimental results; and
- written assignments, such as answering questions or writing about demonstrations.

These strategies allow the teacher to assess a variety of aspects of the learning process, such as students' prior knowledge and current understanding, problem-solving and critical-thinking skills, level of understanding of new information, communication skills, and ability to synthesize ideas and apply understanding to a new situation.



As assessment icon and an annotation that describes the aspect of learning that teachers can assess appear in the margin beside each step in which embedded assessment occurs.

How Can Controversial Topics Be Handled in the Classroom?

Teachers sometimes feel that the discussion of values is inappropriate in the science classroom or that it detracts from the learning of "real" science. The lessons in this module, however, are based on the conviction that there is much to be gained by involving students in analyzing issues of science, technology, and society. Society expects all citizens to participate in the democratic process, and our educational system must provide opportunities for students to learn to deal with contentious issues with civility, objectivity, and fairness. Likewise, students need to learn that science intersects with life in many ways.

In this module, students have a variety of opportunities to discuss, interpret, and evaluate basic science and health issues, some in the light of values and ethics. As students encounter issues about which they feel strongly, some discussions might become controversial. The degree of controversy will depend on many factors, such as how similar the students are with respect to socioeconomic status, perspectives, value systems, and religious preferences. In addition, the language and attitude of the teacher factor into the flow of ideas and the quality of exchange among the students.

The following guidelines may help you facilitate discussions that balance factual information with feelings.

- Remain neutral. Neutrality may be the

single most important characteristic of a successful discussion facilitator.

- Encourage students to discover as much information about the issue as possible.
- Keep the discussion relevant and moving forward by questioning or posing appropriate problems or hypothetical situations. Encourage everyone to contribute, but do not force reluctant students into the discussion.
- Emphasize that everyone must be open to hearing and considering diverse views.
- Use unbiased questioning to help the students critically examine all views presented.
- Allow for the discussion of all feelings and opinions.
- Avoid seeking consensus on all issues. The multifaceted issues that the students discuss result in the presentation of divergent views, and students should learn that this is acceptable.
- Acknowledge all contributions in the same evenhanded manner. If a student seems to be saying something for its shock value, see whether other students recognize the inappropriate comment and invite them to respond.
- Create a sense of freedom in the classroom. Remind students, however, that freedom implies the responsibility to exercise that freedom in ways that generate positive results for all.
- Insist upon a nonhostile environment in the classroom. Remind students to respond to ideas instead of to the individuals presenting those ideas.
- Respect silence. Reflective discussions are often slow. If a teacher breaks the silence, students may allow the teacher to dominate the discussion.
- At the end of the discussion, ask students to summarize the points that they and their classmates have made. Respect students regardless of their opinion about any controversial issue.

Using the Student Lessons

The heart of this module is a set of five classroom lessons that allow students to discover important concepts related to the brain and how it makes us who we are. To review these concepts in detail, refer to the Conceptual Flow of the Lessons chart, on page 6.

Format of the Lessons

As you review the lessons, you will find that all contain common major features.

At a Glance offers a convenient summary of the lesson.

- **Overview** provides a short summary of student activities.
- **Major Concepts** presents the central ideas that the lesson is designed to convey.
- **Objectives** lists specific understandings or abilities students should derive from completing the lesson.
- **Teacher Background** specifies which sections of the background material, Information about the Brain, relate directly to the lesson. This reading material provides the science content that supports the key concepts covered in the lesson. The information is *not* intended to form the basis of lectures to students nor is it intended as a direct resource for students. Rather, it enhances your understanding of the content so that you can facilitate class discussions, answer student questions, and provide additional examples.

In Advance provides instructions for collecting and preparing materials required to complete the activities in the lesson.

- **Web-Based Activities** tells you which of the lesson's activities use *The Brain: Our Sense of Self* Web site as the basis for instruction.
- **Photocopies** lists the paper copies and transparencies that need to be made from masters that are provided after Lesson 5, at the end of the module.
- **Materials** lists all items other than photocopies needed for the activities in the lesson.
- **Preparation** outlines what you need to do to be ready to teach the activities in the lesson.

Procedure provides a step-by-step approach for conducting each activity in the classroom. It includes implementation suggestions and answers to discussion questions.

Within the Procedure section, annotations provide additional commentary.

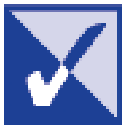
- **Tip from the field test** details suggestions from field-test teachers for teaching strategies, class management, and module implementation.
- **Assessment** provides strategies for gauging student progress throughout the module, and is identified by an assessment icon (see page 18).
- **Icons** identify specific annotations:

NSES identifies teaching strategies that address specific science content standards as defined by the *National Science Education Standards*.

WWW identifies when to use the Web site as part of the teaching strategy. Instructions tell you how to access the Web site and relevant activity.

Information about using the Web site can be found in *Using the Web Site* (see page 19). A print-based alternative to each Web activity is provided for classrooms in which Internet access is not available.

identifies a print-based alternative to a Web-based activity to be used when computers with access to the Internet are not available.



identifies when assessment is embedded in the module's structure. An annotation suggests strategies for assessment.

The **Lesson Organizer** provides a brief summary of the lesson. It outlines procedural steps for each activity and includes icons that denote where in each activity masters, transparencies, and the Web site are used. The lesson organizer is intended to be a memory aid for you to use only after you become familiar with the detailed procedures for the activities. It can be a handy resource during lesson preparation as well as during classroom instruction.

Masters to be photocopied are found after Lesson 5, at the end of the module.

Timeline for the Module

The timeline below outlines the optimal plan for completing the five lessons in this module. The plan assumes you will teach the activities on consecutive days. If your class requires more time for discussing issues raised in this module or for completing activities, adjust your timeline accordingly.

Suggested Timeline

Timeline	Activity
3 weeks ahead	Reserve computers Check performance of Web site
7 days ahead	Make photocopies and transparencies Gather materials
Day 1 Monday	**Lesson 1** Activity 1: *A Difference of Mind*
Day 2 Tuesday	**Lesson 2** Activity 1: *Picturing the Brain* Activity 2: *Decisions, Decisions*
Day 3 Wednesday	**Lesson 3** Activity 1: *Information Flow* Activity 2: *Inside Information, Part 1*
Day 4 Thursday	**Lesson 3** Activity 2: *Inside Information, Part 2* Activity 3: *Summing It Up*
Day 5 Friday	**Lesson 4** Activity 1: *Effect of Social Interaction on Learning*
Day 6 Monday	**Lesson 4** Activity 2: *Effects of Enrichment and Exercise on Learning* Activity 3: *A Human Perspective*
Day 7 Tuesday	**Lesson 5** Activity 1: *Our Sense of Self*

Using the Web Site

The Web site for *The Brain: Our Sense of Self* is a wonderful tool that can engage student interest in learning, enhance the student's learning experience, and orchestrate and individualize instruction. The Web site features simulations that articulate with three of this unit's lessons. To access the Web site, type the following URL into your browser: *http://science.education.nih.gov/supplements/self*. Click on the link to a specific lesson under *Web Portion of Student Activities*. If you do not have computer or Internet access, you can use the print-based alternative provided for each Web activity. Text pertaining only to Web-based activities is lightly shaded.

Hardware/Software Requirements

The Web site can be accessed from Apple Macintosh and IBM-compatible personal computers. Links to download the Macromedia Flash plug-in are provided on the Web site's Getting Started page. *This plug-in is required for the activities to function properly*. The recommended hardware and software requirements for using the Web site are listed in the table below. Although your computer configuration may differ from those listed, the Web site may still be functional on your computer. The most important items in this list are current browsers and plug-ins.

Downloading and Installing Macromedia Flash Player

To experience full functionality of the Web site, Macromedia Flash Player, version 6 or better, must be downloaded and installed on the hard drive of each computer that will be used to access the site. The procedure for downloading and installing Macromedia Flash Player is outlined below.

- Open a Web browser.

Recommended Hardware/Software Requirements for Using the Web Site*

CPU/Processor (PC Intel, Mac)	Pentium III, 600 MHz; or Mac G4
Operating system (DOS/Windows, Mac OS)	Windows 2000 or higher; or Mac OS 9 or newer
System memory (RAM)	256 MB
Screen display	1024 × 768 pixels, 32 bit color
Browser	Netscape Communicator 7.1 or Microsoft Internet Explorer 6
Browser settings	JavaScript Enabled
Free hard drive space	10 MB
Connection speed	T1, cable, or DSL
Plug-ins, installed for your Web browser	Macromedia Flash Plug-In, version 6 or better; or Apple QuickTime Plug-In, version 6 or better
Audio	Sound card with speakers

* For users of screen-reader software, a multichannel sound card such as Sound Blaster Live!™ is recommended.

- Access the main page of the Web site at *http://science.education.nih.gov/supplements/self*.
- Click on the “Getting Started” section.
- Click on the link to “Macromedia Flash.” This will bring up the Macromedia Flash Player Download Center Web site.
- The Download Center Web site should present you with the option of installing the latest version (highest number) of Macromedia Flash Player. As of August 2004, this should be at least version 7.0.
- Click on the button marked “Install Now” or “Download Now.” Clicking this button will allow Macromedia’s Web site to download and install Flash Player on your computer’s hard drive. If you are using Internet Explorer, the installation will happen automatically after you click the “Install Now” button. If you are using Netscape, you will have to download and run the installation file. Follow the on-screen instructions provided.
- Your Web browser may present you with a Security Dialog Box asking if you would like to install and run Macromedia Flash Player. Click “Yes.”
- After a minute or so, you should once again see the Macromedia Download Center Web page on your browser. There will be a box toward the top of the page containing clickable text. The appearance of this box in your browser window indicates that you have successfully downloaded and installed Macromedia Flash Player.

Getting the Most out of the Web Site

Before you use the Web site, or any other piece of instructional software in your classroom, it may be valuable to identify some of the benefits you can expect the software to provide. Well-designed instructional multimedia software can

- motivate students by helping them enjoy learning and want to learn more because it enlivens content that they might find uninteresting otherwise;
- offer unique instructional capabilities that allow students to explore topics in greater depth and in ways that are closer to actual field experience than print-based resources can offer;
- provide teachers with support for experimenting with new instructional approaches that allow students to work independently or in small teams and that give teachers increased credibility among today’s technology-literate students; and
- increase teachers’ productivity by helping them with assessment, record keeping, and classroom planning and management.

The ideal use of the Web site requires one computer for each student team. However, if you have only one computer available, you can still use the Web site. For example, you can use a projection system to display the monitor image for the whole class to see. Giving selected students in the class the opportunity to manipulate the Web activities in response to suggestions from the class can give students some of the same autonomy in their learning that they would gain from working in small teams. Alternatively, you can rotate student teams through the single computer station.

Collaborative Groups

We designed many of the activities in the lessons to be done by teams of students working together. Although individual students working alone can complete these activities, this strategy does not stimulate the student-student interactions that are a goal of active, collaborative, inquiry-based learning. Therefore, we recommend that you organize students into teams of two to four students each, depending on the number of computers available. Students in teams larger than this have difficulty organizing student-computer interactions equitably. This can lead to one or two students’ assuming the primary responsibility for the computer-based work. Although this arrangement can be efficient, it does not allow all team members to experience the in-depth discovery and analysis that the Web site was designed to provide. Team members not involved directly may become bored or disinterested.

We recommend that you keep students in the same collaborative teams for all the activities in the lessons. This will allow each team to develop a shared experience with the Web site and with the ideas and issues that the activities present. A shared experience will also enhance your students' perceptions of the lesson as a conceptual whole.

If your student-to-computer ratio is greater than four to one, you will need to change the way you teach the module from the instructions in the lessons. For example, if you have only one computer available, you might want students to complete the Web-based work over an extended time period. You can do this several ways. The most practical way is to use your computer as a center along with several other centers at which students complete other activities. In this approach, students rotate through the computer center, eventually completing the Web-based work you have assigned.

A second way to structure the lessons if you have only one computer available is to use a projection system to display the desktop screen for the whole class to view. Giving selected students in the class the opportunity to manipulate the Web activities in response to suggestions from the class can give students some of the same autonomy in their learning they would have gained from working in small teams.

Web Activities for Students with Disabilities

The Office of Science Education (OSE) is committed to providing access to the Curriculum Supplement Series for individuals with disabilities, including members of the public and federal employees. To meet this commitment, we comply with the requirements of Section 508 of the Rehabilitation Act. Section 508 requires that individuals with disabilities who are members of the public seeking these materials will have access to and use of information and data that are comparable to those provided to members of the public who are not individuals with disabilities. The online versions of this series comply with Section 508.

If you use assistive technology (such as a Braille reader or a screen reader) and the format of any material on our Web sites interferes with your ability to access the information, please let us know. To enable us to respond in a manner most helpful to you, please indicate the nature of your accessibility problem, the format in which you would like to receive the material, the Web address of the requested material, and your contact information.

Contact us at

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The Brain: Our Sense of Self 508-Compliant Web Activities

Lesson	For students with hearing impairment	For students with sight impairment
Lesson 1, Part 1: *Attention Station, Stroop Test*	Although the on-screen directions ask students to say the name of a word's color, please direct hearing-impaired students to sign the name of the color.	If you have a student in your classroom with color-blindness, the accessible version of the activity may be more suitable. Open this activity by clicking on the "Accessible Activities" button on the Student Activities menu. If a student is using screen magnification or screen-reading software, they will be presented with an alternate version of the activity. In this activity, students will listen through stereo headphones or stereo speakers and hear the words "left" and "right." During Test 1, the words will sound on their respective sides. During Test 2, the words will sound opposite their respective sides. The students are instructed to press the right- and left-bracket keys to indicate the side on which they heard the sound. This provides an equivalent experience of a divided attention activity. During both tests, the words will appear on screen for the benefit of the teacher or partner who will be working with the student. **Note:** Students using a screen magnifier may prefer the original version of the activity. Stereo speakers or stereo headphones are required. When the activity loads, there is a button to proceed to the original version or screen-reader-friendly version of the activity. Supervision is recommended.

Lesson 1, Part 1: *Emotion Station*	No special considerations are required.	If a student is using screen magnification or screen-reading software, they will be presented with an alternate version of the activity. Students will hear two audio clips and are instructed to note how the different clips make them feel. **Note:** Students using a screen magnifier may prefer the original version of the activity. When the activity loads, students choose (by clicking on a button) to proceed to the original version or to the screen-reader-friendly version of the activity. Supervision is recommended.
Lesson 3, Activity 2: *Inside Information*	Students may click on the closed-captioning icon to view the captioning for the introduction.  The icon is located below the graphics at the bottom of the window. The text appears in the same place.	If a student is using screen magnification or screen-reading software, they will be presented with an alternate, text-based version of the activity. This content of the activity is equivalent, but in a text format. **Note:** Images within the reference manual are kept to a minimum. The print version of the activity should be kept handy for reference. **Note:** Students using a screen magnifier may prefer the original version of the activity. When the activity loads, students choose (by clicking on a button) to proceed to the original version or to the screen-reader-friendly version of the activity. The computer students use must be linked to a printer. Supervision is recommended.
Lesson 4, Outside Influence, Activity 1: *Effects of Social Interaction on Learning*	No special considerations are required.	Same as Lesson 3. Additionally, the computer students use must be linked to a printer.

Lesson 4, Outside Influence, Activity 2: *Effects of Enrichment and Exercise on Learning*	No special considerations are required.	Same as Lesson 3. Additionally, the computer students use must be linked to a printer.

Information about the Brain

1 Introduction

"I think, therefore I am."
—René Descartes, 17th-century philosopher

Few of us question the crucial importance of the brain. It is vital to our existence. Our brains enable us to think, as René Descartes so skillfully pointed out nearly 400 years ago. Yet the human brain is responsible for so much more. It directs almost everything we do. It controls our voluntary movements, and it regulates involuntary activities such as breathing and heartbeat. The brain serves as the seat of human consciousness: it stores our memories, allows us to feel emotions, and gives us our personalities.

The brain makes up only 2 percent of our body weight, but it consumes 20 percent of the oxygen we breathe and 20 percent of the energy we consume. This enormous consumption of oxygen and energy fuels many thousands of chemical reactions in the brain every second. These chemical reactions underlie the actions and behaviors we use to respond to our environment. In short, the brain dictates the behaviors that allow us to survive.

Scientists have worked for many years to unravel the complex workings of the brain. Their research efforts have greatly improved our understanding of brain function. During the past decade alone, scientific and technical progress in all fields of brain research has been astonishing. Using new imaging techniques, scientists can visualize the human brain in action. Images produced by these techniques have defined brain regions responsible for attention, memory, and emotion. A series of discoveries (in multiple fields of study) has displaced the long-standing assumption that brain cells are stable and unchanging. Amazingly, new findings show that some adult brain cells can divide and grow! In addition, advances in research are allowing scientists to analyze and make progress toward understanding the causes of inherited brain disorders such as **Alzheimer's disease** and Parkinson's disease. Taken together, these discoveries provide hope for the recovery of **nervous system** function lost through injury or disease.

Despite these and other significant advances in the field of brain research, most of the processes responsible for the integrated functioning of billions of brain cells remain a mystery. Research on the brain in the new millennium is crucial to our effort to come to a complete understanding of this fascinating organ. In turn, improved understanding makes the development of new treatment options possible. Research continues to bring new insights into how the brain is put together, how it works, and whether damage to the brain can be reversed.

An essential aspect of any scientific research is communicating results to the public in a way that is easily understood. The American public has the opportunity to learn of new research findings about the brain regularly through media reports of scientific breakthroughs and discoveries. However, not all the information we receive is accurate. Commercial products promoted through television advertisements claim to improve memory, enhance concentration, or relieve depression, among other things. The media may oversimplify research findings into a "sound clip" open to misinterpretation. In addition, movies, television shows, and the World Wide Web often contain inaccuracies in their portrayal of research findings about brain structure or function.

To correctly interpret the information transmitted through these venues, we need a better understanding of basic concepts related to the brain. By providing students with a conceptual framework about the brain, we significantly increase our chances of producing an informed public that has the tools to interpret brain research findings. Accordingly, it is the goal of this supplement to provide teachers and students with correct information regarding the brain, its role in the nervous system, and how it provides us with our sense of self.

2 Myths and Realities about the Brain

As a result of the misinformation presented by various media, many people maintain misconceptions about the brain and brain function. The problem may be compounded by textbooks for middle school students that present little, if any, scientific information on the brain as the organ that controls human behavior. As a result, students may build their understanding of the brain on "fictions" rather than facts. The constructivist learning model holds that when students dispel their own misconceptions, they are more open to constructing a correct understanding of the subject. The following list of commonly held misconceptions about the brain, followed by correct information about each concept, should help teachers address these issues in their classrooms.

As a result of the misinformation presented by various media, many people maintain misconceptions about the brain and brain function.

Myth: The brain is separate from the nervous system.

Reality: Students often assume that the brain and the nervous system are separate, unrelated entities. Furthermore, surveys of middle school students have shown that they often believe organs such as the heart and lungs are part of the nervous system. In reality, the nervous system is composed of only the brain, the spinal cord, neurons, and neural support cells. Section 3, *The Nervous System: Composition and Organization*, contains more detail about the components of the nervous system.

Myth: The brain is a uniform mass of tissue.

Reality: The only exposure that middle school students often have to brain anatomy is a photo or drawing of a gray, bulbous, wrinkled mass of tissue. This may lead students to believe that the brain is uniform throughout. Although the brain may appear uniform at a gross anatomic level, it is actually composed of billions of specialized cells. These cells, called **neurons** and **glia**, are further organized into specialized functional regions within the brain. This type of variation within the brain is what allows it to function as "command central" of the human body. The cellular nature of the brain is discussed in Section 4, *Cells of the Nervous System.*

Myth: Control of voluntary activity is the sole purpose of the brain.

Reality: When do we use our brains? Students may have the misconception that they use their brains only when they are *doing* something, such as thinking or performing a physical action. Most students do not recognize that we use our brains constantly for a variety of activities that, while crucial to our survival, require no conscious thought. For instance, the human brain is responsible for involuntary activities, such as regulating heartbeat, breathing, and blinking. Although the brain controls both voluntary and involuntary activities, different regions of the brain are devoted to each type of task. Activities controlled by the brain are explored in Section 5, *The Brain*.

*Myth: The **vertebral column** and the **spinal cord** are the same thing.*

Reality: The only exposure most students have to the human spine is as a component in models of skeletons. Thus students may assume that the spine consists solely of the skeletal structure of the vertebral column, or backbone. They can feel their own backbone, and they know that it is a structural component of their body. Students may not realize that the backbone encases the spinal cord, a vital part of our nervous system. The components and functions of the spinal cord are described in Section 6, *The Spinal Cord.*

Myth: The brain does not change.

Reality: The idea that the brain does not change after growth ceases may be the greatest misconception that students have. In actuality, the brain changes throughout life. During embryonic development and early life, the brain changes dramatically. Neurons form many new connections, and some neurons die. However, scientists have discovered that changes in the brain are not restricted to early life.[8,12] Even in the adult brain, neurons continue to form new connections, strengthen existing connections, or eliminate connections as we continue to learn. Recent studies have shown that some neurons in the adult brain retain the ability to divide.[11] Finally, damaged neurons have some capability to regenerate if the conditions are right. The changing nature of the brain is discussed further in Section 7, *Plasticity and Learning.*

The idea that the brain does not change after growth ceases may be the greatest misconception that students have.

Myth: Learning disabilities are the only manifestation of a problem with brain function.

Reality: Many students will encounter someone who has a learning disability during their school years. For many students, this is their only experience with a brain disorder. Because many types of neurological diseases (such as Alzheimer's disease and Parkinson's disease) affect older people, students may not have experience with them. They may not realize that emotional and behavioral conditions such as depression and hyperactivity are also brain disorders. Students should be aware that diseases of, and injuries to, the brain and nervous system afflict millions of Americans of all ages each year. Although some injuries and diseases are of short duration, others are permanent and disabling. Brain disorders are discussed in Section 8, *Nervous System Injury*.

3 The Nervous System: Composition and Organization

While our brains control nearly everything we do, the brain does not work alone. The brain is the central part of a complex body system known as the *nervous system*. The nervous

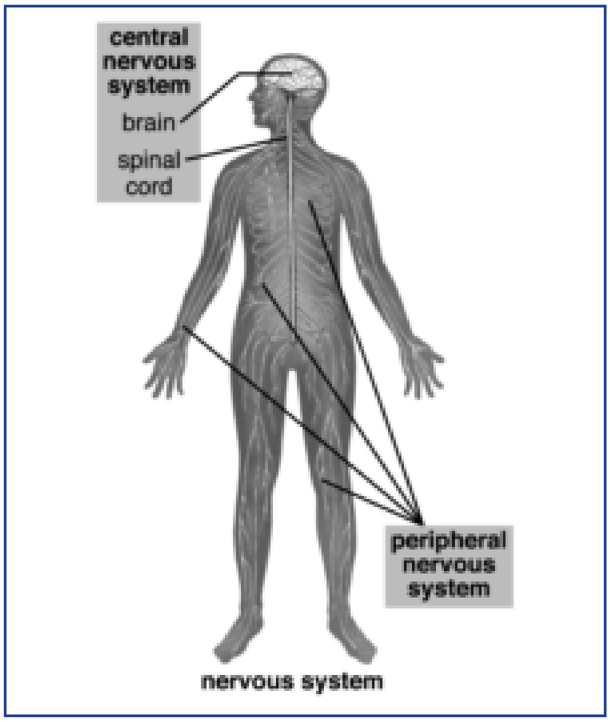

Figure 1. The human nervous system can be subdivided into the central nervous system (CNS) and the peripheral nervous system (PNS).

system allows us to respond to the world around us. Both our involuntary actions, such as our blink **reflex** to bright light, as well as our voluntary actions, such as choosing to put on sunglasses, can be attributed to our nervous system. Such a system must necessarily be both complex and extraordinarily well organized to produce the coordinated functions that define human life. How does our nervous system manage to perform its various functions?

The nervous system is organized into two major subdivisions: the **central nervous system (CNS)** and the **peripheral nervous system (PNS**; Figure 1).[3,15] A brief examination of the nervous system's components helps create a broader context in which to understand the brain and brain function.

3.1 The central nervous system (CNS). The central nervous system consists of the brain and spinal cord. It is the major information-processing center of the body. The spinal cord conducts sensory information (information from the body) from the peripheral nervous system to the brain. After processing its many **sensory inputs**, the brain initiates **motor outputs** (coordinated mechanical responses) that are appropriate to the sensory input it receives. The spinal cord then carries this motor information from the brain through the PNS to various locations in the body (such as muscles and glands).

Not all of the body's motor responses travel through the brain for processing. The spinal cord alone is able to direct simple reflex actions, such as the knee jerk reflex, that require a quick response from the body. More complex motor actions, such as some involuntary and all voluntary actions of the body, require brain involvement. The brain is both the integrator and director of information through our bodies. Our brain devotes most of its considerable volume, energy, and computational power to processing various sensory inputs from the body in order to determine and initiate appropriate, coordinated motor output to the body.

3.2 The peripheral nervous system (PNS). The peripheral nervous system is composed of all nerve tissue outside the brain and spinal cord. The PNS delivers information between the body and the central nervous system. It is divided into two subsections: the sensory/somatic nervous system and the autonomic nervous system. The somatic nervous system carries messages between the CNS and the body's sensory organs and voluntary muscles. It allows us to detect changes in the world around us, and it delivers information related to actions that we decide to perform. In contrast, the autonomic nervous system carries messages between the CNS and our internal organs. It delivers information related to automatic tasks such as the regulation of breathing and digestive functions.

4 Cells of the Nervous System

All components of the nervous system, including the brain, are composed of billions of specialized cells: *neurons* and *glia*. Though the two cell types work together to provide the coordinated functioning of the nervous system, the unique structure of each type of cell allows it to perform its specific function.

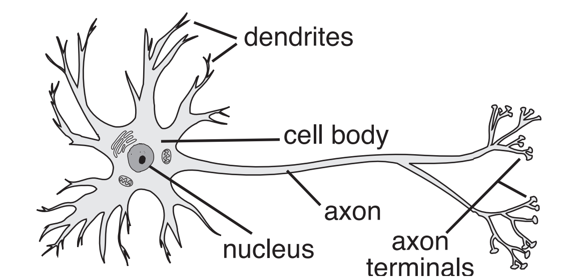

Figure 2. *A neuron is made up of a cell body, dendrites, and an axon. Dendrites bring information into the cell body; information travels through the axon and exits the cell through axon terminals.*

4.1 Neurons. The *neuron* (Figure 2) is the basic functional unit of the nervous system. Its primary function is communication. Neurons receive information from cells, and then transmit this information to other cells. The transmission of information between cells of the body and neurons enables us to react to changes in our internal and external environments. Neurons have a **cell body**, which contains a nucleus that directs the cell's activities. Specialized extensions called **dendrites** bring information into the cell body. Other extensions at the opposite end of the neuron are called **axons**. These carry information away from the cell body. Information leaves a neuron through **axon terminals**, the endpoints of the axon. Bundles of axons are called nerves.

The nervous system includes three general types of neurons: sensory neurons, interneurons, and motor neurons. **Sensory neurons** are specialized to detect stimuli from the environment, such as light, sound, taste, or pressure. Detection of a **stimulus** triggers the sensory neuron to transmit a message to the central nervous system. There, the message is relayed to **interneurons** that integrate the information and generate instructions about how to respond. Instructions are sent back to the peripheral nervous system as messages along **motor neurons**. The motor neurons then stimulate muscles to contract or relax to make the appropriate responses. They also stimulate glands to release hormones.

Our nervous system is able to pass a message from a sensory neuron, through several interneurons, to a motor neuron within several milliseconds. Though this seems very fast, some sensory inputs (such as pain) requires an even more rapid response. If we touch a hot stove, for instance, it is beneficial for us to pull back as quickly as possible. How does the nervous system handle this *reflex* response? When responding to input that requires a very fast response, our nervous system allows sensory neurons to relay information through only one interneuron, or to connect directly to motor neurons. By reducing the number of interneurons required for signal processing, reflex responses are able to occur more quickly than other responses. Reflex responses are discussed further in Section 6, *The Spinal Cord.*

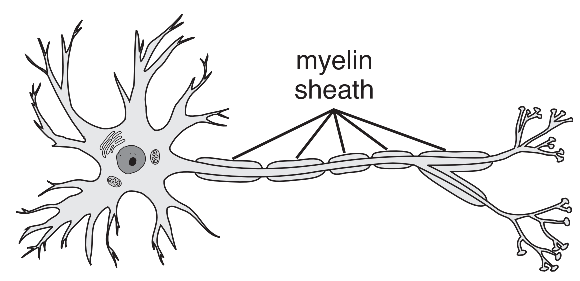

Figure 3. *Specialized glial cells form myelin sheaths around the axons of neurons.*

4.2 Glia. **Glial cells**, collectively called **glia**, greatly outnumber neurons. Why do we need so many glia? The functions of glia, though not as well known as for neurons, are generally to serve as the support structure for our immense neural network.[14] For instance, some glia form **myelin**, the insulating sheath that surrounds certain axons (Figure 3). Myelin keeps electrical signals contained within axons and enhances the conduction of electrical signals. Other glia are scavengers that remove debris after injury or neuronal death. Some glia guide the migration of neurons and direct the outgrowth of axons during development, while others facilitate communication between neurons.[2] Some glia may even serve to "feed" neurons, providing them with essential nutrients.

4.3 Transmission of nerve impulses: electrical transmission. Neurons send and receive messages to and from each other and the body. They do this through a two-part process called **neural signaling**. Neural signaling begins with the generation of an electrical impulse that is passed down the length of one neuron.

How does this work? An electrical impulse is generated when a stimulus (such as sensory input) causes a rapid change in electrical charge in one part of a neuron's membrane. This electrical impulse is one unit of neural information. An electrical impulse flowing along the length of a neuron is called a **nerve impulse**.

Nerve impulses proceed in just one direction within a neuron—from the dendrites, through the cell body and axon, to the axon terminals (Figure 4). In addition, neurons produce nerve impulses in an all-or-nothing way. For example, if the stimulus that a neuron receives is too weak to trigger a nerve impulse, nothing happens—the neuron does not initiate an impulse. If the stimulus is strong enough or much stronger than the minimum required to trigger a nerve impulse, the neuron does initiate an impulse. However, the neuron does not initiate a stronger impulse in response to a more powerful stimulus. All that is required to initiate a nerve impulse is a minimum, or threshold, amount of stimulation. The frequency of nerve impulses, or the rate at which nerve impulses are initiated in a neuron, determines the intensity of the signal that travels through the neuron.

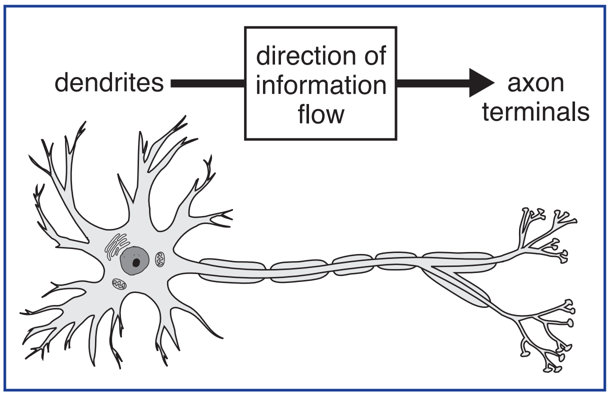

Figure 4. A nerve impulse is information (in the form of an electrical impulse) flowing through the dendrites, cell body, and axon of a neuron.

4.4 Transmission of nerve impulses: chemical transmission. What happens when an impulse reaches the end of one neuron and must move to another neuron? The junction between two neurons or between a neuron and a muscle is called a **synapse** (Figure 5). The two cells involved in a synapse do not physically touch each other. Instead, they are separated by a very small space. The cell that carries the impulse to the synapse is the **presynaptic cell**, and the cell that receives the impulse is the **postsynaptic cell**. Information flows from the axon of the presynaptic cell, across the synapse, to the dendrites of the postsynaptic cell. But how does the information cross the synapse?

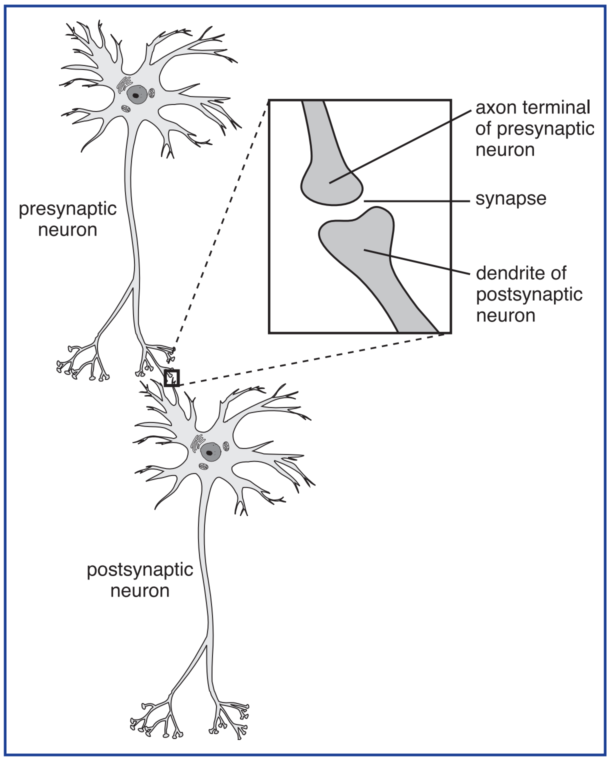

Figure 5. A synapse is a junction point between neurons.

When an impulse that is traveling along the presynaptic cell reaches the end of the axon, it causes that cell to release molecules known as *neurotransmitters*. These molecules are released into the synapse and diffuse approximately 20 millionths of a millimeter to where they bind with receptors on the dendrites of the postsynaptic cell (Figure 6). When neurotransmitters bind to the receptors, the charge across the postsynaptic membrane changes, and if the change is great enough, it triggers a nerve impulse. The new nerve impulse then travels along the postsynaptic cell.

Scientists have discovered a large number of neurotransmitters. Some are *excitatory*—they cause the postsynaptic neuron to become more likely to initiate a nerve impulse. Others are *inhibitory*—they cause the postsynaptic neuron to become *less* likely to generate a nerve

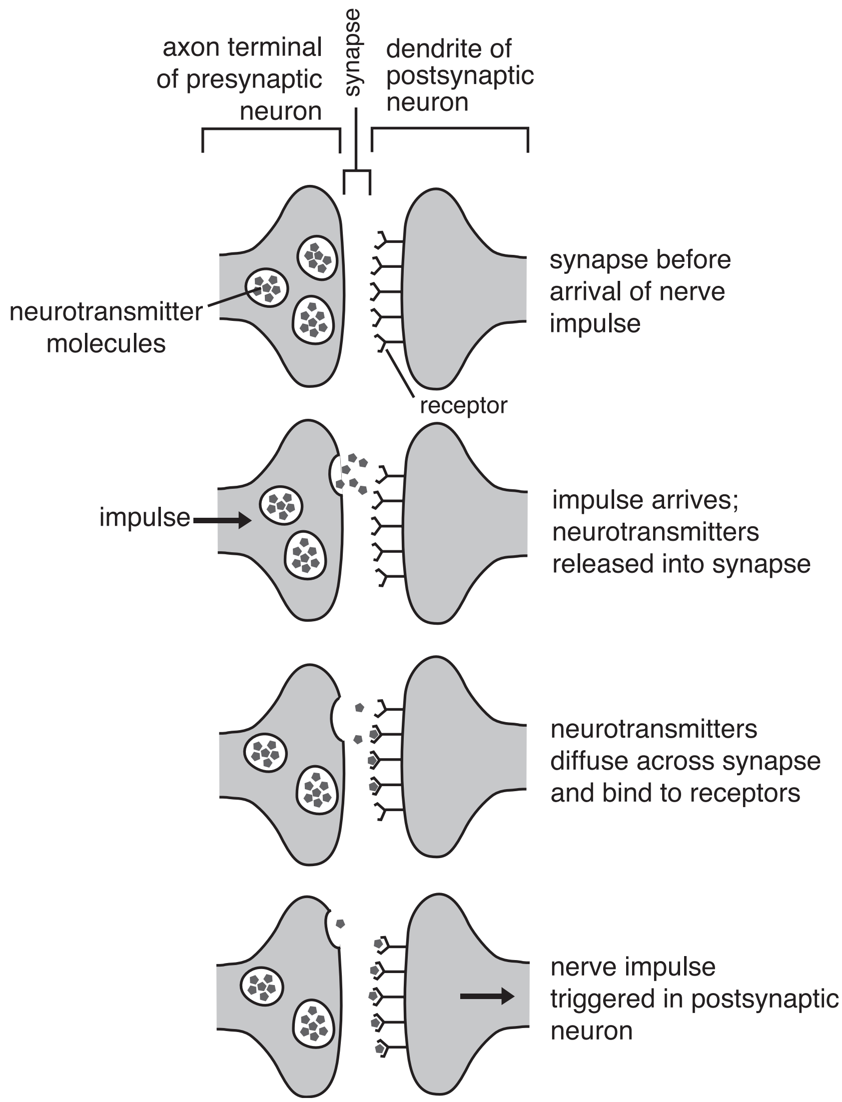

Figure 6. An electrical impulse is converted to a chemical signal to cross a synapse.

impulse. How important are neurotransmitters to our nervous system? Ultimately, excitatory and inhibitory neurotransmitters are the very molecules responsible for producing a specific motor response to a sensory input.

5 The Brain

The brain is the root of what makes us human. We begin our discussion of CNS components with an examination of brain structure and function.

5.1 Imaging the brain. Until recently, scientists could gather information about the human brain only by removing it from cadavers, slicing it, staining it, and taking pictures of the sliced sections. This method has many limitations, including the inability to study the brain in action. Technological advances, however, have enabled scientists to use advanced imaging methods to learn more about the function and anatomy of the brain.[20,29,30]

Static imaging. The first methods used to image the living brain employed static imaging, which provides an image of the brain's anatomy at one point in time. One static imaging method is *computed tomography (CT)*, a computer-assisted technique for assembling a "cross-sectional" X-ray image of the brain. Another imaging method, *magnetic resonance imaging (MRI)*, has mostly replaced CT as the brain-imaging method of choice. MRI reveals the anatomy of the brain in greater detail than does CT, does not require X-rays, and is much more flexible with regard to the plane of sectioning. To create an MRI image of the brain, a strong magnetic field is rotated about the head. Exposure to this energy field induces the brain's many hydrogen atoms to resonate, or jump to a higher energy state. As the field passes through, some of the hydrogens return to a lower energy state. Sensors detect these up and down jumps in energy, and computers coordinate the data gathered. MRI scans can produce strikingly detailed images of the brain. The image produced by an MRI scan depicts a virtual "section" of the brain along the plane of the scan (Figure 7).

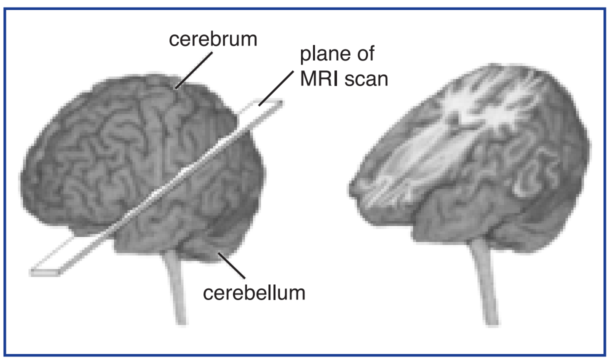

Figure 7. An MRI scan allows a scientist to view a detailed black-and-white image of a virtual "section" of the brain.

Functional imaging. While static imaging allows scientists to view the living brain and detect structural changes, it does not allow detection of electrical or chemical brain activity. Incredibly, imaging technologies now allow scientists to view the *active* brain. One of the most extensively used techniques is **positron emission tomography (PET)**. PET works by measuring the distribution and movement of radioactively labeled molecules in the tissues of living subjects. Because a person is awake during a PET scan, the technique can be used to investigate changes in brain activity while the subject performs assigned tasks. Computers reconstruct PET scan data to produce two-dimensional or three-dimensional images. While MRI scans are used for research and in clinical settings for patient diagnosis, PET scans are used exclusively for research.

Another common method is functional magnetic resonance imaging (fMRI). The technology behind fMRI imaging is similar to that of MRI imaging. However, fMRI imaging takes advantage of a special property of hemoglobin, a blood protein that brings oxygen to body tissues. Hemoglobin that is carrying oxygen has different properties from hemoglobin that is not carrying oxygen. By detecting oxygen-containing hemoglobin, scientists use fMRI to assess changes in blood flow to areas of the brain. Since active regions of the brain receive more blood and more oxygen, fMRI images provide scientists with both functional and anatomical information (Figure 8).

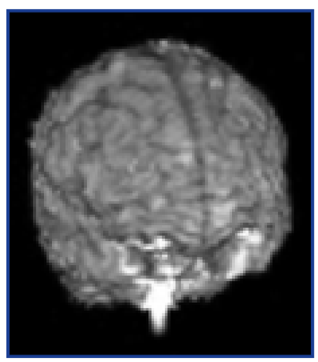

Figure 8. An fMRI scan provides information about activity in the brain. The active areas appear to be lighter than the rest of the brain.

5.2 Specialized regions of the brain. How does the human brain process efficiently the billions of neural signals passing through its immensely complex network of cells? Part of the answer lies in its organization. The human brain can be divided into three major sections: the *cerebrum (forebrain)*, the *cerebellum (hindbrain)*, and the *brainstem* (Figure 9).

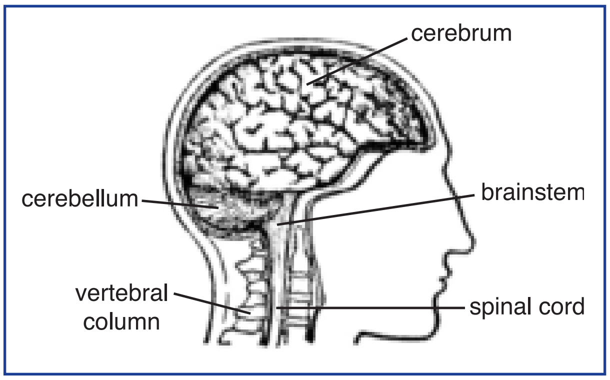

Figure 9. The brain can be subdivided into the cerebrum, cerebellum, and brainstem.

Functional imaging techniques have allowed scientists to discover that different areas of the brain regulate different functions. The cerebrum itself can be divided into many functionally specialized regions. One region toward the front of the cerebrum is devoted to decision making, problem solving, and planning. Other regions are devoted to processing specific categories of sensory information. For instance, the cerebrum uses different regions to interpret smell, taste, and hearing information. By devoting sections to specific tasks, the brain is able to process multiple inputs more efficiently.[13] Though groups of neurons in the brain are devoted to specific tasks, multiple sections of the brain must generally work together to process information. For instance, regions of both the cerebrum and the cerebellum work together to regulate body functions such as breathing and heartbeat.

To make the most efficient use of its neurons, the brain processes information by splitting a single behavior into component parts. For instance, when we take a bite of food, there is sensory information (this is an apple), voluntary motor information (lift piece to mouth, chew), and involuntary motor information (salivate) for the brain to process. The different components are split, sent to the appropriate regions of the brain, then processed accordingly. This distributed processing of information adds great speed to our ability to take in information and respond.

5.3 The brain and sensory input. Most of us take for granted the subtleties of the world around us. We may not always be aware of the sights, sounds, or smells in our environment. However, our brain is continuously processing signals sent through our eyes, ears, nose, mouth, and skin. In addition to the traditional five senses, scientists now recognize other kinds of sensations, including pain, pressure, temperature, joint position, and movement. Specialized sensory neurons respond to input from the environment. This input is then transmitted to the brain as electrochemical signals. In the brain, signals are received in categories. Thus the processing of sensory input begins with specific regions in the brain separately deciphering each message. Subsequently, multiple types of sensory input are integrated, thus allowing the mass of information to be interpreted into an appropriate (motor) response.

5.4 The brain and motor output. If the brain were able to process only sensory input, we would be silent, motionless observers of the world around us. Fortunately, our brains perform another important function. After interpreting sensory input, the brain generates neural impulses that flow through the nervous system to other parts of the body. These impulses, carried by motor neurons, allow us to respond to input from the environment. Some responses are voluntary. We see the door to our house, choose to open that door, and enter. Other responses are involuntary. We hear the sound of a window breaking, interpret this as an unusual (and perhaps frightening) event, and our heart begins to race. Both types of motor responses require interpretation of sensory input and regulation of motor output; however, the parts of the brain involved are different. The cerebrum initiates voluntary movement, while the cerebellum coordinates and smoothes out our movements. Regions of both the cerebrum and the cerebellum work together to regulate **involuntary responses**. In addition, while the CNS generates information to regulate both voluntary and involuntary responses, the PNS delivers that information to the appropriate parts of the body. In the window-breaking example, a sound (the tinkling of broken glass) sets off a CNS-regulated, PNS-mediated increase in heartbeat. It is interesting to note that thought alone can initiate involuntary reactions. In our example, merely the thought of someone breaking a window to burglarize your home can result in increased heart rate.

6 The Spinal Cord

The second component of the central nervous system is the *spinal cord*. The spinal cord is responsible for connecting the peripheral nervous system to the vast signal-processing power of the brain. In addition, neurons of the spinal cord are themselves able to process certain signals from the body. We will first examine the structure of this unique organ, then explore its multiple functions.

The spinal cord is responsible for connecting the peripheral nervous system to the vast signal-processing power of the brain.

6.1 Structure of the spinal cord. The nerves of the spinal cord are encased in a protective skeletal structure called the *vertebral column*. The vertebral column is made up of bones called *vertebrae*. The rigidity of the vertebral column allows us to stand upright, and it protects our spinal cord from harm. However, the vertebral column also remains somewhat flexible, allowing us a wide range of motion. The vertebrae protecting the spinal cord are composed of much thicker bone than the skull, the bony plates that protect the brain. This suggests how important the spinal cord is to the human body; any system under such heavy protective armor must be important to our existence.

The structure of the spinal cord is directly related to its function as a conveyor of information. Information, in the form of nerve impulses, reaches the spinal cord through sensory neurons and exits the spinal cord through motor neurons. Information enters and departs from the spinal cord through *spinal nerves*. Spinal nerves are known as "mixed" nerves because they contain the axons of both sensory and motor neurons. Shortly before reaching the spinal cord, the sensory and motor axons are segregated from one another (Figure 10).[3]

Information is delivered into the spinal cord through the axon terminals of sensory neurons. Once in the spinal cord, the information may flow to motor neurons, to **interneurons** that pass it directly to motor neurons, or to interneurons that transmit the information to the brain.

The dendrites of spinal motor neurons can receive information from sensory neurons, from interneurons that connect with sensory neurons, or from interneurons that connect to neurons in the brain. The axons of spinal motor neurons are able to deliver information through the spinal nerves and out to all parts of the body (Figure 10). The axon terminals of motor neurons connect to various muscles and glands, delivering information for both voluntary and involuntary actions.

6.2 Spinal cord functions. The spinal cord carries out two major activities: generating simple behaviors and transferring information. The response generated by the spinal cord is a *reflex*: an automatic, involuntary response to a sensory input, such as withdrawing from a hot stove. Some reflex pathways (a set of nerves that relay a particular message) are relatively simple. In the simplest reflex pathways, a motor neuron connects directly to a sensory neuron. The patellar, or knee-jerk, reflex is an example of this type of pathway (Figure 11). When we are hit lightly at a certain point below the kneecap (patella), the lower half of the leg jerks upward.

The spinal cord relays information in more complex pathways as well. Some reflex actions require the involvement of multiple spinal interneurons before a motor output can be generated.

Another role of the spinal cord is to relay information between the brain and the peripheral nervous system. Information, in the form of

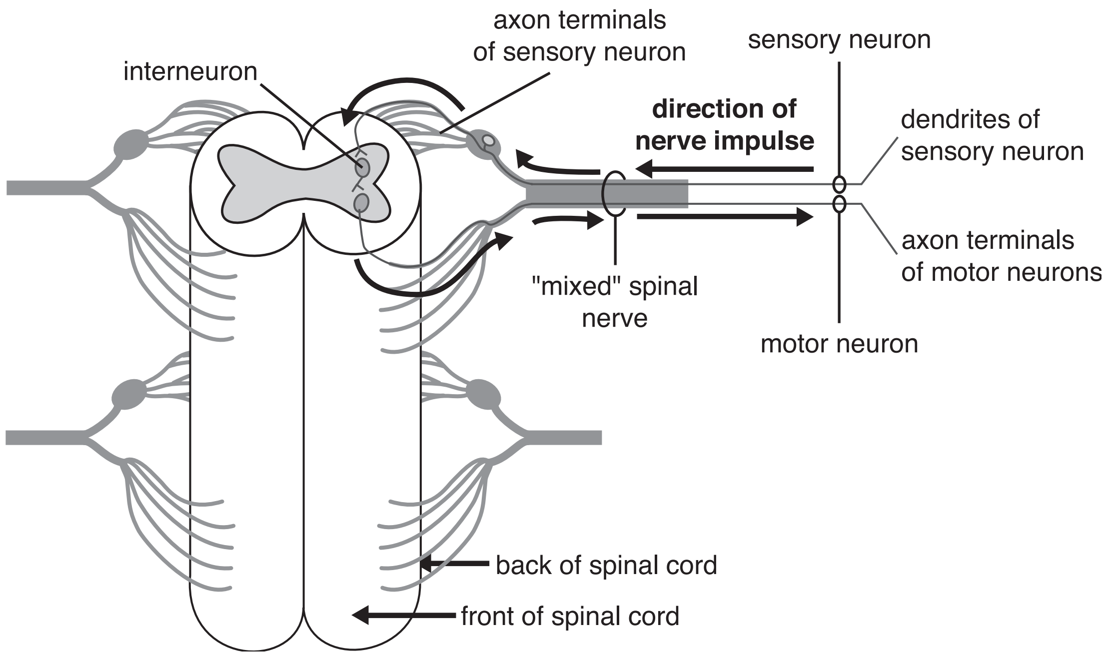

Figure 10. The organization of neurons in the spinal cord plays an important role in the effective functioning of our nervous system.

nerve impulses, reaches the spinal cord through sensory neurons of the PNS. These impulses are transmitted to the brain through the interneurons of the spinal cord. Finally, response signals generated in the motor areas of the brain travel down the spinal cord through other interneurons and move to the body in the axons of spinal motor neurons. The spinal cord is thus responsible for mediating all information flow between the body and the brain. Injuries to the spinal cord result in a loss of responsiveness below the injury. This loss is not due to an inability of the muscle to function, but to the inability to relay messages between the body

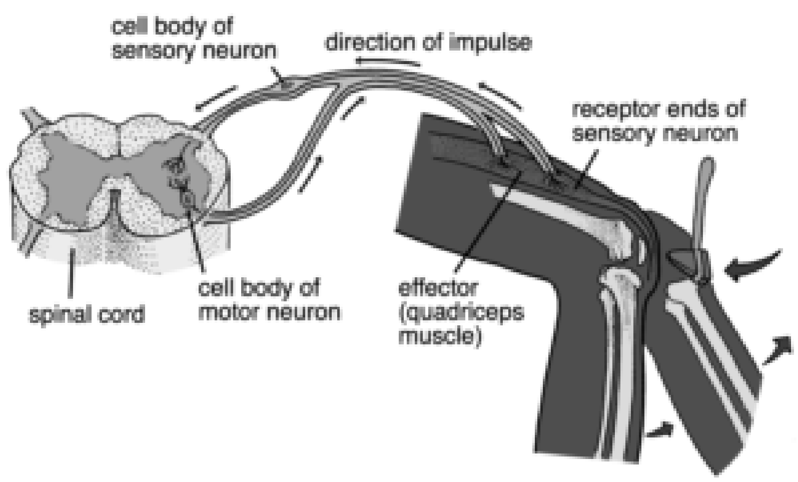

Figure 11. The patellar reflex is mediated by the spinal cord.

and the brain. Spinal cord injuries are discussed in Section 8, *Nervous System Injury*.

7 Plasticity and Learning

7.1 The changing brain. For many years, scientists have known that neurons form new connections during the first few years of a human's life. Until recently, however, scientists believed that after this initial phase of neural development, the nervous system was complete and relatively fixed. Scientists have now found that nerve fibers continue to grow and innervate areas of the cerebral cortex in children between age three and puberty.[27] Scientific investigations have demonstrated that even the adult brain generates new neurons within a region important for learning and memory.[8] The brain's ability to change and reorganize in response to some input is known as **plasticity**. Plasticity is defined by a change in the anatomy of the neuron. New synapses may form, existing synapses may strengthen, some synapses may be eliminated, or more dendrites may form.[16,17,19]

7.2 Learning and memory. Learning is a form of plasticity, since it leads to structural changes in the brain. Brain plasticity functions in both positive and negative directions.[9,21] Neurons that are stimulated to form additional synaptic connections may grow and strengthen. However, neurons or synapses that are neglected may weaken over time. Factors have been identified that can function as positive or negative regulators of neural plasticity. Several are discussed below.

Positive regulators of neural growth. People first used the saying "use it or lose it" in reference to physical fitness. Now the saying also seems valid for learning and brain function. Practicing a task appears to improve the brain's efficiency.[10] For instance, when a person first learns to play the piano, he or she uses a large amount of the motor section of their brain. However, professional piano players who have been playing for many years devote a much smaller region of their motor cortex to finger dexterity.[16] How is this possible? By repeatedly stimulating the same region of their body (fingers) for the same action (piano playing), their brains have strengthened the related synapses. Thus, fewer neurons are needed to perform the same task.

Additional studies have revealed that physical, social, and mental activity may protect memory

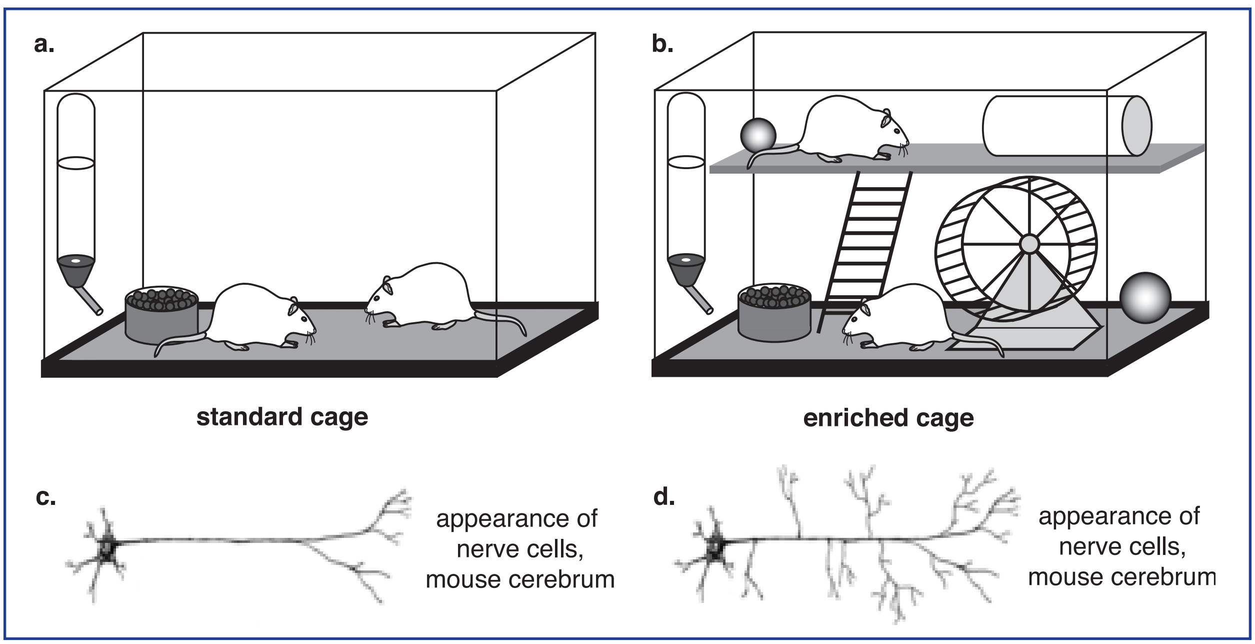

Figure 12. Mice raised in an impoverished environment (a) show less dendrite growth (c) than do mice raised in an enriched environment (b, d).

and alertness. For example, mice raised in an "enriched" environment, which contains other mice and a variety of stimulating toys, displayed dendrite growth and performed better on learning tasks than inactive, isolated mice did (Figure 12).[16,28] These results were observed in mice of all ages. Mice raised with toys but no social interaction, as well as mice raised with other mice but no toys, performed less well on learning tasks and showed less neural growth than those raised with both toys and social interaction did. Thus, mental, social, and physical stimulation are all positive regulators of neural growth and seem to have an additive effect on learning and memory. In addition, mice subjected to learning tasks tend to retain more of the dendrite growth they experience during enrichment than do mice that are left alone after enrichment.

Negative regulators of neural growth. One negative regulator of neural growth is deprivation, the opposite of the positive factor of enrichment. Mice, rats, nonhuman primates, and humans all show lower ability to learn tasks and less dendrite branching when raised in environments deprived of stimulation. Poor nutrition, lack of social contact, and absence of mental engagement can all contribute to deprivation. Another major factor known to have a negative effect on neural growth is stress. Scientists have shown consistently that animals and humans living under constant stress conditions show less neural growth and/or learning than their less-stressed counterparts do.[7]

7.3 Pain and learning. Intuitively, we can understand the link between pain and **learning**. It is obviously to our advantage to avoid painful input. By doing so, we can live longer, healthier lives. But how does our body determine what is painful? Recent studies indicate that our bodies have special pain receptors known as *nociceptors* (for "noxious stimuli receptors"). These receptors only respond to potentially damaging stimuli.[26] For instance, when we hold a mug of hot cocoa, our fingers feel the pleasant warmth, and we tend to hold on to the mug. However, if we splash scalding cocoa on our fingers, we tend to pull our hand back abruptly. The burning sensation in our fingers provided a painful damaging stimulus.

Once a nociceptor response has been activated, the neuron responsible becomes inflamed, leading to hypersensitivity. This means that a lesser stimulus in the same spot will activate the pain response. For instance, once skin has been damaged by sunburn, further stimulation (touching the sunburned skin) is painful. This seemingly counterintuitive step occurs because nociceptors respond as other neurons do: their synapses strengthen with use. Once we injure ourselves and stimulate a pain pathway, we are more likely to feel pain if we stimulate the same region again before it has a chance to heal.

Nociceptor response is useful in everyday learning ("don't touch a hot stove" is a lesson most of us don't have to learn twice). However, the synaptic strengthening of pain pathways can become a problem for those who experience chronic pain. In these individuals, pain appears to sensitize the nociceptor pathway almost indefinitely. Thus, additional stimulation is that much more painful, until it becomes unbearable. Researchers are developing therapies that disrupt synaptic strengthening in a nociceptor-specific manner.

8 Nervous System Injury

8.1 Neurological disorders. An estimated 50 million Americans suffer from disorders of the brain or nervous system. Some brain disorders are influenced by genetics, such as Huntington's disease; some are environmental, resulting from spinal cord or brain injury; and some result from a combination of genetic and environmental factors, such as stroke. Ongoing neuroscience research continues to elucidate the causes for the disorders as well as reveal new therapies to minimize or eliminate the disabilities that result from them.

During the past few years, events have occurred that have raised public awareness of neurological disorders. Several well-known people have experienced either neurological disease or traumatic injuries that have been publicized extensively. For example, President Ronald Reagan was diagnosed with Alzheimer's disease. Alzheimer's disease is a progressive, degenerative brain disease that leads to loss of **cognitive function** and memory, behavioral changes, personality changes, and impaired judgment.[1] The brains of Alzheimer's patients contain tangled masses of abnormal protein in the cerebrum.[22] Scientists continue to investigate the causes of this disease.

Another human brain disorder is Parkinson's disease, a motor system disorder affecting more than 500,000 Americans.[23] Public knowledge of Parkinson's has been increased by actor Michael J. Fox and former U.S. Attorney General Janet Reno, both public figures who have been forthcoming about their conditions. The disease is characterized by tremor, rigidity, slowness of movement, and impaired balance and coordination. It occurs when neurons in certain sections of the midbrain die or become impaired. The neuronal loss causes a decrease in the level of an excitatory neurotransmitter, which causes the neurons in another part of the brain to initiate aberrant neural impulses. Genetic factors may play a stronger role in some forms of the disease, while environmental factors play a prime role in other forms.[23,24] The drug L-dopa, sometimes in combination with other drugs, is the standard pharmacological treatment for Parkinson's disease. However, for some individuals, surgical intervention can relieve tremors. Scientists continue to study new ways of treating this debilitating disorder.

8.2 Injuries to the nervous system. Our nervous system is especially sensitive to damage by injury. Both brain and spinal cord injuries have the potential to cause severe and life-changing disabilities. However, the type of disability sustained depends greatly on the region of trauma.

The spinal cord is responsible for information transfer between the brain and the body. It follows that injuries to the spinal cord disrupt information transfer. The position of trauma to the spine largely determines the effect of a spinal cord injury on the body. For instance, injuries to the lower half of the spine can lead to paraplegia (**paralysis** of the lower half of the body with involvement of both legs), while injuries closer to the skull may lead to quadriplegia (paralysis of both arms and both legs). Leading causes of spinal cord injuries are motor vehicle accidents, violence, and falls.[4] Exciting new research provides hope of someday restoring function to paralyzed individuals and improving their quality of life.

Traumatic brain injury (TBI) refers to damage resulting from trauma to the brain. TBI, like spinal cord injuries, may result in impaired physical function. However, the brain not only controls our sensory and motor functions, it is also our center of conscious thought. Therefore, injuries to the brain can affect our cognitive abilities or disturb behavioral and emotional functioning. In addition, brain trauma has the potential to alter personality and, thus, that elusive part of ourselves we often consider unchangeable: our sense of self.

The story of Phineas Gage illustrates a dramatic instance of personality change.[19] Gage was the foreman of a railway construction team in the mid-19th century. On Sept. 13, 1848, an accidental explosion blew a 20-pound metal rod all the way through Gage's head, from below his left cheekbone to just behind his right temple (Figure 13). Amazingly, Gage never lost consciousness. However, the injuries he sustained resulted in a complete reversal of his personality. Before the accident, his calm, collected demeanor and level-headedness made him one of the best foremen on his team. After the accident, his demeanor was characterized by rage, impatience, and gross profanity. Though physically capable of work after a few months of recovery, he was not the same man mentally. He never worked as a foreman again. He spent his remaining days as a farmhand until he died while having a seizure in 1921. Gage's case was the first to draw attention to the effect of brain injuries on personality, and it remains one of the

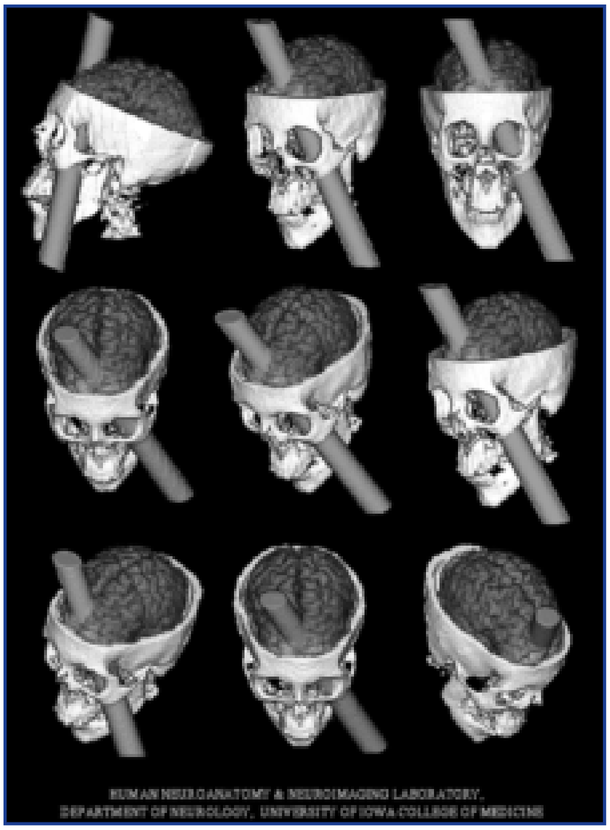

Figure 13. Phineas Gage's skull and frontal lobe were pierced by a metal rod, changing his personality forever.

most dramatic cases of personality change due to TBI.[5]

Most TBIs result from closed-head injuries (as opposed to penetrating injuries like that of Phineas Gage). As with spinal cord injury, the leading causes of TBI are motor vehicle accidents, violence (such as can occur with firearms), and falls. Sports injuries, especially to young athletes, are another major cause of brain injury. TBI is a leading cause of death and disability in the United States. The Centers for Disease Control and Prevention's National Center for Injury Prevention and Control estimates that 5.3 million Americans (2 percent of the population) live with a disability resulting from TBI.

8.3 Regional specificity and effects of trauma. Trauma to the brain results in different types of disabilities. Some injuries have the capacity to alter a person's sense of self, while others affect abilities, such as speech or vision, but do not affect a person's sense of who they are. Before the advent of functional imaging, scientists used case studies of brain injury to determine functional regions of the brain. Scientists continue to depend upon information from case studies to define brain regions. However, functional imaging has greatly aided these research efforts. Now, doctors and scientists work together to investigate the functional specialization of regions of the living brain.

Sometimes it is difficult to decipher the exact story of brain functionality using case studies and functional imaging of human brains. For instance, while a physician may diagnose Alzheimer's disease, it is not possible to use physical examination of a patient to determine the possible genetic influences on the disease. Similarly, when scientists investigate a brain injury case study, they can determine that some areas of the brain are damaged. However, they may not be sure whether they have determined all areas that have experienced trauma, or whether any of the patient's disability is a direct result of the injured region. In such cases, scientists find it helpful to use **animal models** to further understand how the brain works. Genetic and trauma studies in animal models such as the mouse and rat have been pivotal in producing the knowledge we have about the brain.

8.4 Protecting our nervous system. Nervous system injuries in prominent public figures have drawn attention to the importance of protecting our nervous system. The late actor Christopher Reeve, well known for his role in the movies as Superman, was paralyzed as a result of a fall from a horse. Several football players, including Steve Young and Troy Aikman, suffered concussions that jeopardized their careers and their long-term health. In some cases, neurological disorders cannot be predicted or prevented. Continuing research should be able to provide treatments for some diseases. In other instances, the behaviors that contribute to the development of a neurological problem can be avoided.[6] For example, chronic use of certain drugs, such as methamphetamine and alcohol, can cause neurons in certain parts of the brain to die. Individuals can make choices to avoid these substances. Certain sports injuries can be minimized by using appropriate protective gear (Figure 14).

These situations illustrate only a few of the health problems that result from functional disorders of the brain and nervous system. Statistics show that neurological diseases and injuries are surprisingly common. In addition to the toll they take on affected individuals, such diseases and injuries exert a dramatic economic influence on all citizens. Continuing research is key to alleviate this impact. It is unlikely that a single discovery will lead to reversing damage from traumatic injury. Undoubtedly, environmental and genetic factors influence the onset, severity, and progression of many neurological diseases. Scientific researchers need to examine these disorders thoroughly in order to develop effective treatments and cures.[25]

By learning the fundamental principles of brain structure and function, students will better understand how they respond to and interact with their environment and how scientific research contributes to better health. By learning how individual behaviors can alter the function of the brain either positively or negatively, students will be better prepared to prevent neurological trauma.

Figure 14. *A helmet can greatly reduce one's chances of sports-related head trauma.*

Glossary

Alzheimer's disease: A progressive, neurodegenerative disease characterized by loss of function and death of nerve cells in several areas of the brain. This leads to loss of cognitive functions such as memory and language.

animal model: A laboratory animal used in research that simulates processes comparable to those that occur in humans.

axon: A long, branching outgrowth of a neuron that carries information, in the form of a nerve impulse, away from the cell body of the neuron. Each neuron has one axon, which can be over a foot long. A neuron delivers information to other cells through the axon terminals at the end of its axon.

brain: The center of thought and emotion in the central nervous system. The brain is responsible for the coordination and control of body activities and the interpretation of information from inside and outside the body.

cell body: In neurons, the main part of the cell around the nucleus excluding long processes such as axons and dendrites.

central nervous system (CNS): One of the two major divisions of the nervous system. The CNS consists of the brain and spinal cord.

cognitive function: The mental process of knowing, thinking, learning, and judging.

dendrite: A branching outgrowth of a neuron that carries information, in the form of a nerve impulse, into the cell body of the neuron. Each nerve usually has many dendrites.

glial cells (glia): Specialized cells that surround neurons. They provide mechanical and physical support to neurons and electrical insulation between neurons.

interneuron: A type of neuron that connects only with other neurons and thus delivers information only between neurons.

involuntary response: A nervous system response, such as a reflex, that is not under the control of the brain, and thus does not involve choice.

learning: The acquisition of knowledge or skill. It occurs in, and may lead to changes in, the brain.

motor neuron: A neuron that delivers information from a sensory neuron or interneuron to muscles or glands in the body in order to produce a response.

motor output: The body's response to motor information delivered through motor neurons.

myelin: The insulating sheath that surrounds axons.

nerve: A bundle of neurons bound together by a protective sheath of connective tissue.

nerve impulse: Information in the form of an electrochemical signal that travels through a neuron in response to a stimulus.

nervous system: The entire, integrated system of nerve tissue in the body. It is composed of the brain, spinal cord, nerves, and glia. The human nervous system can be subdivided into the central nervous system (CNS) and the peripheral nervous system (PNS).

neural pathway: An interconnected set of neurons that delivers information (in the form of a nerve impulse) related to a body function.

neural signaling: The delivery of information through a neural pathway.

neuron: A specialized cell that delivers information within the body.

paralysis: Loss or impairment of motor function due to damage of the nervous system by injury or disease. Paralysis below the waist only is referred to as paraplegia; complete paralysis below the neck is referred to as quadriplegia.

peripheral nervous system (PNS): One of the two major divisions of the nervous system. Nerves in the PNS connect the central nervous system (CNS) with sensory organs, other organs, muscles, blood vessels, and glands.

plasticity: The ability of the brain to change through the formation or strengthening of connections between neurons in the brain.

positron emission tomography (PET): A technique for imaging the brain in action. PET images show active regions in the brain.

postsynaptic cell: A neuron that receives a nerve impulse across a synapse.

presynaptic cell: A neuron that sends a nerve impulse across a synapse.

reflex: A type of involuntary response.

sensory input: Information received by the body through sensory organs, such as the eyes, ears, nose, and skin.

sensory neuron: A neuron that delivers sensory information from the sensory organs to interneurons or motor neurons.

spinal cord: The part of the central nervous system that is located inside the vertebral column. Neurons in the spinal cord connect neurons in the brain to neurons in the body.

stimulus: Any information coming into the body that is capable of generating a nerve impulse.

synapse: The space separating the axon terminals of a neuron from the dendrites of the next neuron in a neural pathway.

traumatic brain injury (TBI): Injuries to the brain caused by physical trauma to the head.

vertebral column: The series of bones that extend from the skull to the tailbone. It provides support and forms a flexible, protective case for the spinal cord. The bones of the vertebral column are called vertebrae.

voluntary response: A nervous system response that is under control of the brain, and thus involves choice.

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Lesson 1
Engage
Explore

A Difference of Mind

At a Glance

Overview

Students explore four brain functions: attention, memory, language, and emotion. Through reflection and class discussion, students discover that each person's brain responds differently to tasks related to these functions.

Major Concepts

The human brain performs diverse functions. Each person's brain responds differently to tasks related to these brain functions.

Objectives

After completing this lesson, students will be able to

- recognize that the human brain performs diverse functions,
- identify several characteristic human brain functions, and
- explain that each person's brain is unique in its response to tasks controlled by the brain.

Teacher Background

Refer to the following sections in Information about the Brain:
1 Introduction *(pages 25–26)*
2 Myths and Realities about the Brain *(pages 26–27)*
5 The Brain *(pages 31–34)*

In Advance

Web-Based Activities

Activity	Web Version?
1	Yes (Attention Station and Emotion Station)

Photocopies

Activity (Parts 1 and 2)	• Master 1.1(a), *Station Instructions 1*, 1 copy (on cardstock) • Master 1.1(b), *Station Instructions 2*, 1 copy (on cardstock) • Master 1.3, *Memory Station Game Cards*, 1 copy for every eight students (on cardstock) • Master 1.4, *Word Puzzle Cards*, 1 copy for every eight students (on cardstock) • Master 1.5, *Station Notes*, 1 copy (on paper) per student

Materials

Web Version	• 4 pieces of typing paper • 1 black marker • 1 computer with Internet connection for every eight students • 1 stopwatch for every eight students
Print Version	• 4 pieces of typing paper • 1 black marker • 6 color markers, one each of blue, green, yellow, red, orange, and purple • 1 sheet of white poster board for every eight students • 2 stopwatches for every eight students

Preparation

Tip from the field test: Station activities work best when each pair of students has a computer or set of cards to themselves. Plan to have one set of cards or one computer at each station for every eight students in your class.

Set up four areas of the classroom as "stations." Create station signs by writing station names (Attention Station, Memory Station, Language Station, and Emotion Station) in black marker on typing paper; post at appropriate station areas. Cut copies of Masters 1.1(a) and 1.1(b) into station cards; place station cards at appropriate station areas.

Attention Station

Web Version

Set up one to three computers in the classroom with Internet connections. Key up the Web page *http://science.education.nih.gov/supplements/self/student*, which contains a link to "Lesson 1—A Difference of Mind." Clicking this link brings up the unit's "desktop," which contains a link to "A Difference of Mind: Attention Station."

Print Version

Use Master 1.2 as a guide, and write out Test 1 and Test 2 on opposite sides of three sheets of poster board. For Test 1, write out names of colors in the same colored marker. For example, write “RED” in red marker, “BLUE” in blue marker, and so forth. For Test 2, write out names of colors in a different-colored marker. For example, write “RED” in green marker, “BLUE” in yellow marker, and so forth. Place three stopwatches at the station.

Memory Station
Cut copies of Master 1.3 into squares. Lay squares out (in sets) face down at the station. You may wish to copy sets on different colors of paper to keep sets separate. Place three stopwatches at the station.

Language Station
Cut copies of Master 1.4, *Word Puzzle Cards*, into cards. Place cards face down at the station.

Emotion Station
Web Version
Set up one to three computers in the classroom with Internet connections. Key up the Web page *http://science.education.nih.gov/supplements/self/student*. Clicking on “Lesson 1—A Difference of Mind” brings up the unit’s “desktop,” which contains a link to “A Difference of Mind: Emotion Station.”

Print Version
Locate two pictures—from magazines, for example—that would elicit different emotional responses from your students. The Web version uses a picture of a roller coaster in motion and a picture from the view of a patient in a dental chair. Possible subjects include animals, pictures from movies conveying a scary theme, and extreme weather. Use your imagination!

Procedure

Part 1, Station Explorations

1. **Introduce the unit by asking, “What makes you who you are?”**

   Students are likely to list their various talents and abilities. Accept all responses at this time.

   Teacher note: Asking this question allows students to call on their prior knowledge and to engage their thinking. At this point, do not critique student responses. Appropriate teacher comments are short and positive, such as “good” and “what else?” To push student thinking a bit farther, you may wish to ask students to explain their answers briefly. Questions such as these allow the teacher to assess current student knowledge about the subject and adjust lessons accordingly. Generally, it is time to move forward when the teacher sees that thinking has been engaged.

2. **Explain to students that they will explore this question through activities at four different stations.**

   The four stations represent the following brain functions: attention, memory, language, and emotion. Stations should be labeled with signs posted on the walls.

3. **Explain that directions for an activity are on a card or on the computer screen at each station. Ask students to follow the directions carefully to complete each activity.**

   Tip from the field test: Take time at the beginning of this activity to explain that students should read and follow the directions on the cards at each station.

4. **Give each student one copy of Master 1.5, *Station Notes*. Ask students to take notes on this handout as they complete each activity.**

   Taking notes will help students participate in classroom discussion in Part 2.

Assessment:
Collecting Master 1.5, *Station Notes*, at the end of Lesson 1 will allow you to evaluate students' understanding of sense of self.

5. **Divide the class into pairs, and assign pairs to stations.**

   Tip from the field test: Station activities work best when each pair of students has a computer or set of cards. If possible, plan for one set of cards or one computer at each station for every eight students in your class.

   Teacher note: The following descriptions of student activities at the four stations are for your reference. Since the station explorations are meant to engage student thinking, we recommend that you not provide these explanations to the students at this time. Instead, allow students to use the directions at each station to investigate the activities on their own.

   Attention Station:
   In the Web version, students are prompted to take two tests and are presented with the amount of time it took to complete each test. In the print version, students take the two tests you have written out on poster boards while their partners time them with stopwatches. Together, the tests are called the Stroop test, after J.R. Stroop, the psychologist who developed them in 1935. In Test 1, the names of colors are in the same color as the name; for instance, the word "blue" is written in blue. In Test 2, the names of colors are in a color different from the name's; for instance, the word "yellow" is written in green. The object in each test is to name the *color* of the word (instead of reading the word) as quickly as possible. Students find that it takes longer to name colors in Test 2 than Test 1, since

the color of the word and the meaning of the word compete for their attention. In addition, students find that individuals differ in their ability to separate color information from language information.

Language Station:
Students decipher words and phrases from clues on each of two cards. On the first card, students combine letters and symbols to come up with the following words:

1. brain,
2. Internet, and
3. restaurant.

On the second card, students interpret the arrangement of words to come up with the following phrases:

1. officer undercover,
2. made in America, and
3. evenly spaced.

Students find that letters, symbols, and even the position of words are all ways that we use language to interpret information. In addition, students find that individuals differ in their abilities to interpret information.

Memory Station:
Students play a matching game twice while their partners time them with stopwatches. A set of cards is placed face down at the station. Students turn over two cards at a time, leaving them turned over if they match. The object is to match all cards as quickly as possible, then flip them over (without shuffling) and repeat the exercise. Students find that it takes longer to complete the game the first time than the second, since their memory retains the first results when they play the game a second time. In addition, students find that individuals differ in their ability to memorize position information.

Emotion Station:
Students look at two photographs that evoke different emotions. In the Web version, students are prompted to look at two different photographs on-screen. In the print version, students look at images from a media source. As they record their responses to the two pictures, students find that emotions play a role in how they interpret information. In addition, students find that individual reactions to the photos differ based on past experiences.

6. **Allow groups five minutes at each station, then ask them to move clockwise to the next station.**

Walk around the classroom to monitor student progress and answer questions.

7. **As groups complete the activities, draw the following chart on a board or transparency:**

Attention Station		Memory Station		Language Station		Emotion Station	
Test 1 time:	Test 2 time:	Game 1 time:	Game 2 time:	Puzzles were easy:	Puzzles were hard:	Photo 1 feeling:	Photo 2 feeling:

This chart will be used in Part 2 of the lesson.

Part 2, Celebrating Differences

1. **Reconvene the class and ask, "At the Attention Station, which was harder, Test 1 or Test 2?" Ask several students to share times it took to complete Tests 1 and 2.**

   On the board under "Attention Station," record several student responses for times required to complete Tests 1 and 2.

2. **Ask students to share ideas about why Test 2 might be harder than Test 1.**

   In the Attention Station tests, students had to focus specifically on the color of the word and ignore the meaning of the word. In addition, these tests are made up of lists of words that are themselves the names of colors. In Test 1, the meaning and color of the words are the same. However, in Test 2, the meaning and color of the words are different; the brain receives conflicting information and must choose between paying attention to the meaning of the word or the color of the word. Generally, it is harder to read the colors in Test 2 than in Test 1.

3. **Ask the class, "At the Memory Station, which was easier, Game 1 or Game 2?" Ask several students to share times it took to complete Games 1 and 2.**

   On the board under "Memory Station," record Game 1 and Game 2 times from several students.

4. **Ask students to share ideas about why Game 2 might be easier than Game 1.**

Students will likely find Game 2 easier than Game 1. At the Memory Station, students flipped over pairs of game pieces until all the pieces were matched into sets. In Game 1, students had not yet seen the positions of any game pieces, so it was impossible to know which pieces would match. In Game 2, students had already been exposed to the location of each game piece, so it should have been easier to flip over matching pairs (from memory).

5. **Ask the class to answer the following questions with a show of hands: How many thought the puzzles at the Language Station were easy to solve? How many thought they were hard to solve?**

   Count the number of responses for each question. On the board under "Language Station," record the number of students in each category.

6. **Ask students to explain why they felt the puzzles were easy or hard to solve.**

   As they share their reasons for believing the puzzles were easy or hard, students discover that letters, symbols, and even the position of words are all ways that we use language to interpret information. In addition, students find that individual abilities differ when interpreting information.

7. **Ask several students to describe in one word, how they felt when they saw Picture 1 at the Emotion Station. Repeat the question for Picture 2. As students provide responses, ask them why they felt the way they did.**

   Record the one-word descriptions on the board in the appropriate sections (Picture 1 or Picture 2) under "Emotion Station." Students find that as they looked at the photos, they were interpreting information to generate an emotional response. In addition, students find that reactions to the photos differ based on the past experiences of each individual.

8. **Remind students that this was the first lesson of a unit on the brain. Ask the class, "What does today's lesson have to do with the brain?"**

   Students recognize that each station represents a function controlled by the brain. By engaging in these activities, they were exploring ways that their brain works.

9. **Direct student attention to the board. Point out the variation in the results at each station. What do they think this means?**

Assessment:
Listening to students' responses will help you assess their understanding that individual differences in brain-related activities, such as memory, attention, emotion, and language, help make each of us who we are.

Some students may say that this means that some of them are "stupid" or "smarter." Guide them away from value judgments. Instead, emphasize that there are individual differences in the ways brains respond to tasks. Students should realize that these differences make each of us who we are. Explain that they will continue to explore similarities and differences in brain function among individuals in Lesson 2.

Lesson 1 Organizer

Activity 1: *A Difference of Mind*

What the Teacher Does	Procedure Reference
Part 1, Station Explorations	
Ask, "What makes you who you are?"	Page 49 Step 1
Explain to students that they will explore this question through activities at four different stations. Give each student a copy of Master 1.5, *Station Notes*.	Page 50 Steps 2–4 M
Divide the class into pairs and assign pairs to stations. Rotate groups through stations at five-minute intervals.	Pages 50–51 Steps 5–6 WWW
Prepare for Part 2 of activity by drawing chart on board or transparency to record student responses.	Page 52 Step 7
Part 2, Celebrating Differences	
Reconvene class. Ask, "At the Attention Station, which was harder, Test 1 or Test 2?" • Ask several students to share times it took them to complete the test. • Ask students why Test 2 might be harder than Test 1.	Page 52 Steps 1–2
Ask, "At the Memory Station, which was easier, Game 1 or Game 2?" • Ask several students to share times it took them to complete the games. • Ask students why Game 2 might be easier than Game 1.	Pages 52–53 Steps 3–4
Ask, "How many of you thought the puzzles at the Language Station were easy to solve?" • Ask students to explain why they felt the puzzles were easy or hard to solve.	Page 53 Steps 5–6

M = Involves copying a master.

WWW = Involves using the Internet, if available. Alternate print version also available.

Ask several students to describe how they felt when they saw Picture 1 at the Emotion Station. • Repeat for Picture 2. • Ask students why they felt as they did.	Page 53 Step 7
Ask, "What does today's lesson have to do with the brain?"	Page 53 Step 8
Direct student attention to the board. Point out the variation in the results at each station. Ask students what they think the variation indicates. Explain to students that they will continue to explore similarities and differences in brain function among individuals in the next lesson.	Pages 53–54 Step 9

Lesson 2
Explore
Explain

Regional Differences

At a Glance

Overview

This lesson consists of two activities in which students explore how the brain receives and responds to information. In the first activity, students learn that PET scans are used to identify specialized brain regions that receive different types of information, such as visual, auditory, or tactile. In the second activity, students work in pairs to interpret a scenario for the types of information coming into and going out of the brain. Using the PET scans from the first activity as a guide, students diagram the brain regions that would be active in the scenario. Through class discussion, students recognize that although their responses to the scenario are different, the information and the general regions of the brain that are active are the same across individuals. The brain uses information based on past experiences to evaluate the scenario, and this "information in" varies from one student to another. In a homework assignment, students evaluate the scenario in terms of what does and does not contribute to their sense of self.

Major Concepts

Specialized regions of the brain process information from specific sources, such as the eyes, ears, or skin. The location of these specialized regions in the brain is similar from individual to individual. Responses by the brain differ among individuals, even though they receive information from the same sources in the same specialized areas of the brain.

Objectives

After completing this lesson, students will

- be able to explain that specialized regions of the brain process information from specific sources, such as the eyes, ears, or skin,
- recognize that the location of functionally specialized regions in the brain are similar in different individuals, and
- be able to explain that responses by the brain differ among individuals, helping to make each of us who we are.

Teacher Background

Refer to the following sections in Information about the Brain:

2 Myths and Realities about the Brain *(pages 26–27)*

5 The Brain *(pages 31–34)*

- 5.1 Imaging the brain *(pages 31–32)*
- 5.2 Specialized regions of the brain *(pages 32–33)*
- 5.3 The brain and sensory input *(page 33)*
- 5.4 The brain and motor output *(pages 33–34)*

In Advance

Web-Based Activities

Activity	Web Version?
1	No
2	No

Photocopies

Activity 1	• Master 2.1, *Basics about PET Scans*, 1 transparency • Master 2.2, *Sample PET Scans*, 1 transparency
Activity 2	• Master 2.2, *Sample PET Scans*, 1 copy per group • Master 2.3, *Scenario Diagram*, 1 transparency • Master 2.4, *Brain Outline*, 1 copy per group

Materials

Activity 1	Overhead projector and screen
Activity 2	• Overhead projector and screen • Colored pencils, 6 colors per set, 1 set per group

Preparation

Activity 1

Set up overhead projector and screen.

Activity 2

Set up overhead projector and screen.

Procedure

Activity 1: *Picturing the Brain*

Teacher note: The term "types of information" is used in this lesson because students are likely to identify sensory input such as visual information or tactile information as different types of information. In Lesson 3, they will learn that all information goes into and comes out from the brain as electrical and chemical signals along neural pathways. “Types of information” as used in this lesson corresponds to the different sources of information, such as the eye or the skin.

1. **Begin the lesson with the statement, “People often compare the brain to a computer.” Then ask, “What do you think they mean? How is a brain like a computer?”**

   Students will provide a variety of responses. Some may indicate that the brain, like a computer, processes large amounts of information. Affirm this response by saying, “Yes, both computers and brains take information in and interpret it.” Then ask, “What do they do with the information?” Students may say that the brain uses information to “run” the body the way a computer uses information to run programs. You can elaborate on this response by saying, “Yes, both computers and brains respond to information—they send information out.” Summarize the discussion by emphasizing three points about how the brain functions: 1) it receives information (“information in”); 2) it interprets the information; and 3) it responds to the information (“information out”).

2. **Ask students to provide some examples of the types of information that come in to the brain and the information that goes out from the brain.**

   Students will likely identify sensory information such as seeing, hearing, tasting, touching, and smelling as “information in.” Point out that their brains also receive information from within their bodies, such as information about heart and breathing rates. Remind students of the Memory Station in Lesson 1, and note that information stored within their brains also contributes to “information in” for responding to a particular situation. If students are puzzled by the idea of “information out” from the brain, ask, “How do you respond to information that comes into your brain, such as when someone calls your name from behind?” When students respond that they turn around, point out that their brains direct that movement. “Information out” refers to actions that we choose, such as moving/not moving, speaking/not speaking, or paying attention/not paying attention. Information out also refers to actions in the body that the brain controls automatically, such as heartbeat and breathing.

3. **Ask, “Where do different types of information come into the brain? From where in the brain is information sent out?”**

   Students probably will not know how to answer. These questions are meant to encourage students to think about the structures and functions within the brain. Move on quickly to the next step.

NSES

4. **Explain that to determine where information comes into the brain, scientists use special techniques to "see" inside the brain. One of these techniques is the PET scan.**

Tip from the field test: Using the transparency of Master 2.1, *Basics about PET Scans*, will assist you in guiding students through an explanation of PET scans.

Content Standard A: Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.

5. **Show a transparency of Master 2.2, *Sample PET Scans*. Ask students what they observe about brains that are receiving and responding to different types of information. Do the PET scans look the same? What does this suggest about the brain?**

Explain to students that each PET scan on Master 2.2 shows brain activity for a single type of information, as indicated by the label below the image. Remind students that the bright regions of the scan show the active regions of the brain. Students should notice that the active regions of the brain differ with the type of information going into or out of the brain. Students should conclude that the brain has specialized regions that receive and respond to different types of information.

Assessment: Listening to students' responses allows you to assess their understanding of specialized regions in the brain. An understanding of functional specialization within the brain is an important prerequisite for Activity 2.

Activity 2: *Decisions, Decisions*

1. **Organize students into pairs.**

2. **Project a transparency of Master 2.3, *Scenario Diagram*. Ask students to watch and listen as you describe the following scenario.**

"You are riding your bike on a country road. A bike path curves sharply off the road to your right, crossing a swift stream with a rickety wooden bridge. A bit further up the road, a second bike path slopes gently to the right, but the path is riddled with rocks and potholes. To the left, a thunderstorm appears to be moving in your direction. Suddenly, you hear a loud truck horn directly behind you."

NSES

Content Standard C: Specialized cells perform specialized functions in multicellular organisms.

Tip from the field test: Students were less distracted and listened more carefully if colored pencils were handed out *after* teachers described the scenario (in Step 4) rather than before.

3. **Instruct the pairs to work with their partners to**
   - **make a list of the information their brains would receive in this scenario (information in);**
   - **decide what their response to the scenario would be (information out); and**
   - **identify the type of information (such as visual or auditory) for each item on their list and for their response.**

4. **Provide each group with a copy of Master 2.2, *Sample PET Scans*, Master 2.4, *Brain Outline*, and a set of six colored pencils.**

5. **Tell students to use the colored pencils to color in the brain regions on Master 2.4, *Brain Outline*, that would be active in the scenario, based on the type of information they identified in Step 3.**

   Allow groups 15 minutes to complete Steps 2 to 5. Students should use different colored pencils to indicate the different regions of the brain that are active. Student diagrams should include a key indicating the color corresponding to information from each source. Let students know that they will be presenting their findings to the class.

   Teacher note: In this activity, students use different colors to indicate different regions of the brain (such as red for the visual cortex and blue for the motor cortex). This is effective for demonstrating the lesson concept that different regions of the brain are active for different types of information in and information out. Although color PET scans may look similar to students' diagrams, the colors in a PET scan represent the intensity of activity in regions of the brain, not regions that receive information from different sources, as in students' diagrams. Although this point is not important for students' understanding of the major concept in the lesson, some of your students may be familiar with PET scans. If students ask whether they are producing PET scans with their diagrams, you should explain that they are not and clarify the difference.

6. **Ask one of the pairs to provide a one-minute presentation of their results to the class. Advise students to take notes because they will need to discuss the scenarios in a homework assignment.**

   The presentation should include the information presented in the scenario, the brain regions that receive that information (color-coded by source), their group's response to the scenario, and the brain regions that are active in carrying out their response. Encourage students to use their diagrams to identify the various brain regions involved.

7. **Ask a pair who had a different response to the scenario to present their results to the class.**

   The second pair should follow the same guidelines for their presentation as the first pair.

8. **Repeat Step 6 for a third pair.**

9. **Ask students to compare the brain regions they colored in with the regions colored in by the pairs that presented their results.**

Ask, "Did you all color the same regions? Why (or why not)?"

Students should find that all pairs colored in the same brain regions. The scenario included multiple types of information, so multiple brain regions had to be active. Because all pairs were working with the same scenario, they had the same types of information coming in from outside the body. Thus, regardless of the colors used, all diagrams should indicate activity in the *same* brain regions.

10. **Point out that different pairs suggested different responses to the scenario. Ask, "How can you explain that although everyone had the same 'information in,' the responses ('information out') varied?"**

Students will likely say things such as, "We knew we could ride around the potholes and rocks, so we took the second path" or "We just speeded up to get ahead of the truck and get home before the storm broke." Point out that these thoughts—information about their abilities to navigate or to go faster—represent a type of "information in" that was based on past experiences and that varied from pair to pair, even though each pair's brain diagram indicates that the same brain regions were active. This information originated within the brain, rather than from an external source.

11. **As a homework assignment, ask students to write a 5-to-10-sentence paragraph describing**
    - **similarities in all pairs' lists of information in and out and in the active regions depicted in their diagrams;**
    - **differences in the pairs' responses to the scenario; and**
    - **how responses can be different for different individuals even though the information coming in from outside the body and the brain regions that process this information are the same.**

Assessment:
This assignment allows you to assess students' understanding of the role of past experience in defining sense of self. An as informal assessment, you can have several students read their paragraph and listen to the class discussion. As a formal assessment, you can collect the students' written work.

Students should indicate that all pairs described visual, auditory, and tactile "information in" and motor "information out," as well as activity in the same regions of the brain. They should describe several different responses to the scenario. Students should indicate that the brain also uses information from memory (past experiences) to determine a response. Differences in past experiences help account for differences in responses. The way sensory information is related to past experiences contributes to the sense of self.

Lesson 2 Organizer

Activity 1: *Picturing the Brain*	
What the Teacher Does	**Procedure Reference**
Make the statement, "People often compare the brain to a computer." Ask, • "What do you think they mean?" • "How is the brain like a computer?"	Page 59 Step 1
Ask students to provide some examples of the types of information that come into the brain and the information that goes out from the brain. Ask, • "Where do different types of information come in to the brain?" • "From where in the brain is information sent out?"	Page 59 Steps 2–3
Describe a PET scan as a technique scientists use to "see" inside the brain. • Use a transparency of Master 2.1: *Basics about PET Scans*, to assist in the explanation.	Page 60 Step 4 T
Show a transparency of Master 2.2: *Sample PET Scans*. Ask students, • "What do you observe about brains that are receiving and responding to different types of information?" • "Do the PET scans look the same?" • "What does this suggest about the brain?"	Page 60 Step 5 T
Activity 2: *Decisions, Decisions*	
Organize students into pairs. Project a transparency of Master 2.3, *Scenario Diagram*, and describe the scenario for the class.	Page 60 Steps 1–2 T

T = Involves using a transparency.

Instruct students to • make a list of information their brains would receive in this scenario; • decide what their response to the scenario would be; and • identify the type of information (such as auditory or visual) for each item on their list and for their response.	Page 60 Step 3
Provide each group with a copy of each Master 2.2, *Sample PET Scans*, and Master 2.4, *Brain Outline*, and a set of six colored pencils. • Instruct students to color the brain regions that would be active based on the information they identified in Step 3.	Page 61 Steps 4–5 M
Have one group provide a short presentation of their results to the class. • Have a group who had a different response to the scenario to present their results. • Repeat with a third student group.	Page 61 Steps 6–8
Ask the class to compare their results with those of the groups that presented their results. Ask, • "Did you all color the same region? Why, or why not?" • "How can you explain that although everyone had the same 'information in,' the responses (information out) varied?"	Pages 61–62 Steps 9–10
As homework, ask students to write a paragraph describing • similarities in all groups' lists of information in and out and in the active regions depicted in their diagrams; • differences in the groups' responses to the scenario; and • how responses can be different for different individuals even though the information coming in from outside the body and the brain regions that process this information are the same.	Page 62 Step 11

M = Involves copying a master.

Inside Information

At a Glance

Overview

Students construct two pathways for information flow through the human nervous system. First, they build a pathway for an involuntary action, or reflex. Students discover that this pathway does not require information transfer to and from the brain. Next, students build a pathway for a voluntary response. They discover that voluntary responses include an element of choice. Since the brain is required to make a choice, voluntary response pathways involve information transfer to and from the brain.

Major Concepts

The body receives and delivers information through the nervous system. The nervous system is an interconnected set of specialized parts, including the brain, the spinal cord, and nerve cells outside the brain and spinal cord. Information flows in one direction through a nerve cell. Reflex pathways lead to rapid, involuntary responses and include only the spinal cord and nerve cells outside the brain and spinal cord. Voluntary response pathways involve choice, and thus include the brain as well as the spinal cord and nerve cells outside the brain and spinal cord.

Objectives

After completing this lesson, students will be able to

- recognize that information in the body flows through the nervous system,
- describe the major parts of the nervous system, their functions, and how they are interconnected,
- describe the direction of information flow through a nerve cell,
- explain that reflex pathways include the spinal cord but not the brain, and
- explain that voluntary response pathways include the brain.

Teacher Background

Refer to the following sections in Information about the Brain:

4 Cells of the Nervous System *(pages 28–31)*

    4.1 Neurons *(pages 28–29)*

4.3 Transmission of nerve impulses: electrical transmission *(pages 29–30)*
5 The Brain *(pages 31–34)*
5.3 The brain and sensory input *(page 33)*
5.4 The brain and motor output *(pages 33–34)*
6 The Spinal Cord *(pages 34–36)*
6.1 Structure of the spinal cord *(page 34)*
6.2 Spinal cord functions *(pages 34–36)*

In Advance

Web-Based Activities

Activity	Web Version?
1	No
2	Yes
3	No

Photocopies

Activity 1	Master 3.1, *Two Types of Cells*, 1 transparency
Activity 2	**Web Version** • Master 3.2, *Pathway-Building Worksheet*, 1 per student **Print Version** • Master 3.3(a, b, c), *Neuroscience Reference Manual*, 1 copy per group • Master 3.4, *Building a Reflex Pathway*, 1 copy per group, plus 4 transparencies • Master 3.5, *Building a Voluntary Response Pathway*, 1 copy per group, plus 4 transparencies
Activity 3	None required.

Materials

Activity 1	Overhead projector and screen
Activity 2	**Web Version** • Computers with Internet access **Print Version** • Overhead projector and screen • Three water-soluble transparency pens of different colors • Colored pencils, three different colors per group
Activity 3	None required.

Preparation

Activity 1
Set up overhead projector and screen.

Activity 2, Web Version
Reserve computer lab, or set up computers with Internet access in classroom.

Before class, go to the Web page *http://science.education.nih.gov/supplements/self/student*. Clicking on the link to "Lesson 3—Inside Information" brings up the unit's "desktop," which contains a link to "Inside Information." Work through both pathways (reflex and voluntary movement) to familiarize yourself with the activity.

Activity 2, Print Version
Set up overhead projector and screen.
Staple sets of Masters 3.3(a, b, c) together to form Neuroscience Reference Manuals.

Activity 3
None required.

Procedure

Activity 1: *Information Flow (for Print and Web)*

1. **Begin the lesson by displaying a transparency of Master 3.1, *Two Types of Cells*, on the overhead projector. Ask students to make observations about the two cells.**

   Focus discussion on similarities and differences between the two cells. Students may say that the top cell is smooth and round, while the bottom cell is long and thin. They may comment that although both cells have a cell body and a nucleus, there appear to be some "extra" parts sticking out of the bottom cell.

2. **Explain to the class that the top cell is the most common type of animal cell, such as a skin cell. The bottom cell is a special cell that passes information through the body. It is a nerve cell, or *neuron*.**

   Explain briefly that a neuron is made up of three parts: the dendrites, the cell body, and the axon.

3. **Ask students to stand and form a line around the classroom. Explain that they will model information flow through a *neural pathway*.**

   A neural pathway is a path of information flow through the body. Each student represents one neuron along the pathway.

Assessment:
Listen to student responses to assess their understanding that information flows in only one direction through neurons. This concept is key to the following activities.

Content Standard C: All organisms are composed of cells—the fundamental unit of life. Living systems at all levels of organization demonstrate the complementary nature of structure and function. Specialized cells perform specialized functions in multicellular organisms.

4. **Ask students to hold out their arms, forming a fist with their right hand and leaving their left hand open.**

   Students should stand close to one another but leave a space between adjacent hands. Explain that as neurons, the open left hand of each student represents their axon end, and their right fist represents their dendrite end.

5. **Tell students that they will be passing information through their model pathway by using their open hand to tap the fist of the person next to them.**

   Start the flow of information through the pathway by tapping the fist of the rightmost student of the line with your left hand. Each student should pass the information along by using their axon (left hand) to tap the dendrite (right fist) of the student next to them. Allow the information to be passed through the entire line of students.

6. **Now ask a student in the middle of the line to face the opposite direction from the rest of the line, leaving the same hands open and fisted. Once again, start the flow of information by tapping the fist of the rightmost student in the line. What happens to the signal?**

   To make the point of directional information flow, you may want to reinforce the idea that the open hand can only send information and the fist can only receive information. The signal should stop at the student facing the opposite direction from the rest of the line.

7. **Ask students what this experiment suggests about information flow through neurons.**

   Information flows through neurons in one direction only.

Activity 2: *Inside Information*

Content Standard C: Behavior is one kind of response an organism can make to an internal or environmental stimulus.

For classes using the *Web-based version* of this activity:

Part 1, A Reflex Pathway

1. **Ask students to explain the difference between a voluntary response and an involuntary response.**

   A voluntary response is an action we choose to perform. We do not choose to perform an involuntary response; instead, our bodies respond without a conscious choice.

2. **Ask students to provide examples of voluntary and involuntary responses.**

Voluntary responses include walking, talking, eating, or reading books. Involuntary responses include changes in heartbeat, breathing, digestion, or blinking.

3. **Explain to the class that they will investigate an involuntary response known as a reflex action. Ask, "What is a reflex action?"**

   Students should have a general understanding that a reflex involves a quick, automatic response by their bodies to an input from the environment.

4. **Your students probably are familiar with the knee-jerk reflex. Ask for student volunteers to describe and/or demonstrate this reflex.**

   Students may describe the knee-jerk reflex as something they have experienced when they visit the doctor. The doctor taps below their kneecap with a small hammer, and their leg kicks out. Some students may wish to demonstrate this reflex on their own knee. Alternately, you may choose to demonstrate the reflex on yourself by sitting on your desk and hitting your knee. In addition, you may wish to have all students try out this reflex on themselves.

   Some students may be unable to get the knee-jerk reflex to work on themselves and may become concerned that there is something wrong with them. Reassure these students by explaining that finding the precise location to tap below the kneecap can be difficult for nonphysicians. Furthermore, if students consciously tighten their leg muscles, the knee-jerk reflex either may not occur or may occur only subtly.

5. **Give one copy of Master 3.2, *Pathway-Building Worksheet*, to each student.**

   Explain to students that they will use a Web interface to construct the neural pathway that controls the knee-jerk reflex. After they have constructed the neural pathway, they will draw it and answer questions about it on Master 3.2.

6. **Divide the class into groups of two or three students each. Direct groups to computer stations.**

7. **Ask groups to open their Internet browser, go to *http://science.education.nih.gov/supplements/self/student*, and click on "Lesson 3—Inside Information" to bring up the unit's "desktop." Students can then click on the link to "Inside Information" and then the link to the reflex pathway.**

8. **Instruct students to listen to the audio introduction to the activity.**

Assessment:
Collecting the completed masters from students at the conclusion of this lesson provides an opportunity for formal assessment of students' understanding of neural pathways.

Students may replay the audio at any time by clicking on the "Replay Audio" button.

9. **Ask students to click on the link for the "Neuroscience Reference Manual." Explain that the manual contains essential information for constructing neural pathways.**

   Point out several sections of the manual that will be helpful to students as they construct their neural pathways. Part 1 of the manual describes the parts of the nervous system; Part 2 describes neural signaling and the three main types of neurons; and Part 3 contains details about reflex actions and voluntary actions.

   Tip from the field test: Introducing the reference manual before students start working emphasizes the importance of this resource and encourages students to use this information to help them complete the activity.

10. **Explain to students that they may navigate through the Neuroscience Reference Manual by clicking on the section names in the manual's Table of Contents. They may return to the Table of Contents by clicking on the "Back to Main Menu" hotlinks at the end of each section.**

    Encourage students to take a minute to explore this navigation system.

11. **Explain to students that to construct a neural pathway, they will need to select the correct body parts and neurons and place them in the correct position in the figure. Walk students through the process of placing and removing body parts and neurons in the figure on the right side of the Web screen.**

    Placing and removing body parts:
    - To place a body part on the figure, click on the appropriate body part "box" on the left side of the screen. The body part will appear in the figure.
    - To remove the body part from the figure, click on the body part in the figure or in its box.

    Placing and removing neurons:
    - Neurons must be placed across two connection points (red circles) in the body.
    - To place a neuron in the figure, first select the appropriate type of neuron by clicking on its "box" on the left side of the screen. After selecting a neuron, click on a connection point in the figure to place the dendrite end of the neuron at that point. Clicking on a second connection point places the axon end of the neuron at the second point, its target site.

- To remove a neuron from the figure, click on the neuron within the figure.

Tip from the field test: Spending time discussing these basic instructions with the class decreases confusion and allows students to focus on the lesson's content and complete the activity more quickly.

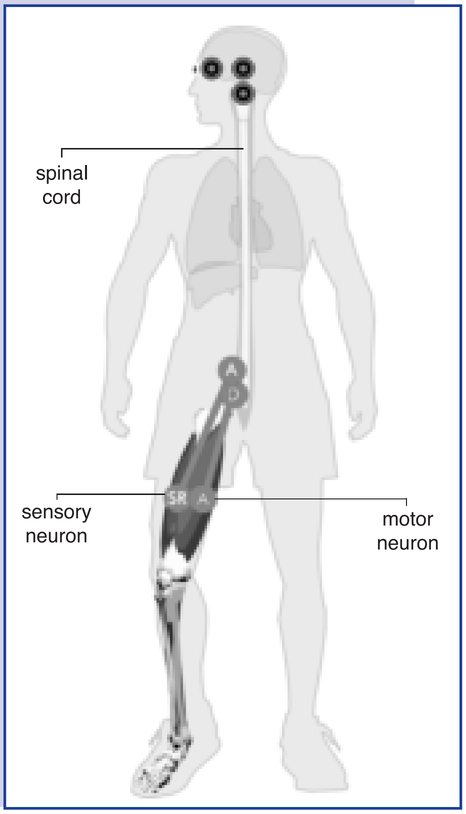
12. **Tell students that they are ready to construct the neural pathway for the knee-jerk reflex. Instruct groups to complete the pathway using only those parts that are involved directly in the pathway.**

Students should read, interpret, and evaluate information in the Neuroscience Reference Manual to determine how to construct the pathway. Students should pay particular attention to the types of neurons described in Part 2 of the manual, and to the "Reflex Actions" section in Part 3 of the manual. As student groups work, walk around the classroom to monitor their progress. Be available to answer questions, but encourage students to consult the appropriate section(s) of the Neuroscience Reference Manual. Students can

- replay the reflex animation by clicking on the "Replay Animation" button,
- test their pathway by clicking on the "Test Pathway" hammer, and
- reset the entire pathway by clicking on the "Reset Pathway" button.

A correctly completed pathway should have the following attributes:

- The pathway should include only the spinal cord, one sensory neuron, and one motor neuron.
- The sensory neuron should have its dendrites on the thigh and its axon terminals on the pelvic region of the spinal cord.
- The motor neuron should have its dendrites on the spinal cord and its axon terminals on the thigh muscle.



If the pathway is correct, the following series of events will take place on the Web page when students click on the "Test Pathway" hammer:

- When the kneecap is hit with the hammer, a spark, representing neural information, travels from the thigh muscle, through the sensory neuron, to the spinal cord.
- At the spinal cord, the spark transfers to the motor neuron.
- The spark travels through the motor neuron to the thigh muscle, and the leg kicks out.

Students must use the correct components of the pathway and place them in the correct orientations. This leads to the discovery that information can only travel through a neural pathway in one direction.

13. **If the pathway is built incorrectly, students will receive one of three error messages when they test the pathway, and the Neuroscience Reference Manual will open to the appropriate section.**

    If the pathway itself is constructed correctly but the spinal cord is not included, or inappropriate body parts (heart, lung, liver) are included, the Web page will provide the following error message:
    "**Your pathway is not correct. Are you using the right body parts? Check the Neuroscience Reference Manual.**"
    The Neuroscience Reference Manual will open to *Part 1: The Central Nervous System.*

    If the neurons of the pathway are correct but placed in the wrong orientation, the Web page will provide the following error message:
    "**Your pathway is not correct. Are the neurons placed correctly? Check the Neuroscience Reference Manual.**"
    The Neuroscience Reference Manual will open to *Part 2: Signaling and Neurons.*

    If the neurons of the pathway are incorrect or the brain is included in the pathway, the Web page will provide the following error message:
    "**Your pathway is not correct. Check the Neuroscience Reference Manual.**"
    The Neuroscience Reference Manual will open to *Part 3: Neural Pathways.*

14. **When students complete the pathway, remind them to answer the questions on Master 3.2, *Pathway-Building Worksheet*, to describe the pathway they have built.**

    At the end of Part 1, ask students to keep Master 3.2, *Pathway-Building Worksheet*, for use in Part 2 of Activity 2.

15. **Reconvene the class. Through discussion, encourage students to examine their pathway-building process critically. Was their**

group able to make a pathway that worked? What types of pathways did not work? Why?

Students may have made errors as they constructed the correct pathway. Encourage them to share their experiences and explain why certain configurations did not work. At the end of the discussion, students should be able to construct the knee-jerk reflex pathway correctly and describe the flow of information through it.

Students will find that the heart, lungs, liver, and brain were not needed to complete the knee-jerk reflex pathway. In fact, the pathway was marked "Incorrect" if any of these parts were included. It was necessary to leave the heart, lungs, and liver out of the pathway because these body parts are not part of the nervous system. It was necessary to exclude the brain from this pathway because the brain is not involved in the transfer of information in this example.

Assessment: Assess students' understanding by listening to their explanations and reasoning.

Part 2, A Voluntary Response Pathway

1. **Instruct groups to return to their computers. Ask them to open up their Internet browser and go to the Web page *http://science.education.nih.gov/supplements/self/student* and click on "Lesson 3—Inside Information." This brings up the unit's "desktop," from which students should click on the link to "Inside Information." Students then click on the link to the voluntary movement pathway.**

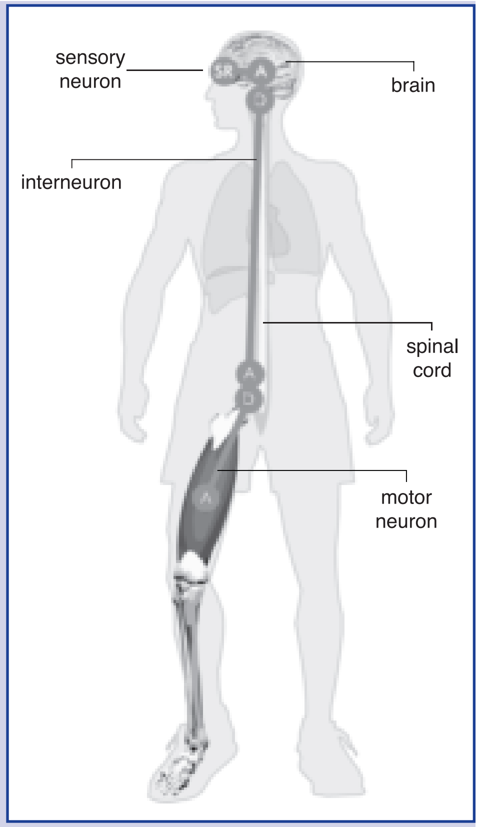
2. **Explain to students that they are to construct a neural pathway for the voluntary leg movement involved in kicking the soccer ball. Instruct groups to complete the pathway using only those parts that are involved directly in the pathway.**

   Explain to the class that the path of information flow begins with the eyes; that is, seeing the soccer ball coming toward them. The response is moving the leg to kick the ball.

   Students should read, interpret, and evaluate information in the Neuroscience Reference Manual to determine how to construct the pathway. Students should pay particular attention to the types of neurons described in Part 2 of the manual, and to the "Voluntary Actions" section in Part 3 of the manual. As student groups work on their pathways, walk around the classroom to monitor their progress. Be available to answer questions, but encourage students to consult the appropriate section(s) of the Neuroscience Reference Manual. Students can

   - replay the animation by clicking on the "Replay Animation" button,
   - test their pathway by clicking on the "Test Pathway" soccer ball, and

- reset the entire pathway by clicking on the "Reset Pathway" button.



A correctly completed pathway should have the following attributes:

- The pathway includes the brain, the spinal cord, one sensory neuron, one interneuron, and one motor neuron.
- The sensory neuron should have its dendrites on the eye and its axon terminals on the brain.
- The interneuron should have its dendrites on the brain and its axon terminals on the pelvic region of the spinal cord.
- The motor neuron should have its dendrites on the spinal cord and its axon terminals on the thigh.

If the pathway is correct, the following series of events will take place on the Web page when students click on the "Test Pathway" soccer ball:

- As the soccer ball falls toward the figure's foot, a spark, representing neural information, travels from the eye, through the sensory neuron, to the brain.
- At the brain, the spark transfers to the interneuron.
- The spark travels through the interneuron from the brain to the spinal cord.
- At the base of the spinal cord, the spark transfers to the motor neuron.
- Finally, the spark travels through the motor neuron to the thigh muscle, and the foot kicks the soccer ball.

Students must use the correct components of the pathway and place them in the correct orientations. This leads to reinforcing the discovery students made in Activity 1 of this lesson, that information can only travel through a neural pathway in one direction.

3. **If the pathway is built incorrectly, students will receive one of three error messages when they test the pathway, and the Neuro-**

science Reference Manual will open to the appropriate section.

If the pathway itself is constructed correctly but the spinal cord is not included, or inappropriate body parts (heart, lung, liver) are included, the Web page will provide the following error message:

"Your pathway is not correct. Are you using the right body parts? Check the Neuroscience Reference Manual."

The Neuroscience Reference Manual will open to *Part 1: The Central Nervous System.*

If the neurons of the pathway are correct but placed in the wrong orientation, the Web page will provide the following error message:

"Your pathway is not correct. Are the neurons placed correctly? Check the Neuroscience Reference Manual."

The Neuroscience Reference Manual will open to *Part 2: Signaling and Neurons.*

If the neurons of the pathway are incorrect or the brain is not included in the pathway, the Web page will provide the following error message:

"Your pathway is not correct. Check the Neuroscience Reference Manual."

The Neuroscience Reference Manual will open to *Part 3: Neural Pathways.*

4. **When students complete the pathway, remind them to answer the questions on Master 3.2, *Pathway-Building Worksheet*.**

   Students use Master 3.2 to answer questions about the pathways built in Parts 2 and 3 of the lesson. At the end of Part 3, you may wish to ask them to hand in Master 3.2.

5. **Reconvene the class. Through discussion, encourage students to examine their pathway-building process critically. Was their group able to make a pathway that worked? What types of pathways did not work? Why?**

   Students may have made errors as they constructed the correct pathway. Encourage them to share their experiences and explain why certain configurations did not work. At the end of the discussion, students should be able to construct the voluntary leg movement pathway correctly and describe the flow of information through it.

   Students will find that the heart, lungs, and liver were not needed to complete the voluntary movement pathway. In fact, the pathway was marked "Incorrect" if any of these parts were included. It was necessary to leave these parts out of the pathway because these body parts are not part of the nervous system. While the heart,

Assessment:
Assess students' understanding by listening to their explanations and reasoning.

lungs, and liver are all important for keeping a body alive, they are not directly involved in the transfer of information through the voluntary movement pathway.

Explain to students that although they used only one type of each neuron in this example, in reality, millions of neurons are used to elicit this response.

NSES

Content Standard C: Behavior is one kind of response an organism can make to an internal or environmental stimulus.

For classes using the *print verson* of this activity:

Part 1, A Reflex Pathway

1. **Ask students to explain the difference between a voluntary response and an involuntary response.**

   A voluntary response is an action we choose to perform. We do not choose to perform an involuntary response; instead, our bodies respond without a conscious choice.

2. **Ask students to provide examples of voluntary and involuntary responses.**

   Voluntary responses include walking, talking, eating, or reading books. Involuntary responses include changes in heartbeat, breathing, digestion, or blinking.

3. **Explain to the class that they will investigate an involuntary response known as a reflex action. Ask, "What is a reflex action?"**

   Students should have a general understanding that a reflex involves a quick, automatic response by their bodies to an input from the environment.

4. **Your students are probably familiar with the knee-jerk reflex. Ask for student volunteers to describe and/or demonstrate this reflex.**

   Students may describe the knee-jerk reflex as something they have experienced when they visit the doctor. The doctor taps below their kneecap with a small hammer, and their leg kicks out. Some students may wish to demonstrate this reflex on their own knee. Alternately, you may choose to demonstrate the reflex on yourself by sitting on your desk and hitting your knee. In addition, you may wish to have all students try this reflex on themselves.

   Some students may be unable to get the knee-jerk reflex to work on themselves and may become concerned that there is something wrong with them. Reassure these students by explaining that finding the precise location to tap below the knee can be difficult for nonphysicians. Furthermore, if students consciously tighten their leg muscles, the knee-jerk reflex either may not occur or may occur only subtly.

5. **Explain to students that they will be working in groups to construct the neural pathway that controls the knee-jerk reflex. Divide the class into groups of two or three students each.**

6. **Give stapled sets of Master 3.3(a, b, and c), *Neuroscience Reference Manual*, to each group.**

   Explain that the Neuroscience Reference Manual contains essential information for this activity. Point out several sections of the manual that will be helpful to students as they construct their neural pathways. Part 1 of the manual describes the parts of the nervous system; Part 2 describes neural signaling and the three main types of neurons; and Part 3 contains details about reflex actions and voluntary actions.

   Tip from the field test: Introducing the reference manual before students start working emphasizes the importance of this resource and encourages students to use this information to help them complete the activity.

7. **Give each group one copy of Master 3.4, *Building a Reflex Pathway*. Explain to students that they will work with their group members to construct a neural pathway for the knee-jerk reflex.**

   Students use colored pencils to draw neurons on Master 3.4, *Building a Reflex Pathway*. This master contains an outline of a person with the brain, spinal cord, and thigh muscle, as well as the heart, lungs, and liver, drawn in.

8. **Give each group pencils of three different colors. Explain to students that they should use these pencils to represent the three types of neurons as they construct their pathway. Only one of each type of neuron used needs to be drawn as a representation. Instruct groups to use the Neuroscience Reference Manual to help them complete their drawings.**

   Students should read, interpret, and evaluate information in the Neuroscience Reference Manual to determine how to construct the pathway. Students should pay particular attention to the types of neurons described in Part 2 of the manual and to the "Reflex Actions" section in Part 3 of the manual. As student groups work, walk around the classroom to monitor their progress. Be available to answer questions, but encourage students to consult the appropriate section(s) of the Neuroscience Reference Manual before you answer.

Assessment:
Collecting the completed masters from students at the conclusion of this lesson provides an opportunity for formal assessment of students' understanding of neural pathways.

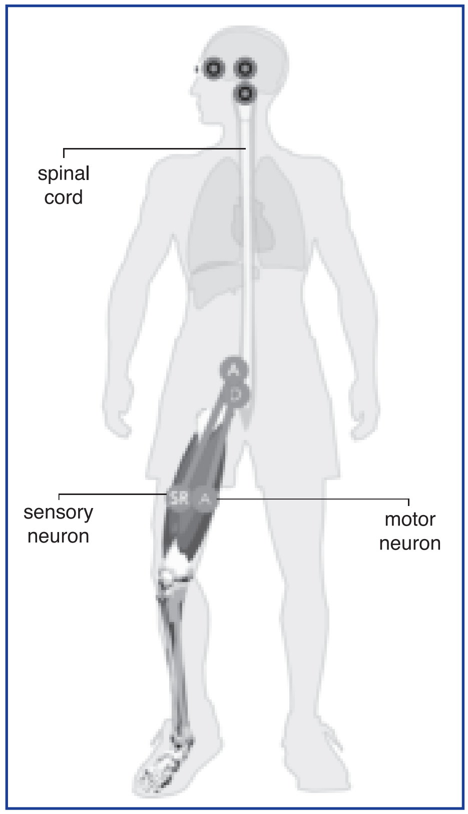
9. **As students construct their diagrams, ask them to discuss the following questions with their group members:**
   1. **Why did their group choose the parts they did?**
   2. **How did they put those parts together?**
   3. **How does information flow through the pathway?**

   You may wish to write these questions on the board so students can refer to them. This step helps students prepare for their presentations (Step 10).

10. **When groups are finished, ask one group to diagram their reflex pathway on a transparency of Master 3.4, *Building a Reflex Pathway.***

    Students should explain the following:
    1. Why their group chose the parts they did.
    2. How they put those parts together.
    3. How information flows through the pathway.

    A correctly completed pathway should have these attributes:
    - The pathway should include only the spinal cord, one sensory neuron, and one motor neuron.
    - The sensory neuron should have its dendrites on the thigh and its axon terminals on the pelvic region of the spinal cord.
    - The motor neuron should have its dendrites on the spinal cord and its axon terminals on the thigh muscle.



    If the pathway is correct, information would flow as follows:
    - Information (the hammer hitting the knee) is received by the dendrites of the sensory neuron in the thigh and flows to the axon terminals of the sensory neuron in the spinal cord.
    - Within the spinal cord, information flows from the axon terminals of the sensory neuron to the dendrites of the motor neuron.
    - Information flows from the dendrites of the motor neuron

in the spinal cord to the axon terminals in the thigh muscle, resulting in the leg kicking out.

Students should use the correct components of the pathway and place the components in the correct orientation. This leads to reinforcing the discovery they made in Activity 1 of this lesson, that information can only travel through a neural pathway in one direction.

11. **When the presentation is completed, ask the other groups if they agree with the pathway of the first group. If another group disagrees, ask a representative from that group to present their pathway using another transparency of Master 3.4.**

The new representative should explain their group's pathway to the class. Student descriptions should consist of the components, construction, and flow of information outlined above. Encourage the class to examine each pathway carefully based on the information provided in the Neuroscience Reference Manual. Does the pathway have enough parts? Too many parts? Are the parts connected in the correct way? Would information flow through the pathway correctly? Why or why not?

Allow presentations to continue until all alternate pathways have been explained to the class. Through discussion of the pathways presented, the class should be able to create a correct pathway by consensus. At the end of the discussion, all students should be able to construct the reflex pathway correctly and describe the flow of information through it.

Assessment: Assess students' understanding by listening to their explanations and reasoning.

Part 2, A Voluntary Response Pathway

1. **Give one copy of Master 3.5, *Building a Voluntary Response Pathway*, to each group.**

2. **Explain to students that they will work with their group members to construct a neural pathway for the voluntary leg movement involved in kicking the soccer ball. Instruct groups to complete their drawings with only those parts that are involved directly in the pathway, using the Neuroscience Reference Manual as a guide.**

Explain to the class that the path of information flow begins with the eyes—that is, seeing the soccer ball coming toward them. The response is moving the leg to kick the ball.

Students should read, interpret, and evaluate information in the Neuroscience Reference Manual to determine how to construct the pathway. Students should pay particular attention to the types of neurons described in Part 2 of the manual and to the "Voluntary Actions" section in Part 3 of the manual. As student groups work on their pathways, walk around the classroom to monitor their progress. Be available to answer questions, but encourage students to consult the appropriate section(s) of the Neuroscience Reference Manual before you answer.

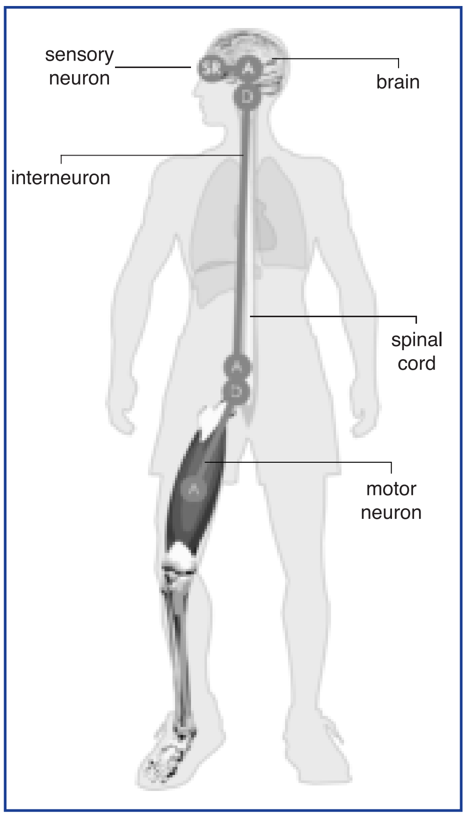
3. **As students construct their diagrams, ask them to discuss the following questions with their group:**
   1. **Why did their group choose the parts they did?**
   2. **How did they put those parts together?**
   3. **How does information flow through the pathway?**

   Writing these questions on the board allows students to refer to them as they work. This step helps students prepare for their presentations (Step 4).

4. **When groups are finished, ask one group to diagram their voluntary response pathway on a transparency of Master 3.5, *Building a Voluntary Response Pathway.***

   Student descriptions should include these components:
   1. Why their group chose the parts they did.
   2. How they put those parts together.
   3. How information flows through the pathway.

   A correctly completed pathway should have these attributes:
   - The pathway includes the brain, the spinal cord, one sensory neuron, one interneuron, and one motor neuron.
   - The sensory neuron should be drawn on the figure with its dendrites on the eye and its axon terminals on the brain.
   - The interneuron should be drawn on the figure with its dendrites on the brain and its axon terminals on the pelvic region of the spinal cord.
   - The motor neuron should be drawn on the figure with its dendrites on the spinal cord and its axon



terminals on the thigh.

If the pathway is correct, information would flow as follows:

- Visual information (seeing the soccer ball) received by the dendrites of a sensory neuron in the eye flows to the axon terminals of that sensory neuron in the brain.
- Within the brain, visual information is transferred from the axon terminals of the sensory neuron to the dendrites of an interneuron. Visual information is processed by the interneuron, which produces response information (kicking the ball).
- Response information flows from the dendrites of the interneuron in the brain to the axon terminals of that interneuron in the spinal cord.
- Within the spinal cord, response information flows from the axon terminals of the interneuron to the dendrites of a motor neuron.
- Response information then flows from the dendrites of the motor neuron in the spinal cord to the axon terminals of the motor neuron in the leg, directing the foot to kick the incoming soccer ball.

Students should use the correct components of the pathway and place them in the correct order and orientation. This leads to the following discoveries: neurons are specific to a certain job, and information flows through a neural pathway in only one direction.

5. **After the presentation is completed, ask the other groups if they agree with the pathway of the first group. If another group disagrees, ask a representative from that group to present their pathway using another transparency of Master 3.5.**

The new representative should explain their group's pathway to the class. Student descriptions should consist of the components, construction, and flow of information outlined above. Students may produce a variety of incorrect answers. Encourage the class to carefully examine each pathway based on the information provided in the Neuroscience Reference Manual. Does the pathway have enough parts? Too many parts? Are the parts connected in the correct way? Would information flow through the pathway correctly? Why or why not?

Assessment: Assess students' understanding by listening to their explanations and reasoning.

Allow presentations to continue until all alternate pathways have been explained to the class. Through discussion of the pathways presented, the class should be able to create the correct pathway by consensus. At the end of the discussion, all students should be able to construct the voluntary leg movement pathway correctly and describe the flow of information through it.

Activity 3: *Summing It Up (for Print and Web)*

1. **The first pathway students constructed was for the knee-jerk reflex. Ask students, "If a physician tested the knee-jerk reflex on each of us, would everyone's response be the same?"**

   Students should generally agree that the knee-jerk reflex would be the same for everyone tested by the physician.

2. **The second pathway students constructed was for the voluntary leg movement to kick a soccer ball. Now ask students to imagine that they are actually playing soccer. They notice that the ball is headed straight for them. What would they do?**

   Students may provide a variety of answers, including kicking, bouncing, or catching the ball, moving out of its way, standing still and allowing the ball to hit them, or not being on the soccer field in the first place. In general, students should answer that they would somehow interact with the soccer ball.

3. **Point out that a variety of responses were provided for the soccer ball scenario, as opposed to the same response by everyone for the knee-jerk reflex. Ask students, "Why were you able to have different responses for the soccer ball scenario?"**

   Students should explain that the soccer ball scenario required a voluntary response. Since voluntary responses involve choice, students were able to choose their response to the soccer ball scenario, which allowed their responses to be different from their peers'.

4. **Ask students why they were not able to choose the response to the reflex action. What is the difference between the two pathways?**

   Students should recall that the voluntary response pathway included the brain, while the reflex pathway did not. Since the brain is required to make a choice, students were unable to choose their response to the reflex action.

Assessment: Asking students to write their answers to the questions in Steps 3 and 4 allows them to organize their thoughts and reflect on what they have learned in this lesson. For a formal assessment of student learning, you can review the written materials.

Lesson 3 Organizer: Web Version

Activity 1: *Information Flow*	
What the Teacher Does	**Procedure Reference**
Display a transparency of Master 3.1, *Two Types of Cells*. • Ask students to make observations about the two cells. • Explain that the top cell is a common type of animal cell. • Explain that the bottom cell is a nerve cell, or neuron, and that it passes information through the body.	Page 67 Steps 1–2 T
Ask students to stand and form a line around the classroom. • Explain that they will model the flow of information through a neural pathway. • Ask students to hold out their arms, forming a fist with their right hand and leaving their left hand open.	Pages 67–68 Steps 3–4
Tell students they will be passing information through their model pathway by using their open hand to tap the fist of the person next to them.	Page 68 Step 5
Ask a student in the middle of the line to face the opposite direction from the rest of the line, leaving the same hands open and fisted. • Start the flow of information by tapping the fist of the rightmost student in the line. • Ask students what happens to the signal. • Ask students what this model suggests about information flow through neurons.	Page 68 Steps 6–7
Activity 2: *Inside Information, Part 1: A Reflex Pathway*	
Ask students • to explain the difference between a voluntary response and an involuntary response, • to provide examples of voluntary and involuntary responses, and • what a reflex action is.	Pages 68–69 Steps 1–3

T = Involves using a transparency.

Ask for student volunteers to describe and/or demonstrate the knee-jerk reflex.	Page 69 Step 4
• Give each student one copy of Master 3.2, *Pathway-Building Worksheet.* • Divide the class into groups of two or three and send groups to computer stations. • Direct students to the activity's Web site. o Instruct students to listen to the audio introduction to the activity. o Have students click on the link for the "Neuroscience Reference Manual" and review its use with them. o Explain to students how to place and remove body parts and neurons.	Pages 69–71 Steps 5–11
• Instruct groups to complete the reflex pathway using only those parts involved directly in the pathway. • After completing the pathway, ask students to answer the questions on Master 3.2, *Pathway-Building Worksheet.*	Pages 71–72 Steps 12–14
Reconvene the class. Discuss the following: • Were groups able to construct a pathway that worked? • What types of pathways did not work? Why?	Pages 72–73 Step 15
Activity 2: *Inside Information, Part 2: A Voluntary Response Pathway*	
Instruct students to go to their computers and have them click on the link to this activity.	Page 73 Step 1
• Explain to students that they are to construct a neural pathway for the voluntary leg movement involved in kicking a soccer ball. • After completing the pathway, ask students to answer the questions on Master 3.2, *Pathway-Building Worksheet.*	Pages 73–75 Steps 2–4
Reconvene the class. Discuss the following: • Were groups able to construct a pathway that worked? • What types of pathways did not work? Why?	Pages 75–76 Step 5

M = Involves copying a master.

www = Involves using the Internet.

Activity 3: *Summing It Up*

Ask students, "If a physician tested the knee-jerk reflex on each of us, would everyone's response be the same?"	Page 82 Step 1
Ask students to imagine that they are playing soccer. • The ball is heading directly for them. • Ask them what they would do.	Page 82 Step 2
Point out that students provided a variety of responses for the soccer ball scenario, as opposed to their having the same response for the knee-jerk reflex. Ask, "Why were you able to have different responses for the soccer ball scenario?"	Page 82 Step 3
Ask students why they were not able to choose the response to the reflex action. What is the difference between the two pathways?	Page 82 Step 4

Lesson 3 Organizer: Print Version

Activity 1: *Information Flow*

What the Teacher Does	Procedure Reference
Display a transparency of Master 3.1, *Two Types of Cells*. • Ask students to make observations about the two cells. • Explain that the top cell is a common type of animal cell. • Explain that the bottom cell is a nerve cell, or neuron, and that it passes information through the body.	Page 67 Steps 1–2 T
Ask students to stand and form a line around the classroom. • Explain that they will model the flow of information through a neural pathway. • Ask students to hold out their arms, forming a fist with their right hand and leaving their left hand open.	Pages 67–68 Steps 3–4
Tell students they will be passing information through their model pathway by using their open hand to tap the fist of the person next to them.	Page 68 Step 5
Ask a student in the middle of the line to face the opposite direction from the rest of the line, leaving the same hands open and fisted. • Start the flow of information by tapping the fist of the rightmost student in the line. • Ask students what happens to the signal. • Ask students what this model suggests about information flow through neurons.	Page 68 Steps 6–7

Activity 2: *Inside Information, Part 1: A Reflex Pathway*

Ask students • to explain the difference between a voluntary response and an involuntary response and • to provide examples of voluntary and involuntary responses.	Page 76 Steps 1–2

M = Involves copying a master.

T = Involves using a transparency.

Tell students they will investigate an involuntary response known as a reflex action. • Ask, "What is a reflex action?" • Ask for student volunteers to demonstrate the knee-jerk reflex.	Pages 76–77 Steps 3–4
Divide the class into groups of two or three. • Give each group a copy of Master 3.3(a, b, and c), *Neuroscience Reference Manual*, and a copy of Master 3.4, *Building a Reflex Pathway*. • Explain the use of these masters. • Give each group three different colored pencils.	Page 77 Steps 5–8 M
Ask groups to construct their reflex pathway, focusing on • why they chose the parts they did, • how those parts were put together, and • how information flows through the pathway.	Page 78 Step 9
Ask one group to diagram their pathway on a transparency of Master 3.4, *Building a Reflex Pathway.*	Pages 78–79 Step 10 T
Ask the other groups if they agree with the work of this group. If any groups disagree, ask them to present their pathway and explanation.	Page 79 Step 11
Activity 2: *Inside Information, Part 2: A Voluntary Response Pathway*	
Give each group a copy of Master 3.5, *Building a Voluntary Response Pathway.* Groups should still have their copy of Master 3.3(a, b, and c), *Neuroscience Reference Manual.*	Pages 79–80 Steps 1–2 M
Ask groups to construct their voluntary response pathway, focusing on • why they chose the parts they did, • how those parts were put together, and • how information flows through the pathway.	Page 80 Step 3
Ask one group to diagram their pathway on a transparency of Master 3.5, *Building a Voluntary Response Pathway*.	Pages 80–81 Step 4
Ask the other groups if they agree with the work of this group. If any groups disagree, ask them to present their pathway and explanation.	Page 81 Step 5

Activity 3: *Summing It Up*

Ask students, "If a physician tested the knee-jerk reflex on each of us, would everyone's response be the same?"	Page 82 Step 1
Ask students to imagine that they are playing soccer. • The ball is heading directly for them. • Ask them what they would do.	Page 82 Step 2
Point out that students provided a variety of responses for the soccer ball scenario, as opposed to their having the same response for the knee-jerk reflex. Ask, "Why were you able to have different responses for the soccer ball scenario?"	Page 82 Step 3
Ask students why they were not able to choose the response to the reflex action. What is the difference between the two pathways?	Page 82 Step 4

Lesson 4
Elaborate

Outside Influence

At a Glance

Overview

In this lesson, students investigate factors that affect the important brain function of learning. In the first activity, students analyze the impact of social interaction on learning in mice. In the second activity, students design an experiment to test the impact of an enriched environment and/or exercise on learning in mice. Students analyze and share the results of their experiments with the class. In the third activity, students consider the validity of extending their conclusions from mouse experiments to humans.

Major Concepts

Learning is an important brain function. There are factors that affect learning. Laboratory animals can serve as experimental models for investigating learning. The ability of the brain to learn is not fixed.

Objectives

After completing this lesson, students will be able to

- describe some factors that affect learning;
- conduct a scientific investigation to generate hypotheses, design experiments, analyze results, and draw conclusions;
- derive the implications of results from mouse experiments to understandings about human learning; and
- recognize that the ability of the brain to learn is not fixed; it can change over time.

Teacher Background

Refer to the following sections in Information about the Brain:

7 Plasticity and Learning *(pages 36–37)*

   7.1 The changing brain *(page 36)*

   7.2 Learning and memory *(pages 36–37)*

In Advance

Web-Based Activities

Activity	Web Version?
1	Yes
2	Yes
3	No

Photocopies

Activity 1	**Web Version** • Master 4.1, *Memo from the Director*, 1 transparency • Master 4.2, *Morris Water Maze Data, Research Question 1 (Web Version)*, 1 copy per team • Master 4.3, *Morris Water Maze Results*, 1 copy per team, or use own graph paper • Master 4.4, *Memo to the Director on Research Question 1*, 1 copy per team **Print Version** • Master 4.1, *Memo from the Director*, 1 transparency • Master 4.3, *Morris Water Maze Results*, 1 copy per team, or use own graph paper • Master 4.4, *Memo to the Director on Research Question 1*, 1 copy per team • Master 4.5(a, b, c), *Scientific Research Reference Manual*, 1 copy per team • Master 4.6, *Memo from Lab Technician*, 1 transparency • Master 4.7, *Morris Water Maze Data, Research Question 1 (Print Version)*, 1 transparency
Activity 2	**Web Version** • Master 4.3, *Morris Water Maze Results*, 1 copy per team plus 1 transparency • Master 4.8, *Morris Water Maze Data, Research Questions 2 and 3 (Web Version)*, 1 copy per team • Master 4.9, *Memo to the Director on Research Question 2*, 1 copy for half of teams • Master 4.10, *Memo to the Director on Research Question 3*, 1 copy for half of teams • Master 4.11, *Summary of Research Findings*, 1 transparency

Activity 2 (continued)	**Print Version** • Master 4.3, *Morris Water Maze Results*, 1 copy per team plus 1 transparency • Master 4.9, *Memo to the Director on Research Question 2*, 1 copy for half of teams • Master 4.10, *Memo to the Director on Research Question 3*, 1 copy for half of teams • Master 4.11, *Summary of Research Findings*, 1 transparency • Master 4.12, *Next Research Assignment*, 1 transparency • Master 4.13, *Experimental Design*, 1 copy per team • Master 4.14, *Morris Water Maze Data, Research Questions 2 and 3 (Print Version)*, 1 transparency
Activity 3	Master 4.15, *Neuron Structure Data*, 1 transparency

Materials

Activity 1	**Web Version** • Overhead projector and screen • Computers with Internet access **Print Version** Overhead projector and screen
Activity 2	**Web Version** • 4 colors of transparency pens • Overhead projector and screen • Computers with Internet access **Print Version** • 4 colors of transparency pens • Overhead projector and screen
Activity 3	Overhead projector and screen

Preparation

Activity 1, Web Version

Verify that the computer lab is reserved for your classes or that classroom computers are ready to use. Go to the Web page *http://science.education.nih.gov/supplements/self/student* and click on "Lesson 4—Outside Influence." This brings up the unit's desktop. Students then click on the link to "Outside Influence, Activity 1: Effects of Social Interaction on Learning." Work through the lesson on the Web to familiarize yourself with the activity.

Set up overhead projector and screen.

Activity 1, Print Version

Set up overhead projector and screen.

Activity 2, Web Version
Verify that the computer lab is reserved for your classes or that classroom computers are ready to use. Go to the Web page *http://science.education.nih.gov/supplements/self/student* and click on "Lesson 4—Outside Influence." This brings up the unit's desktop. Students then click on the link to "Outside Influence, Activity 2: Effects of Enrichment and Exercise on Learning." Work through the lesson on the Web to familiarize yourself with the activity.

Set up overhead projector and screen.

Plot the averaged data from all four sets of mice in Master 4.8, *Morris Water Maze Data, Research Questions 2 and 3 (Web Version)*, on one transparency of Master 4.3, *Morris Water Maze Results*. Use different colors of transparency pens for each set of mice, and fill in the legend as you go.

Activity 2, Print Version
Set up overhead projector and screen.

Plot the averaged data from all four sets of mice in Master 4.14, *Morris Water Maze Data, Research Questions 2 and 3 (Print Version)*, on one transparency of Master 4.3, *Morris Water Maze Results*. Use different colors of transparency pens for each set of mice, and fill in the legend as you go.

Activity 3
Set up overhead projector and screen.

Procedure

Content Standard A: Science as Inquiry. All activities in this lesson emphasize "Abilities necessary to do scientific inquiry" (identify questions and concepts that guide scientific investigations; design and conduct a scientific investigation; use appropriate tools

Teacher note: The data provided in this lesson are based on data from several original research papers. The Morris Water Maze data for each set of mice were normalized, or adjusted, to an initial time of 50 seconds for Day 1. Normalizing the data eases the interpretation of results by students while providing an acceptable data set for conveying the concepts of this lesson.

Activity 1: *Effect of Social Interaction on Learning*

For classrooms using the *Web-based version* **of this activity:**

Teacher note: This activity uses a simulation on the Web. It will save time to have the computers online and at the correct URL: *http://science.education.nih.gov/supplements/self/student*. Students should click on "Lesson 4—Outside Influence." This brings up the unit's desktop. Students then click on the link to "Outside Influence, Activity 1: Effects of Social Interaction on Learning."

1. **Begin by asking students, "What is learning?"**

   Many responses are possible. Students will probably respond that learning is the way they know things. This answer is acceptable at this time.

2. **Continue by asking, "Where does learning occur?"**

   Students should recognize that learning occurs in the brain.

3. **Ask the class, "What affects learning?"**

   Student responses will vary and may include such factors as the size of the brain, the food we eat, and whether we practice. Record all responses on the board. These responses provide an opportunity for informal assessment of students' understanding. In the discussion at the end of the lesson, students will recognize they have evidence that practice affects learning.

4. **Ask students, "How can scientists determine whether these factors affect learning?"**

   Remind students that to conclude whether a factor can affect learning, scientists need evidence obtained through observation and experimentation. Their conclusions must be verified by repeated tests. Explain to students that for the rest of the lesson, they will explore the effects of several factors on learning in mice by designing and analyzing their own experiments.

5. **Organize students into pairs. Number pairs sequentially beginning with 1. Explain that the pairs are research teams at the Learning Research Laboratory.**

6. **Display a transparency made from Master 4.1, *Memo from the Director*. Ask students to follow along as you read the memo to the class.**

   The memo from the director describes a research grant given to the fictitious Learning Research Laboratory. Students play the role of research scientists who design and analyze experiments to answer three research questions. Students investigate Research Question 1 in Activity 1 and Research Questions 2 and 3 in Activity 2.

7. **Direct student attention to Research Question 1 from the director's memo (*Does social interaction affect learning in mice?*). Ask students to raise their hands if they think social interaction has an effect on learning.**

and techniques to gather, analyze, and interpret data; develop descriptions, explanations, predictions, and models using evidence; and communicate scientific procedures and explanations) and "Understandings about scientific inquiry" (scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories; and asking questions and querying other scientists' explanations is part of scientific inquiry).

Students may disagree about the effect of social interaction on learning. This is acceptable; it is unlikely that students have any knowledge on which to base their opinion. This question is meant to stimulate thinking about Research Question 1 and serves as a lead-in to, "Let's investigate."

8. **Direct student teams to computer stations. Ask them to click on the link to "Outside Influence, Activity 1: Effects of Social Interaction on Learning."**

   Clicking on this link brings up an e-mail message from the laboratory technician. Walking the class through the Web site (Steps 8 through 11) provides an opportunity for you to explain how to navigate through the activity.

9. **Tell students to read the e-mail message from the laboratory technician.**

   The technician has set up an experiment to investigate Research Question 1 (*Does social interaction affect learning in mice?*). The e-mail message explains that the research teams will find a description of the experimental setup in the online Lab Notebook. Students will run the experiment and analyze the results.

10. **Tell students to click the "Lab Notebook" button. Review briefly the contents of the Experimental Design page that appears.**

    This page shows the research question, hypothesis, experimental procedure followed, and the mice used for Experiment 1. This page is the model for the experiments students will design in Activity 2.

    Tip from the field test: After students have had a chance to read through the memo, spend some time discussing the hypothesis. Distinguish the hypothesis from the research question. First, note that the hypothesis is a statement, not a question. Second, the hypothesis predicts a specific answer to the research question. The prediction is based on what the researcher already knows about the situation. Third, and most important, the hypothesis is testable; that is, it suggests a way to test whether the prediction is accurate. In this example, the hypothesis (*Socialized mice learn more quickly than isolated mice*) suggests that researchers test and compare learning in socialized mice with learning in isolated mice.

11. **Direct students to click the icon for the Scientific Research Reference Manual on the screen that appears, and review the Table of Contents with them.**

    Emphasize that consulting the reference manual will help students complete the activity more quickly and accurately. It provides information about laboratory mice, the Morris Water Maze, and, even more important for students' work in this lesson, advice for writing hypotheses, designing experiments, analyzing data, interpreting results, and drawing conclusions.

Tip from the field test: Introducing the reference manual before students start working emphasizes the importance of this resource and encourages students to use this information to help them complete the activity.

12. **Give to each team one copy each of Master 4.2, *Morris Water Maze Data, Research Question 1 (Web Version)*, Master 4.3, *Morris Water Maze Results* (or have students use their own graph paper), and Master 4.4, *Memo to the Director on Research Question 1*. Direct teams to**
    - **run the experiment and collect data for each mouse on Master 4.2,**
    - **average the data for each set of mice on Master 4.2,**
    - **construct a line graph of the data averages on Master 4.3 or their own graph paper, and**
    - **fill in the blanks on Master 4.4, *Memo to the Director*.**

Encourage teams to use the Scientific Research Reference Manual as a guide as they work through their investigation.

Students run three trials for each set of mice; each trial represents a different day. The Morris Water Maze data, appearing in a "timer" to the RIGHT of each swim tank, represents the time it takes for each mouse to reach the hidden platform in the Morris Water Maze. Students should record the data in the appropriate boxes of Master 4.2, *Morris Water Maze Data, Research Question 1 (Web Version)*. Students should then calculate the average time it took each set of mice to reach the platform each day. You may want to ask students to round their answers to the nearest whole number. Students should enter their results in the appropriate sections of the Morris Water Maze data tables on Master 4.2.

Next, students should plot the averages as line graphs on Master 4.3 or their own graph paper. The averages for the Isolated mice and the Socialized mice should be plotted on the same graph, using different colors, symbols, or types of lines (unbroken and dashed, for instance) to distinguish data from the two sets of mice. Students should title their graph and create a legend by identifying which line corresponds to each data set.

Allow about 25 minutes for students to calculate averages, create graphs, and complete the memo to the director.

Assessment:
Listening to student presentations allows you to assess students' abilities to analyze data, create graphs, and draw conclusions. You can collect students' completed Masters 4.3 and 4.4 for a more formal assessment.

13. **Reconvene the class. Ask different student teams to share their graphs, their answers to the questions on the memo, and their conclusion(s) about learning.**

    Encourage teams to challenge the graphs, answers, and conclusions of their classmates, based on the results of the experiment. Students should interpret a decrease in times to platform on the Morris Water Maze test to mean that learning occurred. Since all mice decreased their times to platform over the three days of the experiment, all of the mice learned. However, the mice raised in social conditions learned more rapidly than the mice raised in isolated conditions. Thus, students should conclude that the data support the hypothesis: *Socialized mice learn more quickly than isolated mice*.

For classrooms using the *print version* of this activity:

1. **Begin by asking students, "What is learning?"**

   Many responses are possible. Students will probably respond that learning is the way they know things. This answer is acceptable at this time.

2. **Continue by asking, "Where does learning occur?"**

   Students should recognize that learning occurs in the brain.

3. **Ask the class, "What affects learning?"**

   Student responses will vary and may include such factors as the size of the brain, the food we eat, and whether we practice. Record all responses on the board. These responses provide an opportunity for informal assessment of students' understanding. In the discussion at the end of the lesson, students will recognize they have evidence that practice affects learning.

4. **Ask students, "How can scientists determine whether these factors affect learning?"**

   Remind students that to conclude that a factor can affect learning, scientists need evidence obtained through observation and experimentation. Their conclusions must be verified by repeated tests. Explain to students that for the rest of the lesson, they will explore the effect of several factors on learning in mice by designing and analyzing their own experiments.

5. **Organize students into pairs. Number pairs sequentially beginning with 1. Explain that the pairs are research teams at the Learning Research Laboratory.**

6. **Display a transparency of Master 4.1, *Memo from the Director*. Ask students to follow along as you read the memo to the class.**

   The memo from the director describes a research grant given to the fictitious Learning Research Laboratory. Students play the role of research scientists who design and analyze experiments to answer three research questions. Students investigate Research Question 1 in Activity 1 and Research Questions 2 and 3 in Activity 2.

7. **Direct student attention to Research Question 1 from the director's memo (*Does social interaction affect learning in mice?*). Ask students to raise their hands if they think social interaction has an effect on learning.**

   Students may disagree about the effect of social interaction on learning. This is acceptable; it is unlikely that students have any knowledge on which to base their opinion. This question is meant to stimulate student thinking about Research Question 1 and serves as a lead-in to, "Let's investigate."

8. **Give each team a copy of Master 4.5(a, b, c), *Scientific Research Reference Manual*.**

   Explain that the reference manual contains essential information for conducting research on learning. Point out several sections of the manual that are important for the students' investigations, such as the sections on the Morris Water Maze (the test of learning used in the experiment), raising mice, writing hypotheses, and drawing conclusions.

   Tip from the field test: Introducing the reference manual before students start working emphasizes the importance of this resource and encourages students to use this information to help them complete the activity.

9. **Tell students that a lab technician has completed an experiment to answer Research Question 1. Display a transparency of Master 4.6, *Memo from Lab Technician*. Ask students to follow along as you read the memo out loud.**

   The memo includes a model of the experimental design page students will use in Activity 2.

   Tip from the field test: After reading through the memo, spend some time discussing the hypothesis. Distinguish the hypothesis from the research question. First, note that the hypothesis is a statement, not a question. Second, the hypothesis predicts a specific answer to the research question. The prediction is based on what the researcher already knows about the situation. Third, and most important, the hypothesis is testable; that is, it suggests a way to test whether the prediction is accurate. In this example, the hypothesis (*Socialized mice learn more quickly than isolated mice*) suggests that researchers test and compare learning in socialized mice with learning in isolated mice.

10. **Display a transparency of Master 4.7, *Morris Water Maze Data, Research Question 1 (Print Version)*. Give each team one copy each of Master 4.3, *Morris Water Maze Results* (or have students use their own graph paper), and Master 4.4, *Memo to the Director on Research Question 1*. Direct teams to**
    - **average the data provided on Master 4.7 for each set of mice,**
    - **construct a line graph using the data averages (on Master 4.3 or their own graph paper), and**
    - **fill in the blanks on Master 4.4.**

    Encourage teams to use the Scientific Research Reference Manual as a guide as they work through their investigation.

    The data on Master 4.7 represent the time it took for each mouse to reach the hidden platform in the swim tank of the Morris Water Maze. Students should calculate the average time it took each set of mice to reach the platform each day. You may want to ask students to round their answers to the nearest whole number.

    Students should plot their averaged data as line graphs on Master 4.3 or their own graph paper. The averages for the Isolated mice and the Socialized mice should be plotted on the same graph, using different colors, symbols, or types of lines (unbroken and dashed, for instance) to distinguish data from the two sets of mice. Students should title their graph and create a legend by identifying which line corresponds to each data set.

    Allow about 25 minutes for students to calculate averages, create graphs, and complete the memo to the director.

Assessment:
Listening to student presentations allows you to assess students' abilities to analyze data, create graphs, and draw conclusions. You can collect students' completed Masters 4.3 and 4.4 for a more formal assessment.

11. **Reconvene the class. Ask different student teams to share their graphs, their answers to the questions on the memo, and their conclusion(s) about learning.**

    Encourage teams to challenge the graphs, answers, and conclusions of their classmates based on the results of the experiment. Students should interpret a decrease in times to platform on the Morris Water Maze test to mean that learning occurred. Since all mice decreased their times to platform over the three days of the experiment, all the mice learned. However, the mice raised in social conditions learned more rapidly than the mice raised in isolated conditions. Therefore, students should conclude that the data support the hypothesis: *Socialized mice learn more quickly than isolated mice.*

Activity 2: *Effects of Enrichment and Exercise on Learning*

For classrooms using the *Web-based version* of this activity:

1. **Organize students into their research teams from Activity 1.**

2. **Direct student teams to computer stations. Ask them to click on "Outside Influence, Activity 2: Effects of Enrichment and Exercise on Learning" on the unit's desktop.**

3. **Tell students to read the e-mail message from the director.**

   The e-mail message from the director assigns even-numbered teams to conduct an experiment to answer Research Question 2 (*Does an enriched environment affect learning in mice?*) and odd-numbered teams to conduct an experiment to answer Research Question 3 (*Does exercise affect learning in mice?*).

4. **Tell students to click on their team's assigned research question within the director's e-mail. Review briefly the contents of the Experimental Design page that appears.**

   The Experimental Design page displays either Research Question 2 or Research Question 3 (based on the links students followed from the director's e-mail) and a box in which they can type a hypothesis. Instructions for the student are at the bottom of the page.

5. **Instruct teams to write a hypothesis for their research question, then click on the "Animal Care Laboratory" icon to select mice for their experiment.**

   Student teams may ask for assistance in writing their hypothesis. Remind students that the reference manual provides advice for developing a hypothesis. Also remind them of the discussion about hypotheses in Activity 1. Hypotheses are statements that predict a specific answer to the research question. In addition, hypotheses are testable; that is, a hypothesis suggests a way to test whether the prediction is accurate.

   Examples of hypotheses for Research Question 2 (*Does an enriched environment affect learning in mice?*) include *Enriched-cage mice learn faster than standard-cage mice* and *Mice in standard cages with* *running wheels learn faster than mice in enriched cages with running wheels.* Encourage students to develop specific hypotheses that predict a result they can test through their experiments.

Examples of hypotheses for Research Question 3 (*Does exercise affect learning in mice?*) include *Mice who exercise learn faster than mice who do not exercise* and *Mice in standard cages with running wheels learn faster than mice in standard cages without running wheels.* Encourage students to develop specific hypotheses that predict a result they can test through their experiments.

6. **At the Animal Care Laboratory, instruct student teams to select two sets of mice to use in testing their hypothesis.**

Remind students that the reference manual provides advice for selecting appropriate research subjects. Four sets of mice (Standard Cage, Standard Cage with Running Wheel, Enriched Cage, and Enriched Cage with Running Wheel) are available to students, and they may select any two sets for their experiment. Students should select the two sets they believe to be appropriate for testing their hypothesis.

Two combinations of mouse data sets can be used to test hypotheses for **Research Question 2**. Students may either

- compare data from Standard Cage mice with data from Enriched Cage mice or
- compare data from Standard Cage with Running Wheel mice with data from Enriched Cage with Running Wheel mice.

Either of these combinations will allow students to evaluate enrichment as the only variable.

Two combinations of mouse data sets can be used to test hypotheses for **Research Question 3**. Students may either

- compare data from Standard Cage mice with data from Standard Cage with Running Wheel mice or
- compare data from Enriched Cage mice with data from Enriched Cage with Running Wheel mice.

Either of these combinations will allow students to evaluate exercise as the only variable.

Assessment: Circulate among student groups. Ask questions to assess students' understanding of control and experimental groups and their ability to select two appropriate conditions to test their hypotheses.

7. **Tell students to click on the "To Experimental Design Page" button when they have finished selecting the sets of mice they will use. After confirming the experiment they have designed, students should click the "Run Experiment" button and proceed with collecting their data as they did in Activity 1.**

The Experimental Design page summarizes the students' experiment. It looks the same as in Activity 1, but with the appropriate research question. The program will automatically display the hypothesis students wrote and the sets of mice they selected.

Clicking the "Run Experiment" button takes students to a page with the Morris Water Maze setup, as in Activity 1. Students can return to the Animal Care Laboratory from this page if they decide they need to select a different pair of mouse sets to use in testing their hypothesis.

8. **Give each team a copy of Master 4.8, *Morris Water Maze Data, Research Questions 2 and 3 (Web Version)*, and a new copy of Master 4.3, *Morris Water Maze Results*. Direct teams to**
   - **run the experiment and collect data for the sets of mice they selected for their experiment on Master 4.8,**
   - **average the data for each of their chosen sets of mice on Master 4.8, and**
   - **construct a line graph of their data averages on Master 4.3 or their own graph paper.**

Encourage teams to use the reference manual as a guide as they work through their investigation.

Students run three trials for each set of mice; trials represent three consecutive days of testing. The Morris Water Maze data, appearing in a "timer" to the RIGHT of each swim tank, represents the time it takes for each mouse to reach the hidden platform in the Morris Water Maze. Students should record the data in the appropriate boxes of Master 4.8, *Morris Water Maze Data, Research Questions 2 and 3 (Web Version)*. Students should then calculate the average time it took each set of mice to reach the platform each day. You may want to ask students to round their answers to the nearest whole number. Students should enter their results in the appropriate sections of the Morris Water Maze data tables on Master 4.8.

Next, students should plot the averages as line graphs on Master 4.3. The averages for both sets of mice should be plotted on the same graph, using different colors, symbols, or types of lines (unbroken and dashed, for instance) to distinguish data from the two sets of mice. Students should title their graph and create a legend by identifying which line corresponds to each data set.

9. **While teams prepare their graphs, give each even-numbered team a copy of Master 4.9, *Memo to the Director on Research Question 2*, and each odd-numbered team a copy of Master 4.10, *Memo to the Director on Research Question 3*. Ask teams to complete the memos using the results of their experiment.**

Move among the teams during this time, answering questions and making suggestions as necessary. Point out that the reference manual provides guidance for analyzing data and drawing conclusions from graphs. Allow about 25 minutes for students to calculate averages, create graphs, and complete the memo to the director.

10. **When students have completed their data tables, graphs, and memos, pair odd- and even-numbered teams and tell them to share their results with each other. Encourage teams to challenge their partner team's conclusions if those conclusions are not supported by the data.**

11. **Reconvene the class and display Master 4.11, *Summary of Research Findings*. Ask students to summarize their conclusions about learning from the three experiments by providing evidence-based answers to the three research questions.**

    Use this as an opportunity to assess student understanding of experimental results.

    For **Research Question 1**, students should explain that the data from the experiment indicate that mice from a social environment learn more quickly than do mice from an isolated environment. Therefore, the data support the hypothesis that *Socialized mice learn more quickly than isolated mice*.

    For **Research Question 2**, the data gave mixed results. Teams that compared Standard Cage mice with Enriched Cage mice found that on Day 2, Standard Cage mice appear to be learning more quickly than Enriched Cage mice. By Day 3, Enriched Cage mice appear to be learning more quickly than Standard Cage mice. Teams that compared Standard Cage with Running Wheel mice with Enriched Cage with Running Wheel mice found that the Standard Cage with Running Wheel mice outperformed the Enriched Cage with Running Wheel mice on both Day 2 and Day 3. Encourage students to identify whether their team's data support or do not support the team hypothesis.

    For **Research Question 3**, students should explain that the data from the experiment indicate that mice from a cage with a running wheel learn more quickly than do mice from a cage without a running wheel. Encourage students to identify whether these data support or do not support their team's hypothesis.

12. **Display the transparency of Master 4.3, *Morris Water Maze Results*, you have prepared with averaged results from all four sets of mice plotted on one graph. Ask students to interpret their results in the context of data from all four sets of mice.**

Assessment:
Listening to student presentations allows you to assess students' abilities to analyze data, create graphs, and draw conclusions. You can collect students' completed memos and graphs for a more formal assessment.

For ease of student interpretation of results, clearly label each line of the graph and use different colors for each line. You may need to ask guiding questions, such as, "How does the performance of mice from an enriched cage compare with that of mice from a cage with a running wheel?" or "Does having a running wheel improve the performance of mice raised in an enriched cage?"

Students should notice that mice from a standard cage with a running wheel learn more quickly than mice from either an enriched cage or an enriched cage with a running wheel. These results are somewhat unexpected, since it might seem that the stimulation of an enriched environment would do more to improve learning ability than wheel running would. In addition, it may seem strange that mice in a standard cage with a running wheel would perform better than mice in an enriched cage with a running wheel, since there is less stimulation available for the mice in the standard cage.

13. **Ask students to propose explanations for these findings. How would they test their explanations?**

Student explanations will vary; any reasonable explanation is acceptable. Some possible explanations include that the mice were distracted by the enriched environment instead of stimulated by it; playing in the enriched cage kept mice from learning; since socialized mice learned better than isolated mice, perhaps wheel running is more of a social than an enrichment activity for mice.

The important point here is that students recognize that their explanations must be tested through additional experimentation to determine whether they are valid. Students may suggest experiments to test their explanations. Make sure students understand that their new experiments must have appropriate cage conditions and controls. For instance, if a student suggests that wheel-running mice learned better because wheel running is a more social activity than is enrichment, they might test this by comparing isolated mice in cages with running wheels with isolated mice in enriched cages.

Teacher note: Your students may feel that after analyzing their data, they ended up with more questions than answers. You may find this an appropriate time to talk to your students about the nature of scientific inquiry. Help students understand that science is an ongoing process. Remind students that experimental results present scientists with new questions, explanations, and experiments. New explanations refine or replace old ones, and experimental results lead to new questions that must be tested through new experiments. Scientific knowledge is constantly evolving through the critical examination of new ideas and results.

For classrooms using the *print version* of this activity:

1. **Organize students into their research teams from Activity 1. Display a transparency of Master 4.12, *Next Research Assignment*. Read this memo to the class.**

   Master 4.12 is a memo from the director assigning even-numbered teams to conduct an experiment to answer Research Question 2 (*Does an enriched environment affect learning in mice?*) and odd-numbered teams to conduct an experiment to answer Research Question 3 (*Does exercise affect learning in mice?*).

2. **Give each team a copy of Master 4.13, *Experimental Design*. Make sure each team has a copy of Master 4.5(a, b, c), *Scientific Research Reference Manual*.**

3. **Instruct teams to complete Master 4.13 by writing their research question, writing a hypothesis, and selecting two sets of mice that are appropriate for testing their hypothesis.**

   Remind students that the reference manual provides advice for developing a hypothesis and selecting research subjects. Also remind them of the discussion about hypotheses in Activity 1. Hypotheses are statements that predict an answer to the research question. In addition, hypotheses are testable; that is, the statement of a hypothesis suggests a way to test whether the prediction is accurate.

   Four sets of mice (Standard Cage, Standard Cage with Running Wheel, Enriched Cage, and Enriched Cage with Running Wheel) are available to students. Students should select the two sets they believe to be appropriate for testing their hypothesis.

   Examples of hypotheses for **Research Question 2** (*Does an enriched environment affect learning in mice?*) include *Enriched cage mice learn faster than standard cage mice* and *Mice in standard cages with running wheels learn faster than mice in enriched cages with running wheels*. Encourage students to develop specific hypotheses that predict a result they can test through their experiments.

   Two combinations of mouse data sets can be used to test hypotheses for **Research Question 2**. Students may either
   - compare data from Standard Cage mice with data from Enriched Cage mice or
   - compare data from Standard Cage with Running Wheel mice with data from Enriched Cage with Running Wheel mice.

   Either of these combinations will allow students to evaluate enrichment as the only variable.

Assessment:
Circulate among student groups. Ask questions to assess students' understanding of control and experimental groups and their ability to select two appropriate conditions to test their hypotheses.

Examples of hypotheses for **Research Question 3** (*Does exercise affect learning in mice?*) include *Mice who exercise learn faster than mice who do not exercise* and *Mice in standard cages with running wheels learn faster than mice in standard cages without running wheels*. Encourage students to develop specific hypotheses that predict a result they can test through their experiments.

Two combinations of mouse data sets can be used to test hypotheses for Research Question 3. Students may either

- compare data from Standard Cage mice with data from Standard Cage with Running Wheel mice or
- compare data from Enriched Cage mice with data from Enriched Cage with Running Wheel mice.

Either of these combinations will allow students to evaluate exercise as the only variable.

4. **Display a transparency of Master 4.14, *Morris Water Maze Data, Research Questions 2 and 3 (Print Version),* which contains data for all four sets of mice.**

   Instruct students to average the data for the two sets of mice they chose on Master 4.13, *Experimental Design*. You may want to ask students to round their answers to the nearest whole number.

5. **Give each team a new copy of Master 4.3, *Morris Water Maze Results*, or ask students to take out a new sheet of graph paper. Ask teams to graph their averaged data following the same procedure as they did in Activity 1.**

   Students should plot the averages as line graphs on Master 4.3 or their own graph paper. The averages for both sets of mice should be plotted on the same graph, using different colors, symbols, or types of lines (unbroken and dashed, for instance) to distinguish data from the two sets of mice. Students should title their graph and create a legend by identifying which line corresponds to each data set.

6. **While teams prepare their graphs, give each even-numbered team a copy of Master 4.9, *Memo to the Director on Research Question 2*, and each odd-numbered team a copy of Master 4.10, *Memo to the Director on Research Question 3*. Ask teams to complete the memos by using the results of their experiment.**

   Move among the teams during this time, answering questions and making suggestions as necessary. Point out that the reference manual provides guidance for analyzing data and drawing conclusions from graphs. Allow about 25 minutes for students to calculate averages, create graphs, and complete the memo to the director.

7. **When students have completed their data tables, graphs, and memos, pair odd- and even-numbered teams and tell them to share their results with each other. Encourage teams to challenge their partner team's conclusions if those conclusions are not supported by the data.**

8. **Reconvene the class and display Master 4.11,** ***Summary of Research Findings*****. Ask students to summarize their conclusions about learning from the three experiments by providing evidence-based answers to the three research questions.**

   Use this as an opportunity to assess student understanding of experimental results.

   For **Research Question 1**, students should explain that the data from the experiment indicate that mice from a social environment learn more quickly than do mice from an isolated environment. Thus, the data support the hypothesis: *Socialized mice learn more quickly than isolated mice.*

   For **Research Question 2**, the data gave mixed results. Teams that compared Standard Cage mice with Enriched Cage mice found that on Day 2, Standard Cage mice appear to be learning more quickly than Enriched Cage mice. By Day 3, Enriched Cage mice appear to be learning more quickly than Standard Cage mice. Teams that compared Standard Cage with Running Wheel mice with Enriched Cage with Running Wheel mice found that the Standard Cage with Running Wheel mice outperformed the Enriched Cage with Running Wheel mice on both Day 2 and Day 3. Encourage students to identify whether their team's data support or do not support the team hypothesis.

   For **Research Question 3**, students should explain that the data from the experiment indicate that mice from a cage with a running wheel learn more quickly than do mice from a cage without a running wheel. Encourage students to identify whether these data support or do not support their team's hypothesis.

Assessment:
Listening to student presentations allows you to assess students' abilities to analyze data, create graphs, and draw conclusions. You can collect students' completed memos and graphs for a more formal assessment.

9. **Display the transparency of Master 4.3,** ***Morris Water Maze Results*****, that you prepared with averaged results from all four sets of mice plotted on one graph. Ask students to interpret their results in the context of data from all four sets of mice.**

   For ease of student interpretation of results, clearly label each line of the graph and use different colors for each line. You may need to ask guiding questions, such as, "How does the performance of mice from an enriched cage compare with that of mice from a cage with a running wheel?" or "Does having a running wheel improve the performance of mice raised in an enriched cage?"

Students should notice that mice from a standard cage with a running wheel learn more quickly than mice from either an enriched cage or an enriched cage with a running wheel. These results are somewhat unexpected, since it might seem that the stimulation of an enriched environment would do more to improve learning ability than wheel running would. In addition, it may seem strange that mice in a standard cage with a running wheel would perform better than mice in an enriched cage with a running wheel, since there seems to be less stimulation for the mice in the standard cage.

10. **Ask students to propose explanations for these findings. How would they test their explanations?**

    Student explanations will vary; any reasonable explanation is acceptable. Some possible explanations include that the mice were distracted by the enriched environment instead of stimulated by it; playing in the enriched cage kept mice from learning; since socialized mice learned better than isolated mice, perhaps wheel running is more of a social than an enrichment activity for mice.

    The important point is that students recognize that their explanations must be tested through additional experimentation to determine whether they are valid. Students may suggest experiments to test their explanations. Make sure students understand that their new experiments must have appropriate cage conditions and controls. For instance, if a student suggests that wheel-running mice learned better because wheel running is a more social activity for mice than is enrichment, they might test this by comparing isolated mice in cages with running wheels with isolated mice in enriched cages.

Teacher note: Your students may feel that after analyzing their data, they ended up with more questions than answers. You may find this an appropriate time to talk to your students about the nature of scientific inquiry. Help students understand that science is an ongoing process. Remind students that experimental results present scientists with new questions, explanations, and experiments. New explanations refine or replace old ones, and experimental results lead to new questions that must be tested through new experiments. Scientific knowledge is constantly evolving through the critical examination of new ideas and results.

Activity 3: *A Human Perspective (for Print and Web)*

Teacher note: Ethical treatment is a concern for animal subjects as well as for human subjects. However, try to avoid emotional issues by pointing out that scientists who use laboratory animals comply with stringent guidelines for humane treatment of the animals. Where necessary, focus discussion on the limitations of using human subjects and the advantages and limitations of animal models.

Tip from the field test: After completing the mouse experiments, students often wonder or ask, "What does this have to do with me?" Completing Activity 3 provides an opportunity for students to relate their newly developed understandings about learning in mice to humans.

1. **Ask students, "If mice are a good model system for humans, what do your mouse experiment results mean for humans?"**

   Factors that improve learning in mice should also improve learning in humans.

2. **Display the transparency of Master 4.3, *Morris Water Maze Results*, that you prepared with averaged results from all four sets of mice plotted on one graph. This time, ask students to make observations about the *similarities* in results among all four sets of mice.**

   The time to platform for all mice decreased over the three days of testing. Students should interpret the improved performance as evidence that all mice learned.

3. **Ask students, "Why do you think the time it took to find the platform over the three days of testing decreased for all mice?"**

   Each trial allowed mice to practice finding the platform. By following the visual cues on the wall, mice learned to find the platform more easily with each trial.

   If students listed practice as a factor that affects learning in the initial discussion of this lesson, remind them of this. Point out that they now have evidence, based on a mouse animal model, that supports their idea that practice affects learning.

4. **Encourage students to share their own experiences with practice and learning. Has practicing helped them learn tasks? What does this say about the mouse as a model system for learning research?**

   Students will likely share a variety of examples where practice helped them learn a task. Some possible examples of such tasks include learning a sport, learning to play a musical instrument, and playing computer games. This variety of examples helps make the point that practice improves learning in humans. Since practice also improves learning in mice, the mouse appears to be a good model system for learning research.

5. **Ask students whether they think the brain changes as a result of learning.**

Students probably do not have knowledge on which to base their opinion. This question is meant to stimulate thinking and serves as a lead-in to, "Let's investigate."

6. **Display a transparency of Master 4.15, *Neuron Structure Data*. Explain to students that these pictures show neurons from the brains of four adult mice, each with different experiences.**

Explain the following to your class.

- Mouse 1 and Mouse 2 are both from a standard cage. However, Mouse 1 never experienced the Morris Water Maze, while Mouse 2 was allowed to practice finding the platform on the Morris Water Maze.
- Mouse 3 and Mouse 4 are both from an enriched cage. However, Mouse 3 never experienced the Morris Water Maze, while Mouse 4 was allowed to practice finding the platform on the Morris Water Maze.

7. **Ask students to make observations about the neurons of the mice.**

The mice that practiced on the Morris Water Maze (Mouse 2 and Mouse 4) have more branches on their neurons than do their counterparts that did not practice (Mouse 1 and Mouse 3, respectively). The increase in neuron branching with practice occurs in mice from both enriched and standard cages. Students should also notice that both mice from the enriched cage (Mouse 3 and Mouse 4) have greater neuron branching than the mice from the standard cage (Mouse 1 and Mouse 2) do.

Tip from the field test: A brief review of the parts of a neuron is sometimes helpful to ensure that students use the language of neuroscience to describe what they see.

8. **Ask students whether these results, combined with the results of the Morris Water Maze tests, support the hypothesis that learning results in changes in the brain.**

The results from the Morris Water Maze test and the neuron structure data indicate that there is a correlation between learning and changes in the brain. This does not prove the hypothesis that *Learning results in changes in the brain*. However, combining the Morris Water Maze test data and the neuron structure data provides support for this hypothesis.

Tip from the field test: You may want to add a discussion of the

Assessment:
As a formal assessment of students' understanding, you can direct them to summarize their responses to the questions in Steps 7 to 10 after the class discussion.

difference between *association* and *causation*. Results from the mouse experiments show an association between certain factors and learning; that is, increases or decreases in the rates at which mice learn coincided with the presence or absence of certain factors, such as an exercise wheel or toys. However, from these experiments alone, one cannot determine whether these factors actually caused the changes in learning.

9. **Ask, "If the mouse is a good model system for humans, what do these results predict about humans?"**

   Ask students to state their answer as a hypothesis. Try to get the class to come up with a general, consensus hypothesis such as, *Learning leads to changes in the human brain.*

10. **Remind students that a hypothesis is a testable statement. Ask students to suggest ways to test their hypothesis.**

   Remind students that to look for changes in the human brain, they will need a noninvasive method of examining the brain. Students should recall PET scans from Lesson 2 and suggest this as a method for testing their hypothesis. If PET scans of the same individual before and after learning demonstrate changes in brain activity compared with scans taken before and after the same time period but with no learning, the data would support the hypothesis that *Learning leads to changes in the human brain*. If the PET scans show no changes in brain activity, the data would not support the hypothesis.

Lesson 4 Organizer: Web Version

Activity 1: *Effects of Social Interaction on Learning*

What the Teacher Does	Procedure Reference
Ask students, • "What is learning?" • "Where does learning occur?" • "What affects learning?" • "How can scientists determine whether these factors affect learning?"	Page 93 Steps 1–4
Organize students into pairs. • Number groups sequentially starting with 1. • Explain that pairs are research teams at the Learning Research Laboratory. • Display transparency of Master 4.1, *Memo from the Director* and read it to class. • Direct attention to Research Question 1 and ask students to raise their hands if they think social interaction has an effect on learning.	Pages 93–94 Steps 5–7 T
Send students to computer stations and have them click on the link to this activity. • Have students read the e-mail message from the laboratory technician. • Ask them to click on the "Lab Notebook" button and review with them the contents of the Experimental Design page. • Have students click on the link to the "Scientific Research Reference Manual" and review this resource with them.	Pages 94–95 Steps 8–11 WWW
Give each team one copy each of Master 4.2, *Morris Water Maze Data, Research Question 1 (Web Version)*, Master 4.3, *Morris Water Maze Results* (or have students use their own graph paper), and Master 4.4, *Memo to the Director on Research Question 1*.	Page 95 Step 12 M

T = Involves using a transparency.

WWW = Involves using the Internet.

M = Involves copying a master.

Direct teams to • run the experiment and collect data for each mouse on Master 4.2, • average the data for each set of mice on Master 4.2, • construct a line graph of the data averages on Master 4.3 or their own graph paper, and • fill in the blanks on Master 4.4, *Memo to the Director*.	Page 95 Step 12
Reconvene the class. Ask different student teams to share their graphs, their answers to the questions on the memo, and their conclusion(s) about learning.	Page 96 Step 13
Activity 2: *Effects of Enrichment and Exercise on Learning*	
• Organize students into their research teams from Activity 1. • Direct teams to computer stations and have students click on the link to this activity. • Ask students to read the e-mail message from the director. • Have students click on the link to their team's assigned research question. • Briefly review the contents of the Experimental Design page that appears.	Page 99 Steps 1–4
• Instruct teams to write a hypothesis for their research question and then click on the "Animal Care Laboratory" icon. • Instruct teams to select two sets of mice to use in testing their hypothesis. • Ask students to click on the "To Experimental Design Page" button to review the experiment they have designed. • Students should then click the "Run Experiment" button and collect their data as they did in Activity 1.	Pages 99–101 Steps 5–7
Give each team a copy of Master 4.8, *Morris Water Maze Data, Research Questions 2 and 3 (Web Version)*, and a new copy of Master 4.3, *Morris Water Maze Results*. Direct teams to • run the experiment and collect data for the sets of mice they selected for their experiment on Master 4.8, • average the data for each of their chosen sets of mice on Master 4.8, and • construct a line graph of their data averages on Master 4.3 or their own graph paper.	Page 101 Step 8

While teams are preparing their graphs, give each even-numbered team a copy of Master 4.9, *Memo to the Director on Research Question 2*, and each odd-numbered one a copy of Master 4.10, *Memo to the Director on Research Question 3*. Ask teams to complete the memos using the results of their experiment.	Pages 101–102 Step 9
When students have completed their data tables, graphs, and memos, pair odd- and even-numbered teams and tell them to share their results with each other. Encourage teams to challenge their partner team's conclusions if those conclusions are not supported by the data.	Page 102 Step 10
Reconvene the class and display Master 4.11, *Summary of Research Findings*. Ask students to summarize their conclusions about learning from the three experiments by providing evidence-based answers to the three research questions.	Page 102 Step 11
Display the transparency of Master 4.3, *Morris Water Maze Results*, you have prepared with averaged results from all four sets of mice plotted on one graph. • Ask students to interpret their results in the context of data from all four sets of mice. • Ask students to propose explanations for these findings. How would they test their explanations?	Pages 102–103 Steps 12–13
Activity 3: *A Human Perspective*	
Ask, "If mice are a good model system for humans, what do your mouse experiment results mean for humans?"	Page 108 Step 1
Display the transparency of Master 4.3, *Morris Water Maze Results*, that you prepared with averaged results for all four sets of mice plotted on one graph. • Ask students to make observations about the similarities in results among all four sets of mice. • Ask, "Why do you think the time it took to find the platform over the three days of testing decreased for all mice?"	Page 108 Steps 2–3
Encourage students to share their own experiences with practice and learning. Ask, • "Has practice helped them learn tasks?" • "What does this say about the mouse as a model system for learning research?" • "Do you think the brain changes as a result of learning?"	Pages 108–109 Steps 4–5

Display a transparency of Master 4.15, *Neuron Structure Data*. • Explain that these pictures show neurons from the brains of four adult mice, each with different experiences. • Ask students to make observations about the neurons of the mice. • Ask whether these results, combined with the results of the Morris Water Maze tests, support the hypothesis that learning results in changes in the brain. • Ask, "If the mouse is a good model system for humans, what do these results predict about humans?" • Remind students that a hypothesis is a testable statement. Ask students to suggest ways to test their hypothesis.	Pages 109–110 Steps 6–10

Lesson 4 Organizer: Print Version

Activity 1: *Effect of Social Interaction on Learning*

What the Teacher Does	Procedure Reference
Ask students, • "What is learning?" • "Where does learning occur?" • "What affects learning?" • "How can scientists determine whether these factors affect learning?"	Page 96 Steps 1–4
Organize students into pairs. • Number groups sequentially starting with 1. • Explain that pairs are research teams at the Learning Research Laboratory.	Page 96 Step 5
Display a transparency of Master 4.1, *Memo from the Director*, and read it with the class. • Direct students' attention to Research Question 1. • Ask students to raise their hands if they think social interaction has an effect on learning. • Give each team a copy of Master 4.5(a, b, c), *Scientific Research Reference Manual.*	Page 97 Steps 6–8 T M
Tell students that a lab technician has completed an experiment to answer Research Question 1. Display a transparency of Master 4.6, *Memo from Lab Technician*, and read it with the class.	Pages 97–98 Step 9 T
Display a transparency of Master 4.7, *Morris Water Maze Data, Research Question 1 (Print Version)*. Give each team one copy of Master 4.3, *Morris Water Maze Results*, and one copy of Master 4.4, *Memo to the Director on Research Question 1*.	Page 98 Step 10 M T

T = Involves using a transparency. M = Involves copying a master.

Direct teams to • average the data on Master 4.7 for each set of mice, • construct a line graph using the data averages, and • fill in the blanks on Master 4.4.	Page 98 Step 10
Reconvene the class. Ask different student teams to share their graphs, answers to the questions on Master 4.4, and their conclusions about learning.	Pages 98–99 Step 11
Activity 2: *Effects of Enrichment and Exercise on Learning*	
Organize students into their research teams from Activity 1. • Display a transparency of Master 4.12, *Next Research Assignment*, and read it with the class. • Give each team a copy of Master 4.13, *Experimental Design.* • Make sure each team has its copy of Master 4.5(a, b, c), *Scientific Research Reference Manual.*	Page 104 Steps 1–2 T M
Instruct teams to complete Master 4.13 by • writing their research question, • writing a hypothesis, and • selecting two sets of mice appropriate for testing their hypothesis.	Pages 104–105 Step 3
• Display a transparency of Master 4.14, *Morris Water Maze Data, Research Questions 2 and 3 (Print Version)*. • Give each team a copy of Master 4.3, *Morris Water Maze Results.* • Ask teams to graph their averaged data as they did in Activity 1.	Page 105 Steps 4–5 T M
• Give even-numbered teams a copy of Master 4.9, *Memo to the Director on Research Question 2.* • Give odd-numbered teams a copy of Master 4.10, *Memo to the Director on Research Question 3.* • Ask teams to complete their master.	Page 105 Step 6 M
Pair odd-numbered teams with even-numbered teams and ask them to share and discuss their results with one another.	Page 106 Step 7
Reconvene the class. • Display a transparency of Master 4.11, *Summary of Research Findings.* • Ask students to summarize their conclusions about learning from the three experiments by providing evidence-based answers to the three research questions.	Page 106 Step 8 T

Display the transparency of Master 4.3, *Morris Water Maze Results*, that you have prepared with averaged results from all four sets of mice plotted on one graph. • Ask students to interpret their results in the context of data from all four sets of mice. • Ask students to propose explanations for these findings. • Ask, "How would you test your explanations?"	Pages 106–107 Steps 9–10
Activity 3: *A Human Perspective*	
Ask, "If mice are a good model system for humans, what do your mouse experiment results mean for humans?"	Page 108 Step 1
Display the transparency of Master 4.3, *Morris Water Maze Results*, that you prepared with averaged results for all four sets of mice plotted on one graph. • Ask students to make observations about the similarities in results among all four sets of mice. • Ask, "Why do you think the time it took to find the platform over the three days of testing decreased for all mice?"	Page 108 Steps 2–3
Encourage students to share their own experiences with practice and learning. • Has practice helped them learn tasks? • What does this say about the mouse as a model system for learning research? • Ask students whether they think the brain changes as a result of learning.	Pages 108–109 Steps 4–5
Display a transparency of Master 4.15, *Neuron Structure Data.* • Explain that these pictures show neurons from the brains of four adult mice, each with different experiences. • Ask students to make observations about the neurons of the mice. • Ask whether these results, combined with the results of the Morris Water Maze tests, support the hypothesis that learning results in changes in the brain. • Ask, "If the mouse is a good model system for humans, what do these results predict about humans?" • Remind students that a hypothesis is a testable statement. Ask students to suggest ways to test their hypothesis.	Pages 109–110 Steps 6–10

Lesson 5
Evaluate

Our Sense of Self

Overview

Lesson 5 allows students to demonstrate their understanding of the major concepts from earlier lessons and serves as the final assessment for the module. Students learn about the effects of damage to the nervous system through analysis of four fictitious patient case studies. Each patient has sustained damage to the nervous system that may or may not have resulted in a loss of the patient's sense of self. The class analyzes one case study together. As a homework assignment, students take a position on whether the brain contains the sense of self (determines who we are). They analyze the remaining case studies, then write an essay using the case studies and concepts learned in Lessons 1 to 4 to defend their position.

At a Glance

Major Concepts

The nervous system can be damaged through injury or disease. Damage to the spinal cord does not change who we are, but it may change what we can feel and do. Damage to the brain can change who we are.

Objectives

After completing this lesson, students will be able to

- recognize that the nervous system can be damaged through injury or disease,
- explain why damage to the spinal cord does not change who we are, and
- explain why damage to the brain can change who we are.

Teacher Background

Refer to the following sections in Information about the Brain:

8 Nervous System Injury *(pages 37–40)*

- 8.1 Neurological disorders *(pages 37–38)*
- 8.2 Injuries to the nervous system *(pages 38–39)*
- 8.3 Regional specificity and effects of trauma *(page 39)*
- 8.4 Protecting our nervous system *(pages 39–40)*

In Advance

Web-Based Activities

Activity	Web Version?
1	No

Photocopies

Activity 1	• Master 5.1, *The Brain: Our Sense of Self*, 1 transparency • Master 5.2, *Case Study—John M.*, 1 transparency • Master 5.3, *Three Case Studies*, 1 copy per student

Materials

Activity 1	Overhead projector and screen

Preparation

Set up overhead projector and screen.

Procedure

Assessment:
This activity asks students to integrate information and concepts they have learned in Lessons 1 to 4.

1. **Define the term "sense of self" by explaining that it means to know who you are, or your identity. Ask students to describe things that are part of their identity.**

   If students need help getting started, remind them of Lessons 1 and 2, when they discovered the unique responses they each had to different tasks and situations. Students likely will list being a member of their family, having particular friends, their special talents, and things they do and do not like to do. Affirm all of these by agreeing that their past experiences (memories), their unique talents, and their likes and dislikes all contribute to who they are, the unique way they each think about and respond to the world.

2. **Display a transparency of Master 5.1, *The Brain: Our Sense of Self*. Ask students to think about the statement and decide whether they agree or disagree with it.**

3. **Ask students who agree with the statement to raise their hands. Ask several of these students to explain their reasoning. Then ask several who disagree with the statement to give their reasons.**

   Encourage students to think more deeply by asking questions such as, "Do other parts of the body help you know who you are?" and "How about other parts of the nervous system?" Some students may say that "who they are" is determined by their entire body.

Others may state that the entire nervous system determines how they know who they are. Accept all responses at this time.

4. **Ask, "How could you collect evidence to support your opinion?"**

   Students may have no suggestions, or they may suggest that they could do something to change a particular region of a person's brain or other part of the nervous system and see how that affects a person's behavior. Move quickly to Step 5.

5. **Explain that while it would be unethical to damage a healthy brain deliberately, scientists can study the effects of injuries to the nervous system on a person.**

6. **Introduce students to the case studies by explaining that they are written from the perspective of a physician who has patients with nervous system damage.**

7. **Display a transparency of Master 5.2, *Case Study—John M.* Ask students to follow along as you read aloud.**

8. **Lead a class discussion about the case history by asking students to respond to the following questions:**
   - **Do you think John still has the knee-jerk reflex?**
     He probably does. Students should use their understanding from Lesson 3 to explain that because John can no longer *choose* to move his legs, the voluntary neural pathways between his lower body and his brain no longer function. However, the knee-jerk reflex is an involuntary neural pathway that does not require the brain.
   - **Does the knee-jerk reflex contribute to your sense of self?**
     Students may have different opinions. Ask students if they felt that demonstrating (or being unable to demonstrate) the knee-jerk reflex on themselves changed their identity or the way they think about themselves.
   - **Remember the memory game you played in Lesson 1. Do you think John would perform about the same on this game now as he did before the accident? How about the word game?**
     According to the case history, John's aptitude for physics was unchanged after the accident. This evidence suggests that John's cognitive abilities ("thinking abilities") were unchanged by the injury.
   - **Do abilities in areas such as memory and language contribute to your sense of self?**
     Again, students may have different opinions. Most will probably agree that thinking of themselves as good or not good at games and puzzles is part of what makes them "who they are."

Tip from the field test: Leading students through this discussion of

Assessment:
This question provides an opportunity for an informal assessment of student preconceptions and is a lead-in to, "Let's investigate."

John's case history provides students with a model for the analyses of case histories expected of them in the final assignment of this unit.

9. **Continue the discussion by asking the following questions:**
   - **Do you think John still understands football plays?**
     The evidence from the case history suggests that John's cognitive abilities have not changed; therefore, he likely does still understand football plays.
   - **Do you think he is still interested in sports in general?**
     The evidence from the case history regarding John's participation in wheelchair races suggests that John is still interested in and still enjoys sports.
   - **Does not being able to *play* football make John a different person?**
     Students' opinions will vary.

10. **Focus the class discussion even more on sense of self by asking students questions such as, "Did John lose his 'sense of self'?" "Does he have a different identity?" "Does he still think the same way?" Have students support their opinions with evidence from the case history and their understandings about how the brain and nervous system function from the previous lessons.**

    Students likely will have different opinions. Lead them to the idea that, fundamentally, John is the same person he was before the accident; that is, his sense of self has not changed.

    Some students may argue that John is now a different person and support that opinion by pointing out that he would likely now make different decisions in situations such as the bike-riding or, for John, wheelchair-riding, scenario in Lesson 2 than he would have before the accident. If the accident had not occurred, he might have gone on to be a professional football player and made lots more money than he will as a physicist. They may feel that this changes John's identity.

    Point out that although John cannot do all the things he did before, the core person has not changed. Although some of John's neural pathways are "broken," those that make him who he is have not changed. He can still draw on the same past experiences and unique abilities in his approach to life. Evidence from the case history supports this: he remained an outgoing, upbeat person; his talent for physics was the same. Although he can no longer play football, he remains interested in sports, as evidenced by his participation in wheelchair races. John is still the same person.

11. **Give a copy of Master 5.3, *Three Case Studies*, to each student.**

12. **Tell students that they will evaluate three more case studies as a homework assignment. They should**
    - **read each case study;**
    - **write one paragraph for each case study in which they state whether the patient has lost his/her identity, or sense of self, and support their opinion with evidence from the case study and the concepts they learned in Lessons 1 to 4; and**
    - **write a final paragraph in which they indicate whether they agree or disagree with the statement on Master 5.1, *The Brain: Our Sense of Self*, and why they agree or disagree.**

Students should conclude that Frank's injury caused him to change his identity, or sense of self. The case study included evidence that he no longer thought about or responded to the world in the same way. He no longer finds things funny that once were funny to him. His personality also changed: he once was calm and easygoing and now is angry and unhappy. Frank seems to have become a different person.

Although she is no longer able to do all of things she could before the accident, Lisa has not lost her identity. She continues to work effectively at the same kind of job she had before the accident and to enjoy teaching children. While the accident apparently damaged the region of her brain that receives visual information, it did not change the fundamental, core person.

Mandy's sense of self has changed drastically as her Alzheimer's disease has progressed. Her memories are gone, and her personality has changed dramatically. Students should recall from Lessons 1 and 2 that people have different responses to situations partly because of their past experiences. Because Mandy cannot remember many of her past experiences, she responds to situations differently from how she did before she was stricken by Alzheimer's.

Students may agree or disagree with the statement "The brain contains your sense of self; it makes you who you are." Those who agree may use the examples of Frank's and Mandy's brain injuries to support their opinion—because of damage to their brains, Frank and Mandy are now different people from who they were before. Students who disagree with the statement may indicate that while Frank's and Mandy's cases seem to support the statement, Lisa's case invalidates it. Although her brain was injured, Lisa is fundamentally the same person she was before. The most insightful students will state, correctly, that the three case studies support the idea that some, but not all, regions of the brain contain our sense of self.

NSES

Content Standard C: Disease is a breakdown in structures or functions of an organism.

Content Standard F: The potential for accidents and the existence of hazards imposes the need for injury prevention. Students should understand the risks associated with natural, chemical, biological, social, and personal hazards.

Lesson 5 Organizer

Activity 1: *Our Sense of Self*

What the Teacher Does	Procedure Reference
Define “sense of self” by explaining that it means to know who you are, or your identity. Ask students to describe things that are part of their identity.	Page 120 Step 1
Display a transparency of Master 5.1, *The Brain: Our Sense of Self*. Ask students • whether they agree or disagree with the statement on the master; • why they agree or disagree; and • how they could collect evidence to support their opinion.	Pages 120–121 Steps 2–4
Explain that scientists can study the effects of injuries to the nervous system on a person. Introduce students to the case studies. They are written from the perspective of a physician who has patients with nervous system damage.	Page 121 Steps 5–6
Display a transparency of Master 5.2, *Case Study—John M*. Ask students to follow along as you read aloud. • Ask students to respond to the following questions: o Do you think John still has the knee-jerk reflex? o Does the knee-jerk reflex contribute to your sense of self? o Do you think John would perform about the same on the memory and word games of Lesson 1 as he would have before his accident? o Do abilities such as memory and language contribute to your sense of self? • Continue discussion with the following questions: o Do you think John still understands football plays? o Do you think he is still interested in sports in general? o Does not being able to play football make John a different person? • Focus discussion even more on sense of self with these questions: o Did John lose his sense of self? o Does he have a different identity? o Does he still think the same way?	Pages 121–122 Steps 7–10

Give each student a copy of Master 5.3, *Three Case Studies.* • Have students evaluate three case studies as homework. • They should read each case study and write one paragraph for each study discussing the patient's sense of self. They should use evidence from the study and concepts from Lessons 1 through 4. • They should write a final paragraph indicating whether they agree with the statement on Master 5.1, *The Brain: Our Sense of Self*, and why or why not.	Pages 122–123 Steps 11–12 M

T = Involves using a transparency.

M = Involves copying a master.

Masters

Lesson 1, *A Difference of Mind*

Master 1.1(a), *Station Instructions 1* .... 1 copy (on cardstock)
Master 1.1(b), *Station Instructions 2* .... 1 copy (on cardstock)
Master 1.2, *Stroop Test Diagram* .... write on poster board (*print version* only)
Master 1.3, *Memory Station Game Cards* .... group copies (on cardstock)
Master 1.4, *Word Puzzle Cards* .... group copies (on cardstock)
Master 1.5, *Station Notes* .... student copies

Lesson 2, *Regional Differences*

Master 2.1, *Basics about PET Scans* .... transparency
Master 2.2, *Sample PET Scans* .... transparency and group copies
Master 2.3, *Scenario Diagram* .... transparency
Master 2.4, *Brain Outline* .... group copies

Lesson 3, *Inside Information*

Master 3.1, *Two Types of Cells* .... transparency
Master 3.2, *Pathway-Building Worksheet* .... student copies
Master 3.3, *Neuroscience Reference Manual* .... group copies (*print version* only)
Master 3.4, *Building a Reflex Pathway* .... group copies, plus 4 transparencies (*print version* only)
Master 3.5, *Building a Voluntary Response Pathway* .... group copies, plus 4 transparencies (*print version* only)

Lesson 4, *Outside Influence*

Master 4.1, *Memo from the Director* .... transparency
Master 4.2, *Morris Water Maze Data, Research Question 1 (Web Version)* .... team copies
Master 4.3, *Morris Water Maze Results* .... team copies (2 sets) and 1 transparency
Master 4.4, *Memo to the Director on Research Question 1* .... team copies
Master 4.5 *Scientific Research Reference Manual* .... team copies (*print version* only)

Master 4.6, *Memo from Lab Technician*... transparency (*print version* only)

Master 4.7, *Morris Water Maze Data, Research Question 1 (Print Version)* ....transparency

Master 4.8, *Morris Water Maze Data, Research Questions 2 and 3 (Web Version)*..team copies

Master 4.9, *Memo to the Director on Research Question 2* .... 1 copy for half of teams

Master 4.10, *Memo to the Director on Research Question 3*.................... 1 copy for half of teams

Master 4.11, *Summary of Research Findings*...transparency

Master 4.12, *Next Research Assignment* ....transparency (*print version* only)

Master 4.13, *Experimental Design* ....team copies (*print version* only)

Master 4.14, *Morris Water Maze Data, Research Questions 2 and 3 (Print Version)*... transparency

Master 4.15, *Neuron Structure Data* .... transparency

Lesson 5, *Our Sense of Self*

Master 5.1, *The Brain: Our Sense of Self*..................................transparency

Master 5.2, *Case Study—John M.* .... transparency

Master 5.3, *Three Case Studies*..student copies

Station Instructions 1

Attention Station
The Stroop Test

Step 1: Have your partner time you with the stopwatch as you take two tests.

Step 2: Start each test when your partner says, “Start.” Your partner should stop timing when you say, “Done.”

Step 3: For the first test, name the *colors* of the words on Test 1 as fast as you can (do NOT read the words!).

Step 4: For the second test, name the *colors* of the words on Test 2 as fast as you can (do NOT read the words!).

Step 5: When you are done, switch roles with your partner.

Step 6: Answer the questions about Station 1 on your Station Notes form.

Language Station
Word Puzzles

Step 1: Work by yourself to solve the word puzzles on one of the two cards.

Step 2: Trade cards with your partner.

Step 3: Work by yourself to solve the word puzzles on the second card.

Step 4: Compare and discuss your answers with your partner.

Step 5: Write your answers to the word puzzles on your Station Notes form.

Step 6: Answer the questions about Station 3 on your Station Notes form.

Station Instructions 2

Memory Station

Step 1: Have your partner time you with the stopwatch as you play two games at this station.

Step 2: Start each game when your partner says, "Start." Your partner should stop timing when you say, "Done."

Step 3: For **Game 1**, flip over two cards at a time, leaving them turned over *only* if they match. If they do not match, you must flip them back and pick a different pair of cards. Match all the cards into pairs as quickly as possible.

Step 4: When you are done with Game 1, flip the cards face down again WITHOUT SHUFFLING them.

Step 5: Repeat Steps 1 through 3, complete with timing. This is **Game 2.**

Step 6: Now SHUFFLE the cards and lay them out face down. Switch roles with your partner (you time while your partner plays the game).

Step 7: Answer the questions about Station 2 on your Station Notes form.

Emotion Station

Step 1: Look at Picture 1 while your partner looks at Picture 2.

Step 2: Answer questions about this picture on your Station Notes form.

Step 3: Now switch. Look at Picture 2 while your partner looks at Picture 1.

Step 4: Answer questions about this picture on your Station Notes form.

Stroop Test Diagram

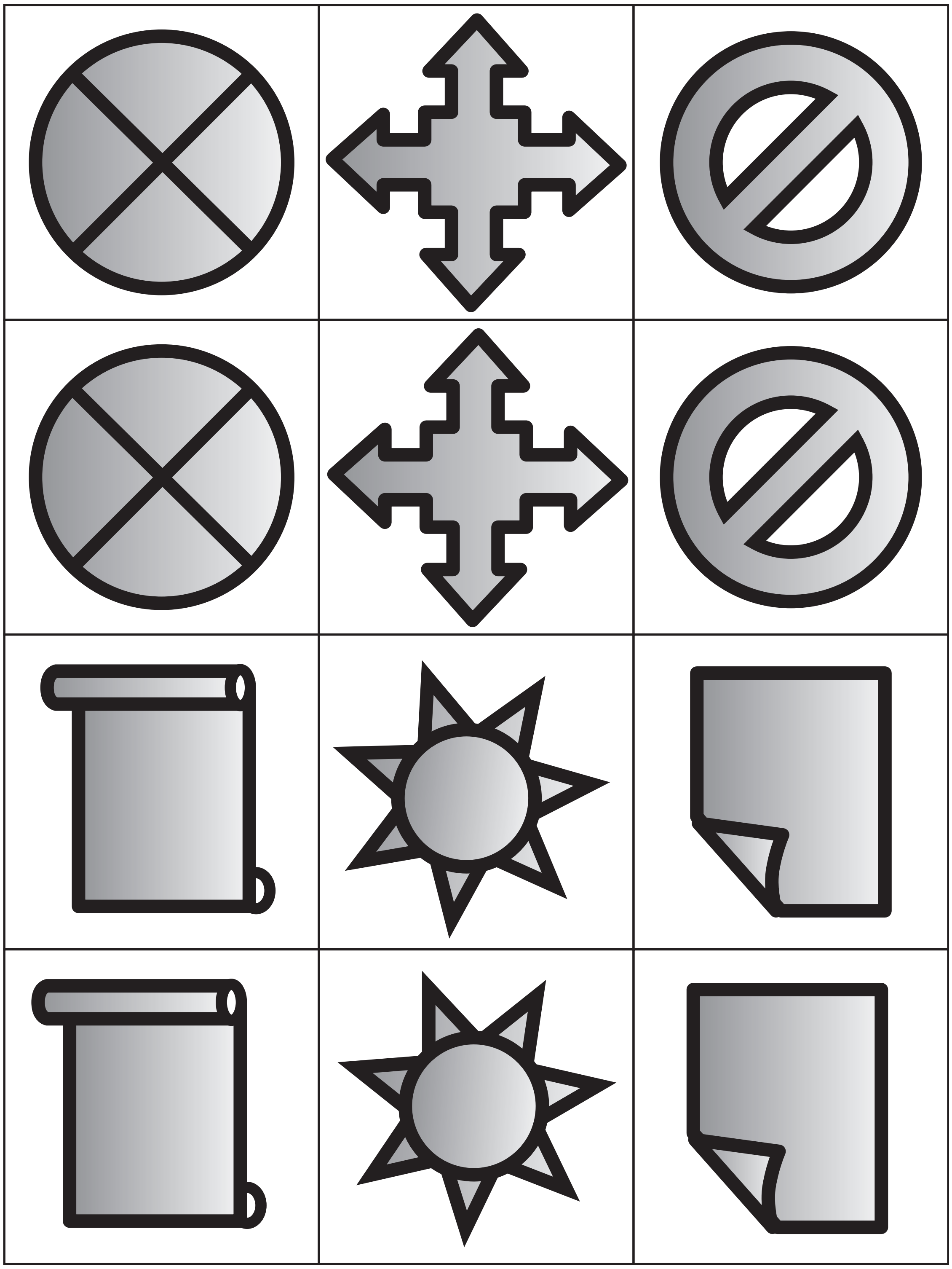
Test 1

Red	Blue	Green	Orange
Yellow	Blue	Purple	Green
Orange	Purple	Red	Red
Green	Yellow	Orange	Blue

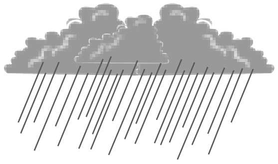
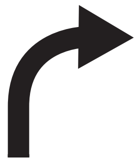
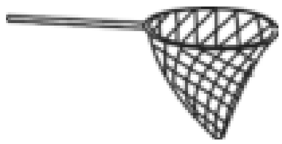
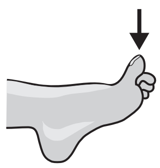
Test 2

Red	Blue	Green	Orange
Yellow	Blue	Purple	Green
Orange	Purple	Red	Red
Green	Yellow	Orange	Blue

Memory Station Game Cards



Word Puzzle Cards

1	b + 
2	in +  + 
3	 – d +  + r + 
4	cover / officer
5	Ame[made]rica
6	ev en ly

Station Notes

Name: ______________________________ Date: ______________

Station 1: Attention Station

Time to finish Test 1: __________ Test 2: __________

Which was harder, Test 1 or Test 2? Why do you think it was harder?

Station 2: Memory Station

Time to finish Game 1:__________ Game 2:__________

Which was easier, Game 1 or Game 2? Why do you think it was easier?

Station 3: Language Station

Answers to the word puzzles:

1. ______________ 2. ______________ 3. ______________

4. ______________ 5. ______________ 6. ______________

Which puzzles were easier for you (1, 2, and 3 *or* 4, 5, and 6)? Why do you think they were easier?

Station 4: Emotion Station

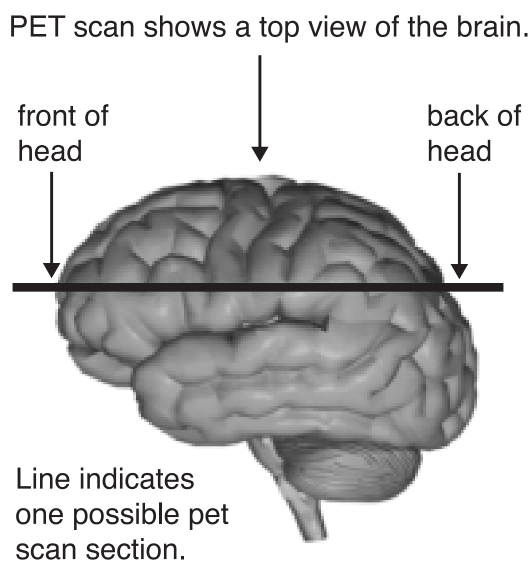
How did you feel after looking at Picture 1? Why did you feel this way?

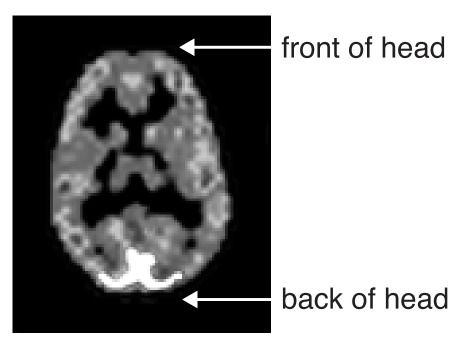
How did you feel after looking at Picture 2? Why did you feel this way?

Basics about PET Scans

One way scientists study the brain is through positron emission tomography (PET) scans. PET scans allow scientists to create images of the brain in action. PET scans look like a slice of a person's brain.

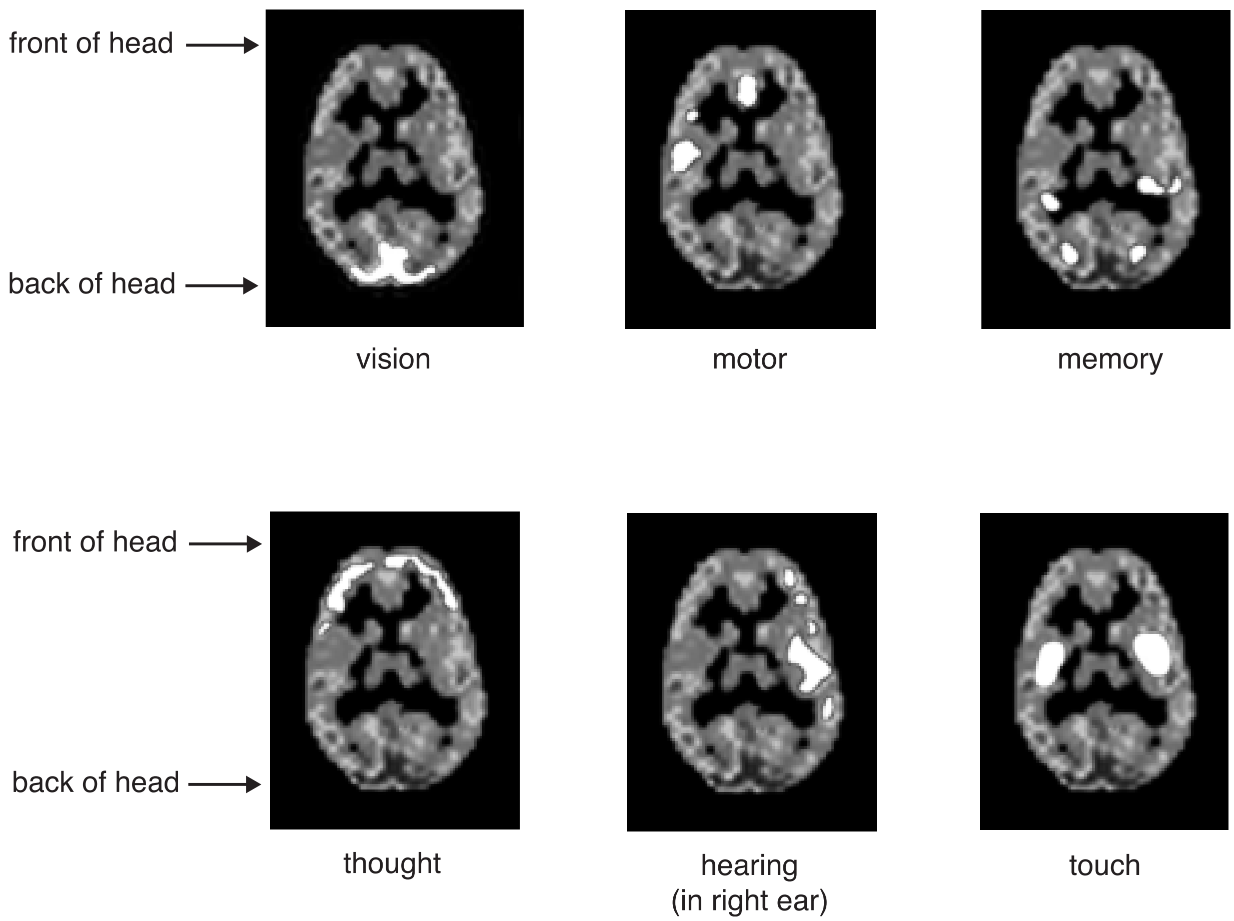
The brain uses the sugar *glucose* for energy. The more active a brain area is, the more glucose it uses. Before they take a PET scan, trained scientists give people small amounts of radioactive glucose so they can see the glucose in their brain. The active parts of the brain appear as bright white spots in the image.





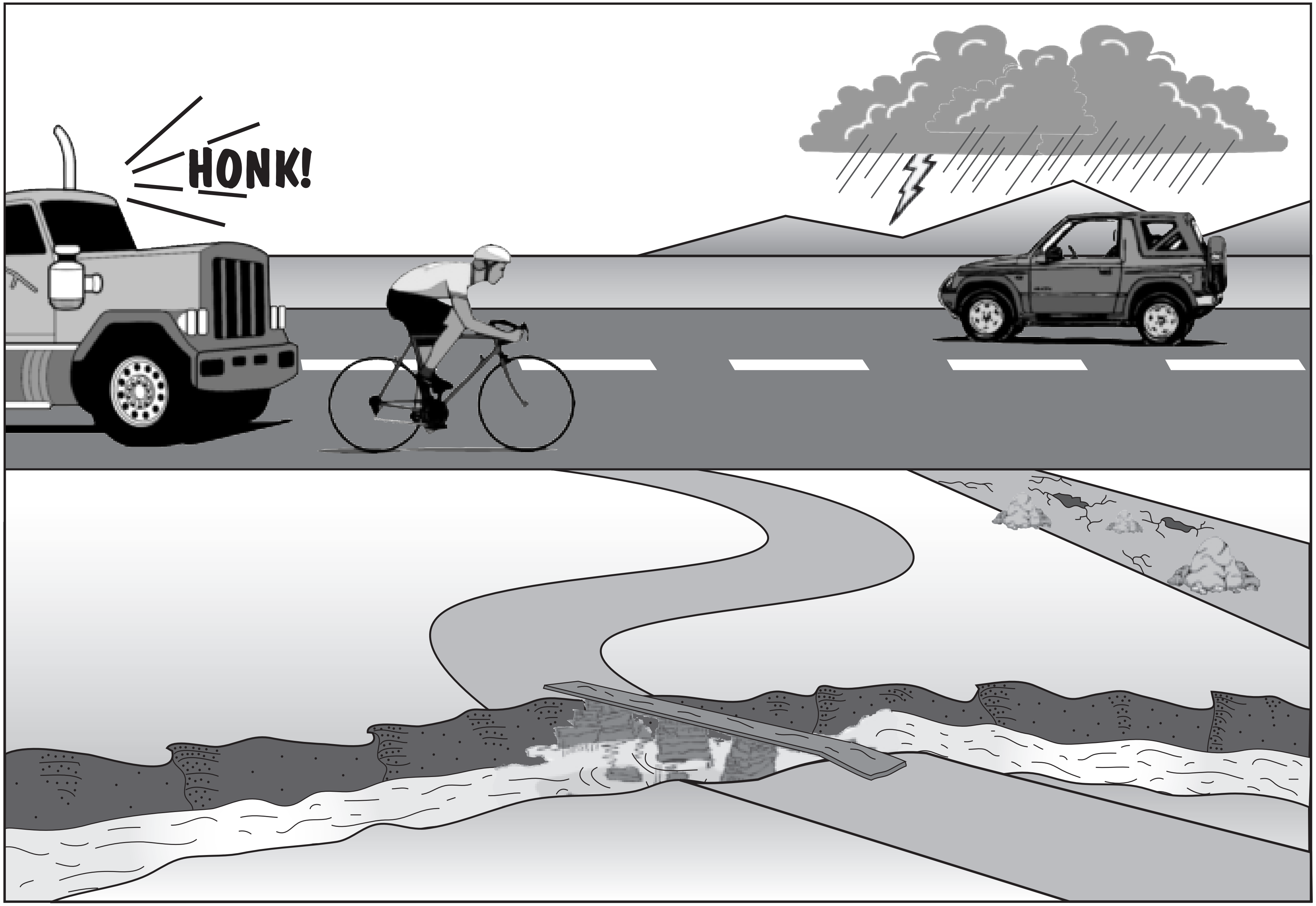
PET scan of a person processing visual information–view is from above the head.

Sample PET Scans



These PET scans show the brain as seen from above.

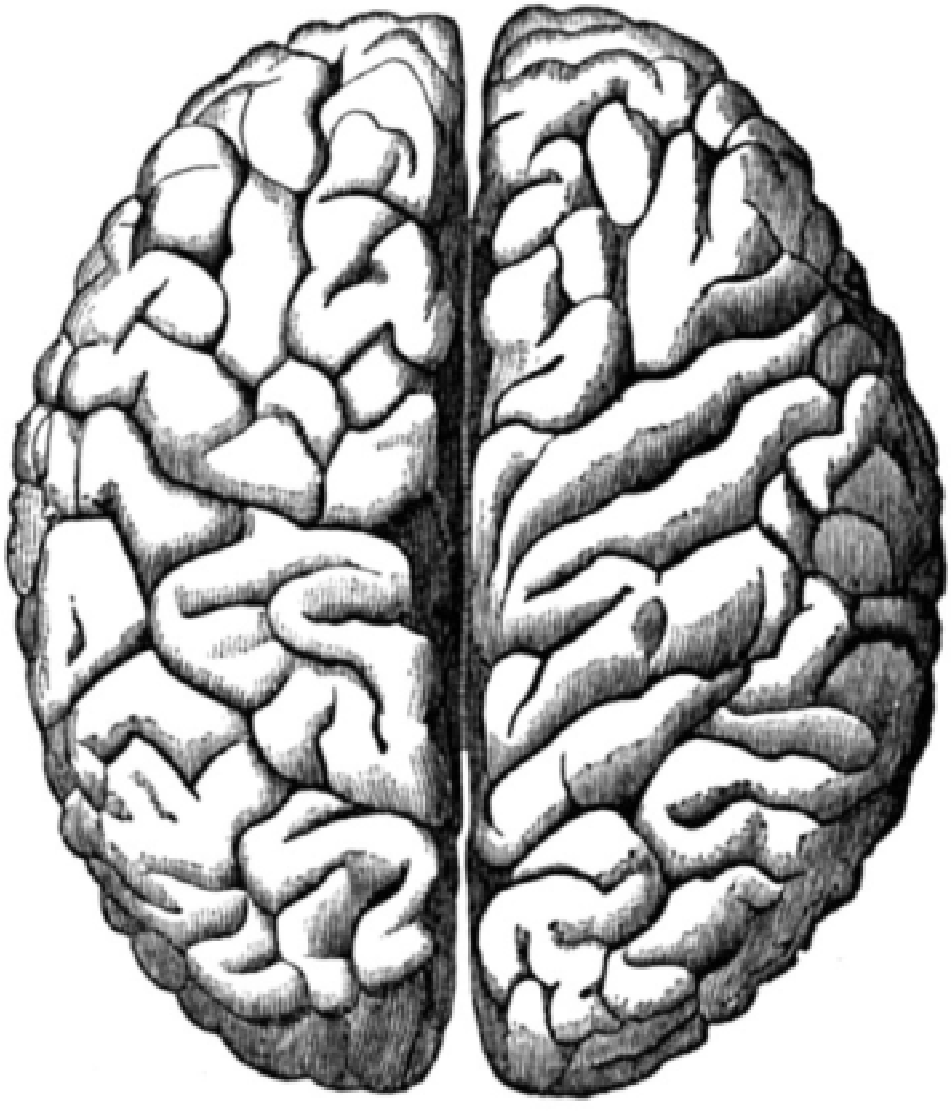
Scenario Diagram



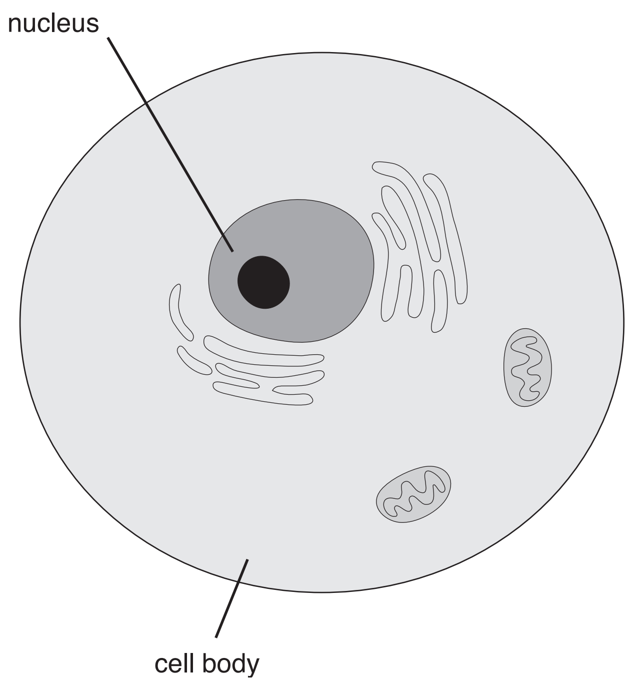
Brain Outline

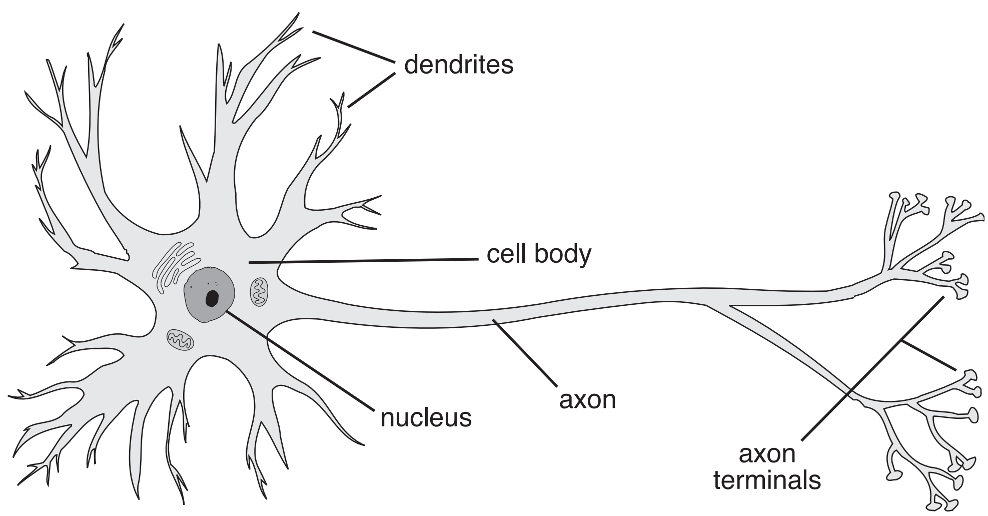
Name: ______________________________ Date: ______________

front of head



Two Types of Cells

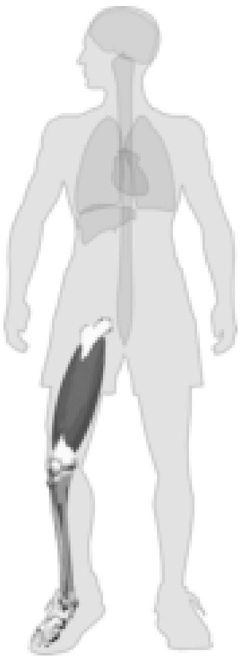




Pathway-Building Worksheet

Name: ______________________________ Date: ______________

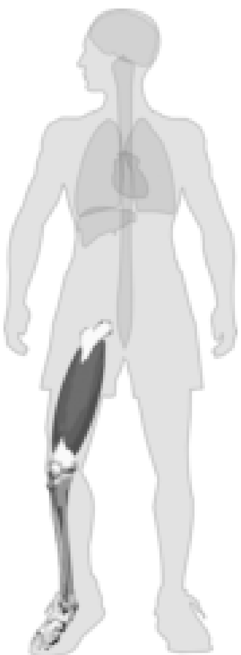
Pathway 1: Knee-Jerk Reflex



Draw your reflex pathway on the figure to the left. Label the parts you used. What is the function of each part?

When you tested your pathway, a spark traveled through the pathway showing the path of information flow. Describe the path of information flow through your pathway.

Pathway 2: Voluntary Leg Movement



Draw your voluntary leg movement pathway on the figure to the left. Label the parts you used. What is the function of each part?

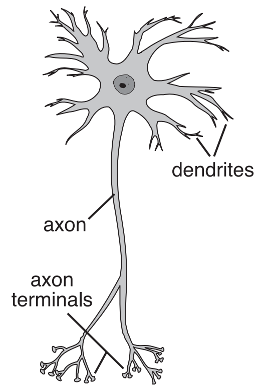
When you tested your pathway, a spark traveled through the pathway showing the path of information flow. Describe the path of information flow through your pathway.

Neuroscience Reference Manual

Part 1: The Central Nervous System

The Neuron

Neurons are cells that transport information. Like most cells, neurons have a cell body containing a nucleus. However, neurons also have special parts called **dendrites** and **axons**. Bundles of axons in the body are called **nerves.**



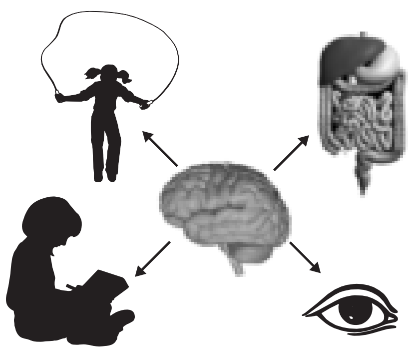
Dendrites pick up incoming signals and deliver them to the cell body. A neuron has many dendrites, so information can enter a neuron from many places at once.

Axons send signals out from the cell body. A neuron has one axon, but that axon may branch into many axon terminals. This allows information to be sent from one neuron to many places at once.

The Brain

The **brain** is a highly organized network of billions of cells protected by the skull. Information flows from all parts of the body to the brain.

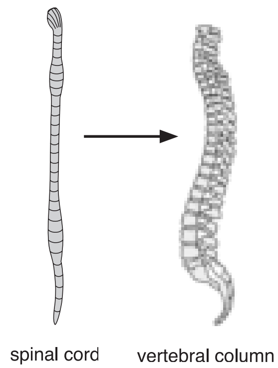
- The brain interprets this information.
- The brain then sends information out so the body can respond.



Voluntary actions, the things we choose to do, are directed by the brain. The brain also directs many **involuntary actions**. For instance, the brain controls blinking, heartbeat, and digestion.

The Spinal Cord

The **spinal cord** is a thin cord of neurons that is only about 1 inch in diameter …



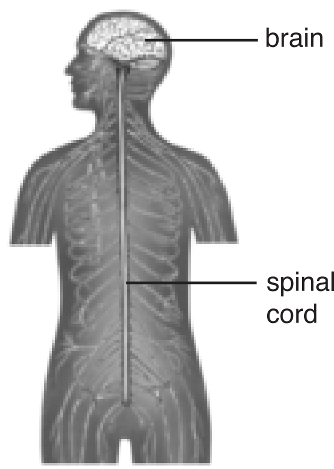
… protected by a series of bony disks called the **vertebral column**.

The spinal cord has two major functions:

- It allows information flow between the body and brain.
- It directs reflex and complex motor actions.

The Central Nervous System

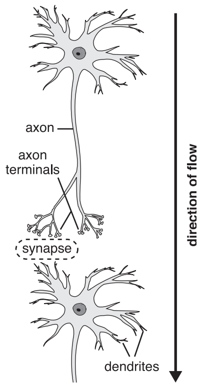
The **central nervous system** is composed of the brain and the spinal cord:



Neuroscience Reference Manual

Signaling

Neural signaling is the function of the nervous system. Each neuron



receives information through its **dendrites** from other neurons or from the environment,

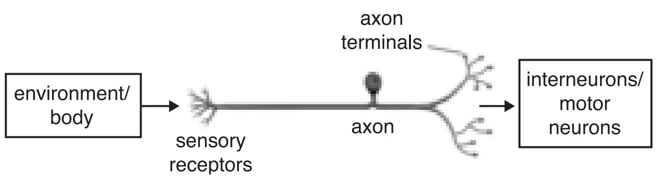
carries this information through its **cell body** and **axon** to its **axon terminals**, and

delivers it either to **the dendrites** of the next neuron in the pathway or to the **body.**

- Information travels in the form of an *electrical signal* from one end of a single neuron to the other end (the axon terminal).
- Only a tiny space separates one neuron from the next neuron in the pathway. This space, together with the axon terminal of the signal-transmitting neuron and the dendrite of the signal-receiving neuron, is called the *synapse*.
- Information crosses the synapse between neurons in the form of a *chemical signal*.

There are three major types of neurons in the nervous system: **sensory neurons**, **motor neurons**, and **interneurons**.

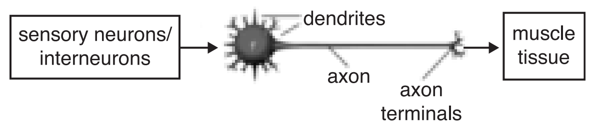
Sensory Neurons Carry Information from the Environment or the Body



Sensory neurons receive information from the *outside environment* or from *inside the body.*

Axons of sensory neurons then carry this information to other neurons located in the brain or spinal cord.

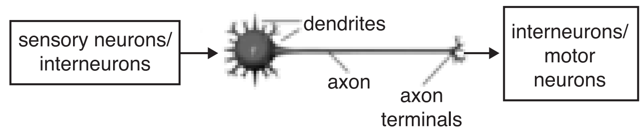
Motor Neurons Cause Actions



Motor neurons receive information from the axon terminals of *sensory neurons* or other *neurons*. The axons of motor neurons are often located in nerves together with axons of sensory neurons.

The **axon terminals** of motor neurons are located in *muscles*. The information delivered to muscle causes the muscle to contract.

Interneurons Carry Information within the Brain and Spinal Cord



Interneurons are neurons that are not motor neurons or sensory neurons.

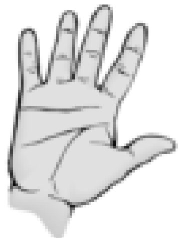
The **dendrites** of interneurons receive signals from the axon terminals of *sensory neurons* or other *interneurons.*

The **axon terminals** of interneurons deliver information to other neurons.

Neuroscience Reference Manual

Reflex Actions

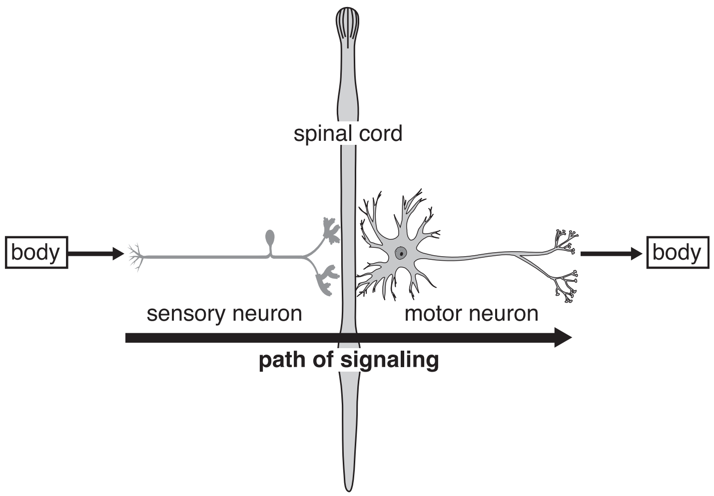
Sometimes the body must respond instantly to a signal from the environment.



If your hand touches a hot stove, you will pull your hand away without thinking about it. Such quick, automatic responses are called **reflex actions**.

Information flows more quickly through short pathways than long ones. We can respond more quickly when information does not have to go all the way to the brain. The neurons of reflex pathways can function without instructions from the brain. Information flows from the body to the spinal cord, then back out to the body, and the body protects itself. Although the brain is not involved in the reflex, it is informed about what is going on, so learning can occur.

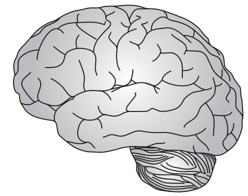
The simplest reflex pathways involve information flowing from a sensory neuron that connects to a motor neuron in the spinal cord.



Voluntary Actions

Voluntary actions, such as talking, eating, or walking, involve making a choice.

To make a choice, we use the **brain**.

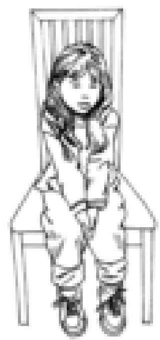


Voluntary pathways require that information collected from sensory neurons goes to the brain. Interneurons carry information within the brain and spinal cord.

Information that activates a voluntary pathway can generate many different responses.

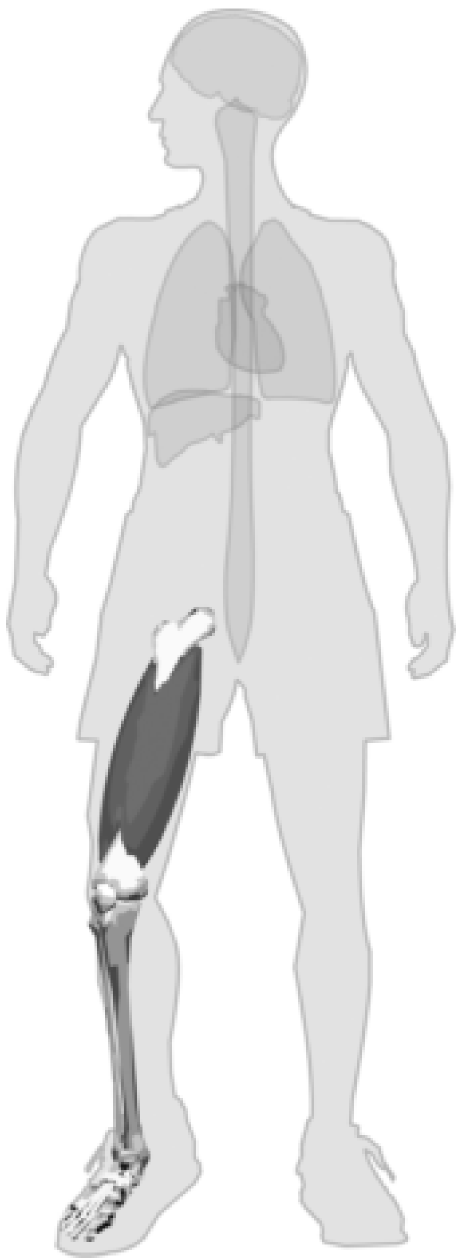
For instance, if someone stands near a chair, he or she can *choose* either to sit or to remain standing.

If sitting were a reflex, people would sit down any time they are near a chair.



Building a Reflex Pathway

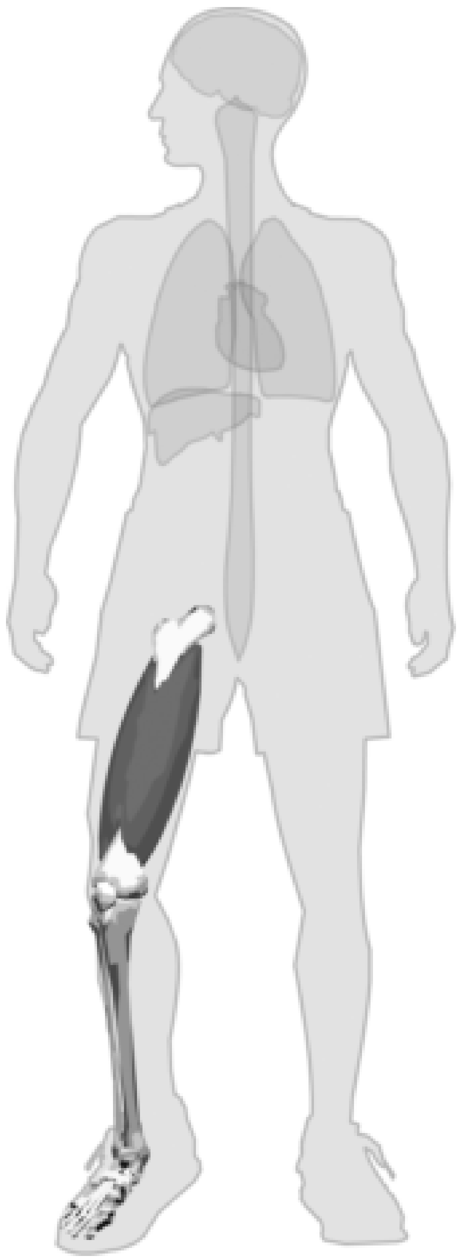
Names: ______________________________ Date: ______________



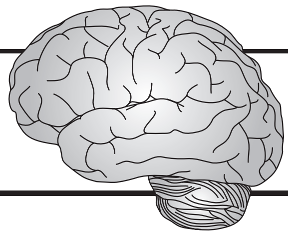
Master 3.4

Building a Voluntary Response Pathway

Names: ______________________________ Date: ______________



Memo from the Director



Learning Research Laboratory

Memo

TO: Research Scientists

FROM: Director of Research

RE: Research Grant

Congratulations everyone! We have received a grant from the National Learning Research Council to investigate factors that affect learning. We will use mice as our experimental model and performance on the Morris Water Maze as our measure of learning in mice.

Our three research questions are as follows:

1. Does social interaction affect learning in mice?
2. Does an enriched environment affect learning in mice?
3. Does exercise affect learning in mice?

This research is very important in helping us understand factors that affect learning. Your hard work is greatly appreciated. I look forward to hearing about your results.

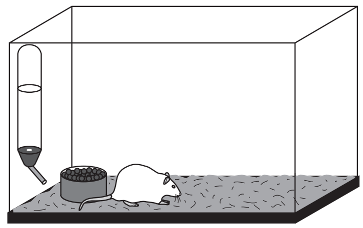
Morris Water Maze Data, Research Question 1 (Web Version)

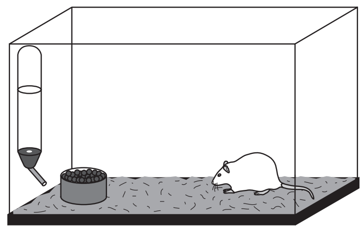
Names: ______________________________ Date: ______________

Research Team #: ______________

Morris Water Maze Data, Isolated Mice
Time to Platform

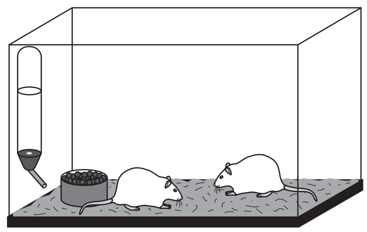
	Day 1	Day 2	Day 3
Mouse 1I			
Mouse 2I			
Average for Isolated Mice			





Morris Water Maze Data, Socialized Mice
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1S			
Mouse 2S			
Average for Socialized Mice			

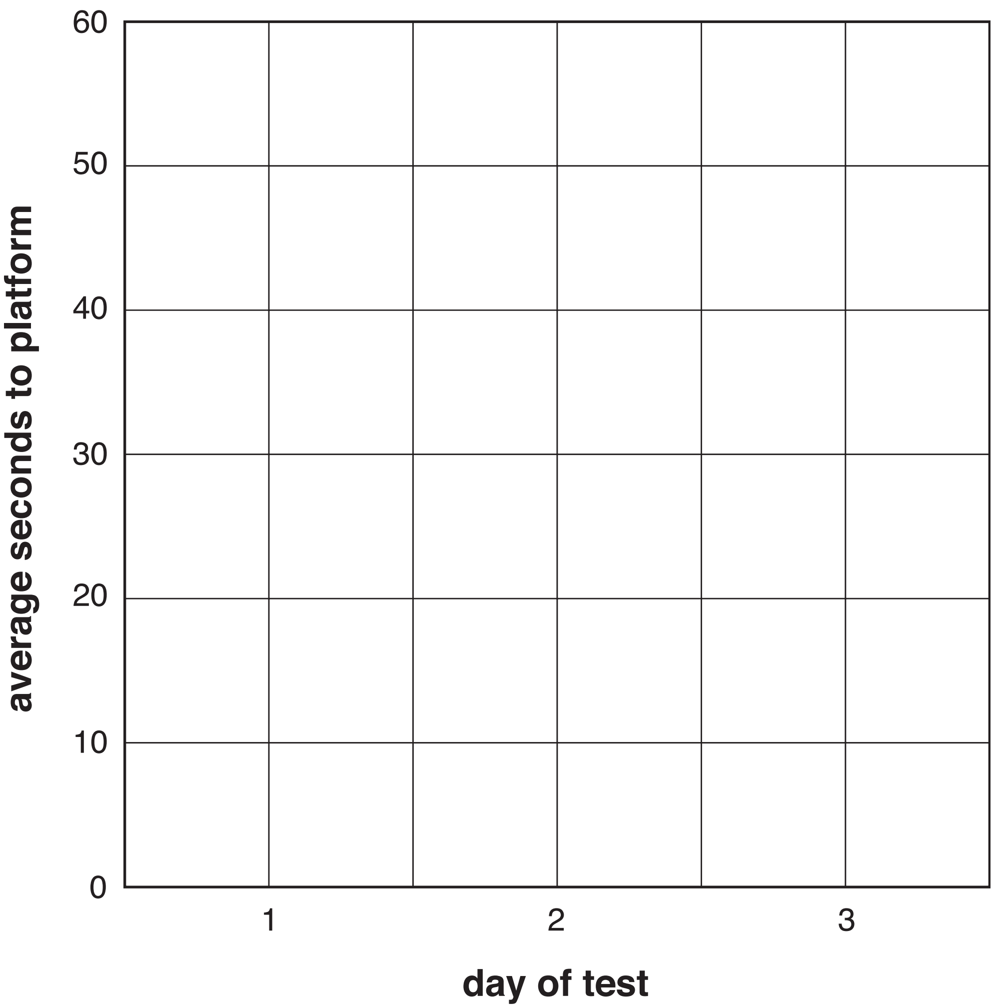


Morris Water Maze Results

Names: ____ Date: ____________________

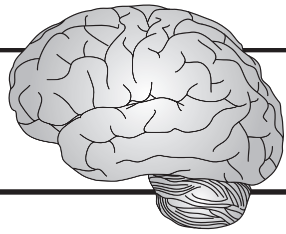
Research Team #: ____________________

Title of Graph: ____



Legend

Memo to the Director on Research Question 1



Learning Research Laboratory

Memo

TO: Director of Research
FROM: Research Team # ______
RE: Analysis of Results, Research Question 1

Below, we describe the experiment to answer Research Question 1, our analysis of the results, and our conclusions.

Research question—Does social interaction affect learning in mice?

Our hypothesis—Socialized mice learn more quickly than isolated mice.

Experiment—Our laboratory technician selected four genetically identical newborn mice from our Animal Care Facility. Two were raised in individual cages, while the other two were raised together in one cage. The performance of each adult mouse was tested over three consecutive days using the Morris Water Maze test.

Results and data analysis—See attached data table and graph.

Conclusions

Our hypothesis was (supported / not supported) by the data from our experiment.

Ways that learning in the isolated and socialized mice were similar: ______________________________

____

Ways that learning in the isolated and socialized mice were different: ____________________________

____

Our conclusion about learning from this experiment is that ______________________________________

____

Scientific Research Reference Manual

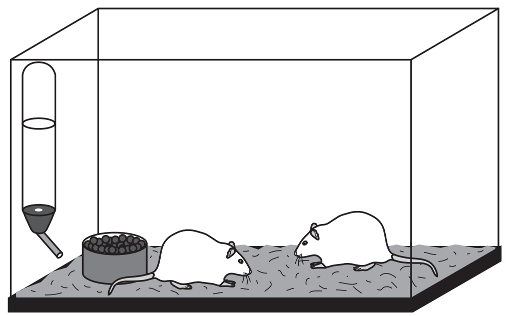
The Mouse: A Model System

Scientists use laboratory animals as *model systems* to study conditions that affect humans. A mouse is a good model system for a human because mice and humans both control their internal functions in about the same way and respond similarly to infection and injuries.

Using mice for research is less expensive and time-consuming than using humans. Researchers can control experimental conditions more easily for animals than for humans.

Raising Mice in the Laboratory

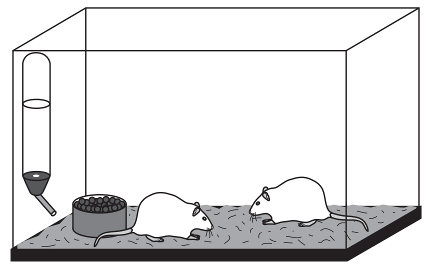
Researchers follow strict guidelines for ethical treatment of animals.



Mouse cages are checked daily to make sure mice have fresh food and water. Cages are kept clean and comfortable.

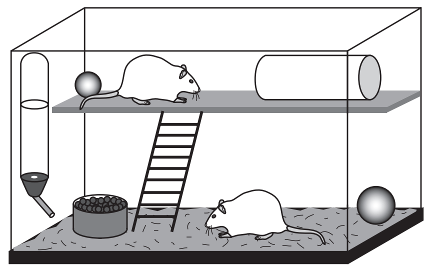
Mouse Cages

Mice are social animals that prefer to be housed together. The following examples show different living conditions.



standard cage

A standard mouse cage contains food, water, and bedding.



enriched cage

An enriched mouse cage contains food, water, bedding, and a variety of stimulating toys.

running wheel

A running wheel allows mice to exercise. Mice use it frequently when it is in their cage.

Scientific Research Reference Manual

Making a Hypothesis

A hypothesis is a testable statement that predicts a result. For example:

Mice raised in different types of cages will learn a task at different rates.

Researchers can make a specific hypothesis if they know something about the situation they are testing. For example, if they know that climbing ladders affects learning, they might make this hypothesis:

Mice raised in cages with ladders learn more quickly than mice raised in cages without ladders.

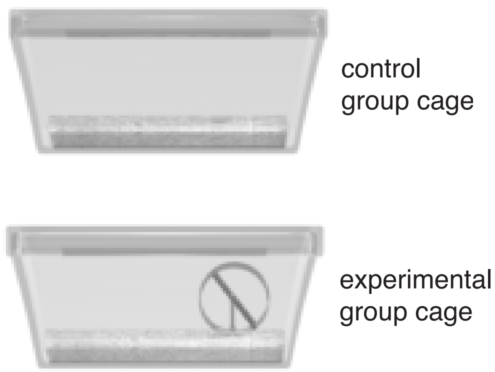
Designing the Right Experiment

Researchers identify experimental and control groups based on their hypothesis. Consider this hypothesis:

Mice that exercise learn more quickly than mice that do not exercise.

The **experimental group** is mice that use an exercise wheel. The **control group** is mice that do not use an exercise wheel, because exercise wheels are not provided under standard laboratory conditions.

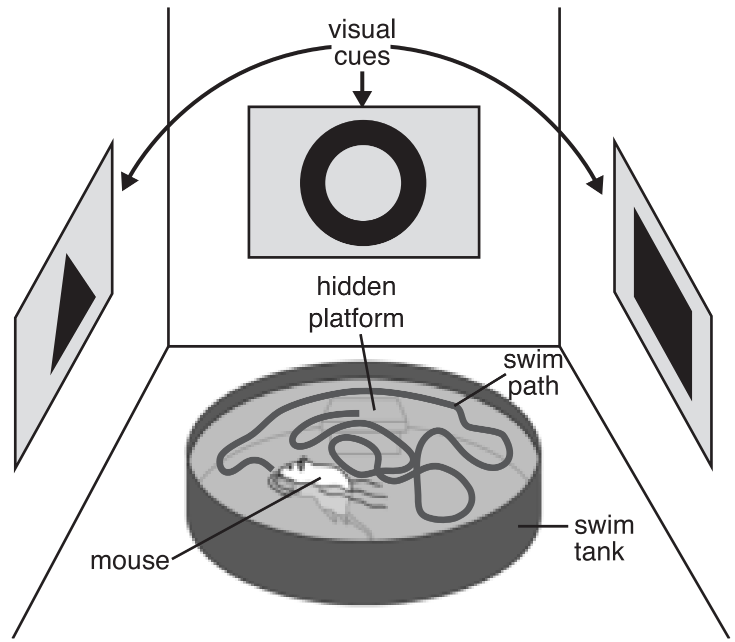
All other conditions are the same for both groups.



Measuring Learning in Mice

Learning in mice can be measured using the Morris Water Maze test. In this test, mice are placed in a swim tank filled with water in which powdered milk has been dissolved. The cloudiness of the water prevents the mice from seeing a platform just under the surface of the water. A mouse standing on the platform can keep its head above water. Mice prefer standing on the platform to swimming in the tank. When mice are placed in the tank, they swim around until they find the platform. The mice use visual cues placed around the room to orient themselves while they are inside the tank.

The Morris Water Maze



Scientific Research Reference Manual

Gathering Data

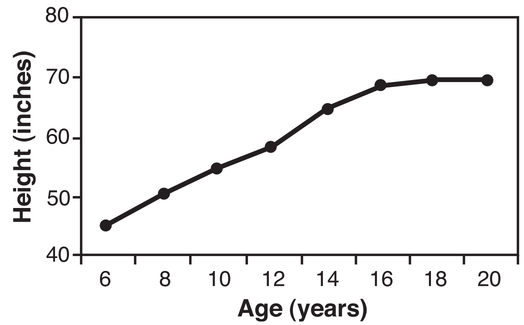
Data are the results of experiments. Scientists write down data as they conduct their experiment. They record their data in a lab notebook, which can be on paper or on the computer.

Analyzing Data

After scientists complete experiments, they analyze their data. Scientists look at all of the data they have collected. The high and low values give them the range of the results. Scientists may calculate data averages. Averages even out natural variations that occur when measures are made across time or across individuals. The average provides scientists with an approximation of a "true" value for the measure.

Mouse #	Length of Swim Path, Day 1
1	56 cm
2	45 cm
3	49 cm
Average	**(56 + 45 + 49)/3 = 50 cm**

Interpreting Data



Graphs help scientists interpret their results by providing a picture of the results. Scientists use graphs to identify trends or patterns in the results of their experiments.

Drawing Conclusions

Because the hypothesis and experiment are based on a research question, you should ask,

Do the results from the experiment provide an answer for the research question?

If the answer is "No" or "I don't know," the experiment was probably not designed correctly. Think about the question and redesign the experiment.

If the answer is "Yes," ask,

Do the results support the hypothesis?

Whether the answer is "Yes" or "No," the research question has been answered. Use evidence from the experiment to defend that answer.

Memo from Lab Technician

Learning Research Laboratory

Memo

TO: Research Scientists
FROM: Lab Technician
RE: Experimental Design, Research Question 1

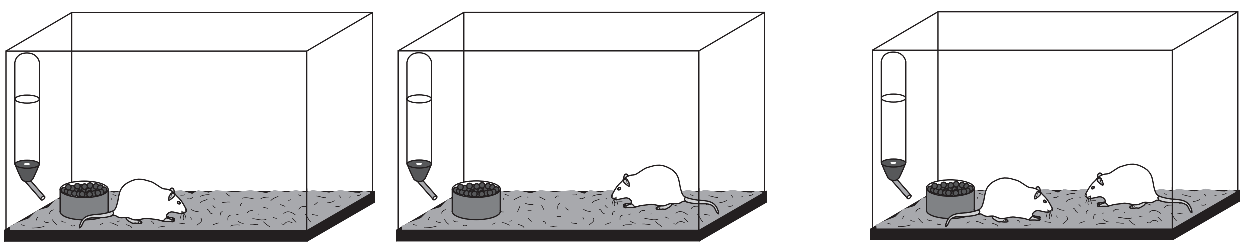
I have designed and run an experiment to answer research question 1. Before you analyze the data, please review my notes on the design of the experiment.

Experimental Design

Research Question: Does social interaction affect learning in mice?

Hypothesis: Socialized mice learn more quickly than isolated mice.

Procedure: I selected four genetically identical newborn mice from our Animal Care Facility. Two were raised in individual cages (Isolated), while the other two were raised together in one cage (Socialized). After they were fully grown, I tested the performance all four adult mice once a day for three consecutive days using the Morris Water Maze test.

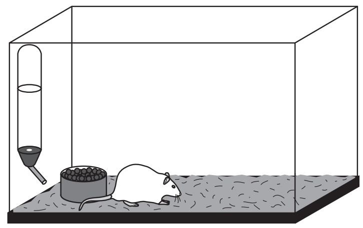


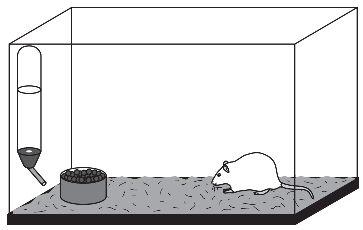
isolated socialized

Morris Water Maze Data, Research Question 1 (Print Version)

Names: ______________________________ Date: ______________

Research Team #: ______________



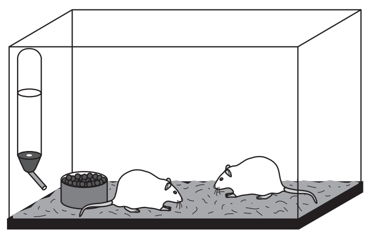


Morris Water Maze Data, Isolated Mice
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1I	50 seconds	34 seconds	33 seconds
Mouse 2I	50 seconds	37 seconds	32 seconds
Average for Isolated Mice			

Morris Water Maze Data, Socialized Mice
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1S	50 seconds	32 seconds	27 seconds
Mouse 2S	50 seconds	33 seconds	30 seconds
Average for Socialized Mice			



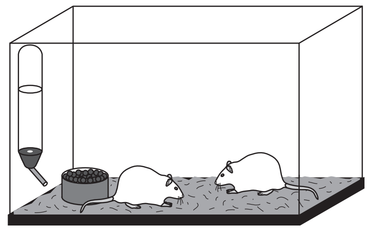
Morris Water Maze Data, Research Questions 2 and 3 (Web Version)

Names: ______________________________ Date: ______________

Research Team #: ______________

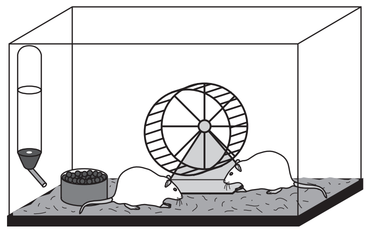
Morris Water Maze Data, Standard Cage
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1S			
Mouse 2S			
Average			



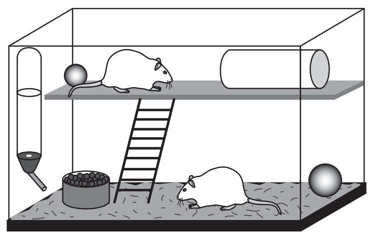
Morris Water Maze Data, Standard Cage with Running Wheel
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1SR			
Mouse 2SR			
Average			



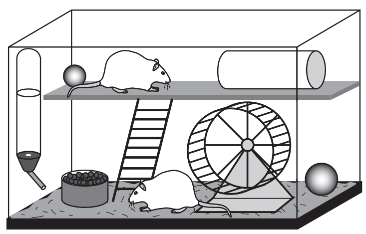
Morris Water Maze Data, Enriched Cage
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1E			
Mouse 2E			
Average			

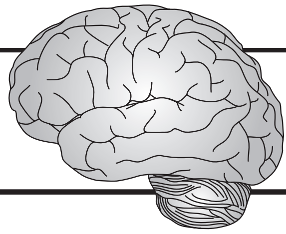


Morris Water Maze Data, Enriched Cage with Running Wheel
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1ER			
Mouse 2ER			
Average			



Memo to the Director on Research Question 2



Learning Research Laboratory

Memo

TO: Director of Research
FROM: Research Team # ______
RE: Results, Research Question 2

Below, we describe the experiment to answer Research Question 2, our analysis of the results, and our conclusions.

Research question—Does an enriched environment affect learning in mice?

Our hypothesis—____

____

Experiment—We selected four infant mice and raised them in pairs in each of the following two conditions:

______ Standard Cage ______ Standard Cage with Running Wheel
______ Enriched Cage ______ Enriched Cage with Running Wheel

The performance of each adult mouse was tested over three consecutive days using the Morris Water Maze test.

Results and data analysis—See attached data table and graph.

Conclusions

Our hypothesis was (supported / not supported) by the data from our experiment.

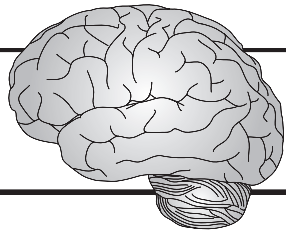
Ways that an enriched environment affected learning in mice: ______________________________

____

Our conclusion about learning from this experiment is that ______________________________

____

Memo to the Director on Research Question 3



Learning Research Laboratory

Memo

TO: Director of Research
FROM: Research Team # ______
RE: Results, Research Question 3

Below, we describe the experiment to answer Research Question 3, our analysis of the results, and our conclusions.

Research question—Does exercise affect learning in mice?

Our hypothesis—____

____

Experiment—We selected four infant mice and raised them in pairs in each of the following two conditions:

______ Standard Cage ______ Standard Cage with Running Wheel
______ Enriched Cage ______ Enriched Cage with Running Wheel

The performance of each adult mouse was tested over three consecutive days using the Morris Water Maze test.

Results and data analysis—See attached data table and graph.

Conclusions

Our hypothesis was (supported / not supported) by the data from our experiment.

Ways that exercise affected learning in mice: ________________________________

____

Our conclusion about learning from this experiment is that ______________________

____

Summary of Research Findings

Learning Research Laboratory

Research Questions

1. Does social interaction affect learning in mice?

2. Does an enriched environment affect learning in mice?

3. Does exercise affect learning in mice?

Next Research Assignment

Learning Research Laboratory

Memo

TO: Research Scientists

FROM: Director of Research

RE: Next Assignment

Excellent work everyone! Thank you for analyzing the experimental data to answer Research Question 1. Now let's move on to Research Questions 2 and 3.

Even-numbered teams, please work on Research Question 2:

> Does an enriched environment affect learning in mice?

Odd-numbered teams, please work on Research Question 3:

> Does exercise affect learning in mice?

Once again, I greatly appreciate your hard work. I look forward to hearing about your results.

Experimental Design

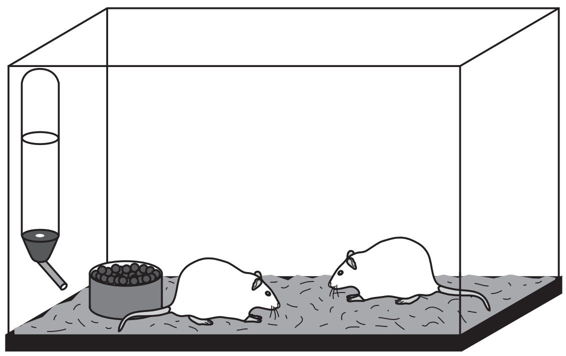
Names: ______________________________________ Date: ______________

Research Team #: ______________

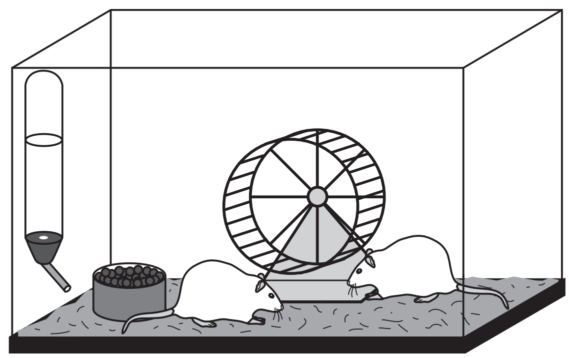
Research Question: ____

Hypothesis: ____

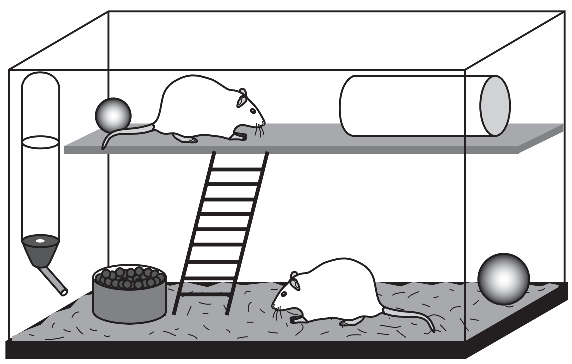
Procedure: Four genetically identical infant mice were selected. Mice were raised in pairs under each of the two conditions circled below. The performance of each adult mouse was tested over three consecutive days using the Morris Water Maze test.



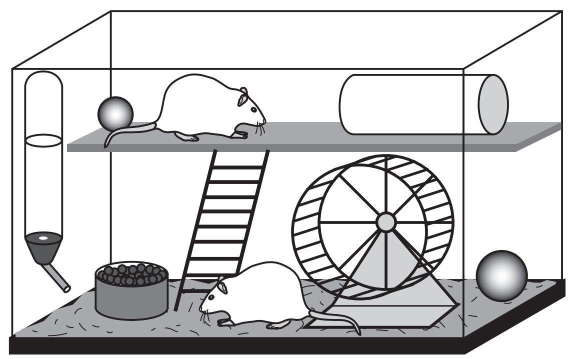
standard cage



standard cage with running wheel



enriched cage



enriched cage with running wheel

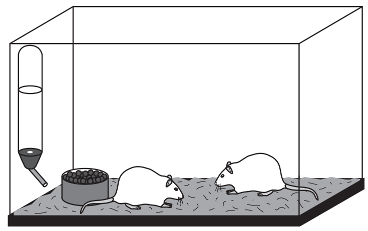
Morris Water Maze Data, Research Questions 2 and 3 (Print Version)

Names: ______________________________ Date: ______________

Research Team #: ______________

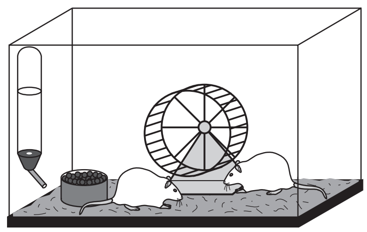
Morris Water Maze Data, Standard Cage
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1S	50 s	32 s	27 s
Mouse 2S	50 s	33 s	30 s
Average			



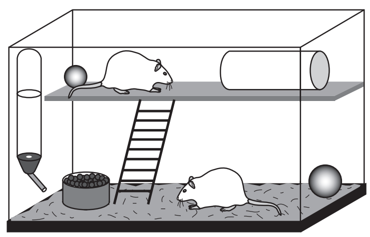
Morris Water Maze Data, Standard Cage with Running Wheel
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1SR	50 s	24 s	17 s
Mouse 2SR	50 s	25 s	20 s
Average			



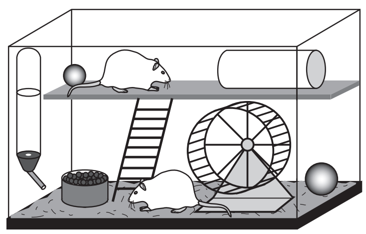
Morris Water Maze Data, Enriched Cage
Time to Platform

	Day 1	Day 2	Day 3
Mouse 1E	50 s	38 s	29 s
Mouse 2E	50 s	36 s	25 s
Average			

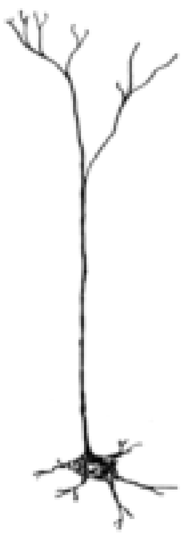


Morris Water Maze Data, Enriched Cage with Running Wheel
Time to Platform

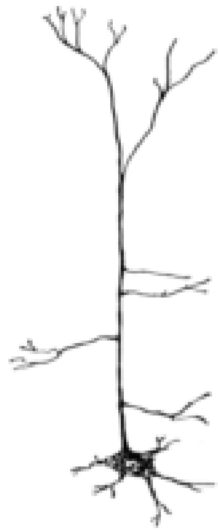
	Day 1	Day 2	Day 3
Mouse 1ER	50 s	26 s	22 s
Mouse 2ER	50 s	27 s	20 s
Average			



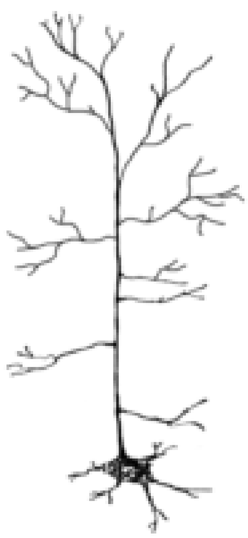
Neuron Structure Data



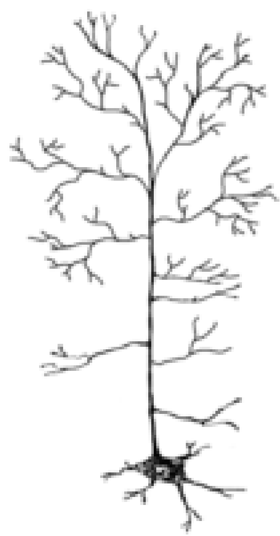
Mouse 1: Standard Cage,
No Water Maze Activity



Mouse 2: Standard Cage,
Practiced Morris Water Maze



Mouse 3: Enriched Cage,
No Water Maze Activity



Mouse 4: Enriched Cage,
Practiced Morris Water Maze

The brain contains your sense of self; it makes you who you are.

Case Study—John M.

John has always been one of my favorite patients. Outgoing and well-liked, John excelled at academics and athletics. Captain of the football team at his high school, he went on to become a star quarterback at his college. The whole town was heartbroken when John injured his spine on the football field and was told he would never walk again. I was very worried that John would lose hope for his life—after all, he was only 22 at the time of his injury.

But John surprised us all by devoting himself to his physical therapy and his schoolwork. He has always had a special knack for physics; after his injury, he completed a tough honors physics program in his remaining years of college. This spring, John graduated at the top of his class, and even won a fellowship for graduate work in particle physics! In addition, he has won several Wheelchair Olympics events in our town over the past three years. John is an inspiration to us all.

Three Case Studies

Case Study—Frank L.

Angelica brought her 54-year-old husband, Frank, to my office last year. Frank had been a devoted police sergeant and husband. Then a burglar shot him in the head. He had emergency surgery to remove a bullet from his brain. Frank recovered physically; he could walk, talk, and take care of himself as he did before. However, he had a great sense of humor before his injury. He loved watching comedy movies with Angelica. Now Frank says he doesn't enjoy movies. He doesn't find many things funny. Before the injury, Frank was a calm, friendly man. Now he is angry all the time. Sometimes Frank smashes things in the house and yells at anyone in sight. Both Frank and Angelica are unhappy.

Case Study—Lisa R.

Lisa is an energetic 36-year-old librarian. She loves her job. Lisa is also blind. She received a blow to the back of her head in a car accident several years ago. The injury caused her loss of sight. She had always enjoyed teaching children's activities at the library. Now she teaches in a special program for blind children. Lisa encourages the children to practice reading because books open new worlds to everyone. The library has become the best source for Braille books in the state. Lisa is very proud of her accomplishments.

Case Study—Mandy T.

Mandy is 78, and she has been my patient for the past 15 years. Her son Kevin has brought her to my office for the past three years. Mandy has Alzheimer's disease, a brain disease that causes memory loss, confusion, and unstable emotions. She no longer knows who I am or why "this strange man" (Kevin) has brought her to the clinic. She swears, complains loudly, and has frequent outbursts of anger at Kevin and me. It is hard for Kevin to see his mother this way. He remembers her as a gentle, kind, and caring mother who took care of everyone around her.