THIS IS YOUR BRAIN

TEACHING ABOUT NEUROSCIENCE AND ADDICTION RESEARCH

TERRA NOVA
LEARNING SYSTEMS

NSTA press
National Science Teachers Association

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NSTApress
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PREFACE

The original idea for *This Is Your Brain: Teaching About Neuroscience and Addiction Research* was developed by two physician-scientists. The curriculum was proposed to the National Institutes of Health and underwent review and critique by scientific experts. The curriculum was seen as a priority, and our multidisciplinary team was encouraged (and funded) to develop it. The curriculum was overseen and approved by a scientist who also serves as a program officer at the National Institute on Drug Abuse. The creation of the educational materials was informed by up-to-date scientific information, and scientists and science teachers methodically evaluated the components of the curriculum. Wherever possible, we integrated and fulfilled national standards for middle school education (e.g., National Science Education Standards, National Council of Teachers of Mathematics, National Council of Teachers of English, Consortium of National Arts Education Associations, and others). Once these steps were completed, the curriculum was reviewed and tested by classroom teachers, by parents, and by students. The curriculum was then revised on the basis of all of this feedback, and the ultimate result is this book, the Mouse Maze, and all of the curricular companion materials included in *This Is Your Brain*.

Our aim in developing this work is to inform young people about the value of science in our world. Our intent is that this curriculum will help support independent and intelligent thinking about some of the very hardest issues in science and society—what questions to pursue, how scientific work is performed, and how science is conducted ethically. Our hope is that this work will inspire many young people to become the scientists who will answer important questions that will lead to healthier lives and a healthier world in the future.

No single individual authored this book, and it does not represent the perspective, approach, or opinion of a single individual. This project was undertaken as a collaborative effort that was based in a small company, Terra Nova Learning Systems (TNLS). TNLS is owned by one of the physician-scientists who conceptualized and served as a principal investigator for this project. At the time in which *This Is Your Brain* was being developed, TNLS was located in Milwaukee, Wisconsin; it subsequently has moved to Palo Alto, California.

This work is dedicated to Helen, Willa, and Tommy Roberts, and to the memory of their father, Brian B. Roberts, M.D., the other physician-scientist who led the Terra Nova Learning Systems team in creating this curriculum.

SECTION ONE

HOW TO UNDERSTAND AND USE *THIS IS YOUR BRAIN*

10-LESSON UNIT DESCRIPTION

Welcome to *This Is Your Brain: Teaching About Neuroscience and Addiction Research*, an innovative curriculum that creatively explores contemporary real-world issues in science and research. Funded by the National Institute on Drug Abuse (NIDA) and developed in consultation with nationally recognized experts, this stimulating unit presents 10 comprehensive, ready-to-use lessons for the middle school classroom. Each 45-minute lesson incorporates National Science Education Standards and purposeful objectives to sharpen important decision-making and higher-order thinking skills.

Following scientific method principles, the lessons in this book guide students through concepts such as brain structure and function, the neurobiology of drug addiction, the role of biomedical research in understanding addiction and prevention, and the ethics of animal inclusion in biomedical research. Filled with skill-based, multicurriculum activities, this unit is ideal for use by middle school science, health, physical education, and family consumer science teachers as well as guidance counselors, social workers, psychologists, and nurses.

INTRODUCTION

Insights from neuroscience are changing how we live each day, and will create a better future for our world. Neuroscience helps us to understand the underlying processes of life and healthy development, and it helps us to know why we may become vulnerable to disease. It also helps to identify ways of preventing, diagnosing, and treating serious illnesses and conditions.

One example is the Nobel Prize–winning neuroscience work from more than 60 years ago that has led to the near-elimination of polio in North America. Polio most commonly affects children and is caused by a virus that kills cells in the spinal cord and brain. When these cells die, the body loses the functions served by these cells, such as motor movement or breathing. Depending on what cells are affected, a person may experience disability (e.g., paralysis of an arm or a leg) or death (e.g., loss of respiratory function). Neurological research led to the identification of the virus that causes polio and gave insights that led to a vaccine effective in neutralizing the virus before it attacked the spinal cord and brain.

More recently, neuroscience has led to a far greater understanding of brain development; of the circuitry and plasticity of the brain; and of the functions of the brain, such as imagination and memory. Neuroscience has also led to greater knowledge of health problems including addiction, autism, bipolar disorder, dementia, depression, infectious diseases such as HIV and "Mad Cow disease," multiple sclerosis, Parkinson's disease, schizophrenia, and stroke. Neuroscience has facilitated the development of new treatments (and the calculation of when treatment interventions will be optimally successful). And amazing new neuroscience research has led to previously unimaginable approaches to rehabilitation. For example, Stanford researchers have developed a way in which people can draw and write on a computer screen just through *thinking* about drawing and writing, without using their hands. These studies are now being tried with people paralyzed due to catastrophic spinal cord injuries—with incredible results.

In *This Is Your Brain*, we have focused on neuroscience and the specific area of drug abuse research. Drug use and abuse has become a substantial public health burden in our country in terms of personal suffering and societal impact, with the greatest impact on today's young people. A recent study, the National Survey on Drug Use and Health (NSDUH), found that over 19 million Americans aged 12 or older were current (past month) illicit drug users, with marijuana use being most prevalent. Moreover, the study reported 3.8% of youths ages 12 or 13 identified themselves as current illicit drug users, 10.9% for youths ages 14 or 15, and 17.3% for youths ages 16

or 17, with use peaking at 21.7% among 18- to 20-year-olds. In another study, the 2009 Monitoring the Future survey, 6.6% of 12th graders admitted to using methamphetamines in the prior year. The CDC's most updated figures suggest that 8.7% of people age 12 and older used illicit drugs in the prior month. The abuse of legal prescription medications has also increased greatly, with recent estimates of 2.8% of people age 12 and older misusing psychotherapeutic agents for non-therapeutic purposes in the prior month. These statistics indicate an urgent need for preventative measures, specifically drug abuse education, to deter drug use by our country's youth.

The economic costs associated with drug use, abuse, and addiction are staggering. The devastating effects influence all aspects of personal and social life, including healthcare, crime, social welfare, lost productivity, infant morbidity and mortality, and premature death. With access to addictive substances at an all-time high, students need a foundational understanding of the underlying causes of and reinforcements to drug abuse in order to make responsible, informed, ethical decisions regarding drug use prevention, research, and treatment.

It is critically important to focus young people's attention on efforts to deter illicit drug use because their risk of exposure to drugs increases substantially as they pass from elementary school to middle and high school. Children in early and middle adolescence, who are struggling with their own identity and morals development, become especially susceptible to peer pressure and the need to "fit in." Education focused on the physiological effects of drug use and dependency provides students with the knowledge needed to make responsible choices regarding their own behavior.

To develop therapies that will help people, scientific research sometimes involves the inclusion of animals. This is true for studies to help treat cancer or infection, as well as studies that look for therapies for diseases that affect the brain, kidney, or other organs of the body. The inclusion of animals in research has historically played a pivotal role in the advancement of medical technology and illness prevention. The need for studies with animals is especially important in the area of drug abuse research. Many invaluable experiments could not be conducted with human volunteers, such as uncovering the mechanisms of drug addiction or the search for safe alternative treatment methods. Our society has said that use of animals for this purpose, of helping humanity and assuring a better future for our environment, is ethical—but only under certain strict conditions. Within the lessons in this book we explore these issues in response to the priorities set by the National Institutes of Health. There are

INTRODUCTION

two objectives: First, we want students to learn how science is helpful and second, we want to examine how science is conducted and overseen in order to assure that it is careful and ethical. Although the need to treat animals humanely is widely accepted and rigorously monitored, media exposés of animal mistreatment (e.g., in the food and cosmetics industries and by some medical researchers) have contributed to increased interest, especially among young people. This curriculum will provide a foundation for students to begin to formulate their own answers to ethical questions concerning the use of animals in medical research.

According to the most recent data from the U.S. Census Bureau (2000), there were approximately 49 million children and youth between the ages of 6 and 17 living in the United States. These young people are the future of our country and they are growing up during a period of explosive scientific growth, particularly in the areas of the neurosciences—including genetics, basic science, and medication development. The need for students to understand the value of the neurosciences and the damaging effects of illicit drug use, the mechanisms of addiction, and of the scientific and ethical basis of animal-based drug abuse research is critical.

10-LESSON UNIT GOALS AND OBJECTIVES

This Is Your Brain: Teaching About Neuroscience and Addiction Research focuses on the neurobiology and consequences of drug use and abuse, the positive role of drug abuse research in our society, and the ethical guidelines and practices for inclusion of animals in research. The unit meets an important ethical need in contemporary scientific education for young people and is designed to generate greater understanding and support for scientists and clinicians who rely on evidence derived from animal research studies.

Developed to cover key scientific and ethical content domains, this unit includes specific lesson plans for teachers, interactive learning materials for students, and companion materials for parents. The content complies fully with the National Research Council's *National Science Education Standards* and all existing ethics standards related to biomedical research.

Key Unit Learning Objectives

As a result of completing the 10-lesson unit, middle school science students will be able to:

1. describe the fundamental principles of the scientific method
2. identify the effects drug use and abuse have on the structure and function of various human body systems
3. develop an understanding of the social/family, biological, legal, academic, psychological/behavioral, and economic consequences of drug use and misuse
4. analyze risk factors associated with drug use and abuse
5. explain the structure and specialized function of the brain and neuron cells
6. demonstrate the process of message transfer between neuron cells
7. illustrate how drugs of abuse interfere with the communication process between neurons
8. define disease and formulate an explanation of why drug addiction is considered a brain disease
9. distinguish the difference between drug abuse and addiction
10. develop an understanding of the four different approaches to scientific research
11. analyze the potential harms/benefits of scientific research to animals and society
12. identify the historical contributions of animals in medical research
13. demonstrate an understanding of the following ethics terms: *autonomy, beneficence, compassion, justice*, *nonmaleficence,* and *veracity*
14. explain the role of an Institutional Animal Care and Use Committee (IACUC) and federal guidelines such as the Animal Welfare Act
15. describe the three Rs (reduce, refine, and replace) of animal inclusion in research and how researchers apply these principles

10-LESSON OVERVIEW

I. Development of a Teen Profile

Lesson 1: Who Is Chris?

Through class and small-group activities, students develop a profile of a teen named Chris, including his/her physical attributes, hobbies, goals, family and school life. Throughout the unit, the story of this teen unfolds as concepts pertaining to drug addiction, biomedical research, and animal inclusion in research are explored. Emphasis is placed on the process of the scientific method.

II. Overview of Brain Structure and Drug Addiction/Abuse

Lesson 2: Thinking Like a Scientist

Students explore the importance of the scientific method and its application both to historic scientific discoveries and our everyday lives. The story of Chris continues to unfold as students discover Chris has tested positive for drugs. Students analyze and categorize a variety of facts related to drug use. By using decision-making skills, students discuss and gain awareness of the many aspects of Chris's life that have been affected by the use of drugs.

Lesson 3: How Does the Brain Work?

Through exploration and discovery, students are introduced to the general regions and functions of the human brain. Neuron structure and purpose are explored, as well as how the brain sends and receives messages. Students build on this inquiry to address the importance of questions in gathering information to understand scientific processes.

Lesson 4: How Do Drugs Affect the Brain?

Students build on Lesson 3's exploration of neuron structure to understand how neurons transfer messages and how drug use and abuse negatively interferes with the function of the brain. Using critical-thinking skills, students analyze the risks associated with drug use and abuse, the science of addiction, and how drug use changes the normal functioning of human body systems.

III. How Science Is Helping Us Understand Drug Addiction

Lesson 5: How Science Is Helping

In this lesson, students explore the four categories of scientific research that are helping us understand drug abuse and addiction: biological, population-based, behavioral, and genetic research. Students analyze and sort a variety of research studies to develop an understanding of how knowledge derived from scientific research translates into clinical practice.

Lesson 6: Why Research Is Important

Students explore, analyze, and sort a variety of research studies. Emphasis is given to illustrations of the historical contributions animals have made in medical research. Students begin to consider some basic ethical issues surrounding the inclusion of both animals and humans in research.

IV. Thinking Like a Scientist: Research and Ethics

Lesson 7: What Is Ethics in Science?

Students investigate and clarify their understanding of the concept of ethics. They explore the meaning of six key ethics principles and how these principles might apply to hypothetical situations.

Lesson 8: Applying Ethics to Research

Students explore ethical considerations in research and focus on the specific example of the inclusion of animals in medical research. They work in small groups to analyze the potential harms and benefits to animals in two hypothetical research scenarios, with the goal of deciding which, if either, they would approve for study. They learn about the factors and guidelines that are important for a researcher to follow to ensure ethical treatment of animals.

Lesson 9: Ensuring the Ethical Conduct of Research

Researchers must comply with very strict rules when doing their scientific work. In this lesson, students learn about studies involving animals that have helped scientists, doctors, and veterinarians to develop new medical treatments, not only for humans but also for animals. Scientists look for ways to reduce, replace, and refine (the three Rs) the number of animals included in research. In this lesson, students explore the federal regulations (e.g., Animal Welfare Act) that are in place to protect animals, and discuss acceptable practices for their inclusion in research.

Lesson 10: Thinking about the Future of Research

Students explore the benefits and shortfalls of alternative research methods, and discuss when and how and these options might be incorporated to help achieve the three Rs. For example, brain imaging technologies and computer simulations may be an appropriate replacement to animal testing, and genetic DNA markers can help refine the extent to which animals are involved in a research project.

NATIONAL SCIENCE EDUCATION STANDARDS

The National Research Council's *National Science Education Standards* (NSES) is the result of the productive collaboration of hundreds of teachers, parents, school administrators, curriculum developers, college professors, scientists, and government officials. Within a framework of developmentally appropriate levels of scientific and ethical knowledge and understanding, the standards emphasize an approach that is

- "hands on" (i.e., involving students in experiments and observations), and
- "minds on" (i.e., stimulating students to inquire, describe, ask questions, formulate and test explanations, and reason about conclusions logically).

Designed to promote "coordination, consistency, and coherence to the improvement of scientific education," the NSES serve as the criteria upon which local, state, and national programs judge the quality of their science education efforts. Not only do these standards identify what students "need to know, understand, and be able to do to be scientifically literate at different grade levels," they provide an educational framework within which teachers can create an effective learning environment that promotes the outstanding performance of all students. To help ensure effective and high-quality content, the Research and Ethics lessons were specifically developed to meet a number of these critical standards (see next page).

In addition, the lessons have been designed to encourage students to reflect on prior knowledge, explore and question new information, and make connections to their everyday lives and the real world in a more complex manner. Founded on the principles outlined in the Biological Sciences Curriculum Study (BSCS) 5E Instructional Model (see p. 12), this process helps students become self-directed learners and construct knowledge that is meaningful to them, an essential process in the cognitive development of learners.

NATIONAL SCIENCE EDUCATION STANDARDS MET IN UNIT

Content Standards: Grades 5–8	Lesson Correlation
Standard A: Science as Inquiry	
• Abilities necessary to do scientific inquiry	All lessons
• Understanding about scientific inquiry	All lessons
Standard B: Physical Science	
• Transfer of energy	3 and 4
Standard C: Life Science	
• Structure and function in living systems	2, 3, 4, 5, 6, 8, and 10
• Regulation and behavior	2, 3, 4, 5, 6, and 8
Standard E: Science and Technology	
• Abilities of technological design	8 and 10
• Understanding about science and technology	10
Standard F: Science in Personal and Social Perspectives	
• Personal health	2, 4, 5, 6, 7, 8, and 9
• Risks and benefits	2, 4, 5, 6, 7, 8, and 9
• Science and technology in society	2, 4, 5, 6, 8, 9, and 10
Standard G: History and Nature of Science	
• Science as a human endeavor	1, 2, 6, and 7
• Nature of science	2, 5, 6, 7, and 8

5E INSTRUCTIONAL MODEL

THE BIOLOGICAL SCIENCES CURRICULUM STUDY (BSCS) 5E INSTRUCTIONAL MODEL

Engage

These experiences mentally engage the students with an event or question. Engagement activities help students make connections with what they know and can do. During the engagement phase, the teacher can

- Create a need to know/create an interest
- Assess prior knowledge
- Focus on a problem/ask questions

Explore

Students work with one another to explore ideas through hands-on activities. Under the guidance of the teacher, students experience a common set of experiences that helps them clarify their own understanding of major concepts and skills. During the exploration phase, the students

- Investigate
- Develop awareness/practice skills
- Design, plan, build models, collect data
- Test predictions and form new predictions

Explain

Students explain their understanding of the concepts and processes they are learning. Teachers help students clarify their understanding and introduce information related to the concepts to be learned. During the explanation phase, teachers and students

- Clarify understanding
- Define concepts or terms
- Share understandings for feedback
- Listen critically to one another
- Form generalizations
- Refer to previous activities

Elaborate

These activities challenge students to apply what they have learned and extend their knowledge and skills. During the elaboration phase, students

- Build on their understanding of concepts
- Use knowledge of concepts to investigate further—extension
- Apply explanations and skills to new, but similar, situations
- Provide practice and reinforcement—application

Evaluate

Students assess their own knowledge, skills, and abilities. Evaluation activities also allow teachers to evaluate students' progress. During the evaluation phase, students

- Draw conclusions using evidence from previous experiences
- Demonstrate an understanding or knowledge of a concept or skill

LESSON FORMAT AND TIMELINE

This Is Your Brain contains all the necessary teacher materials—concepts and overviews, standards and objectives, procedures, group and hands-on activities, material supply list, time management estimates, color reproducibles, answer keys, resource lists[1], optional extensions, daily assessments, several final unit assessment options, a computer-based Mouse Maze knowledge assessment game, and a parent letter describing the course—in a user-friendly kit.

To ensure an optimal learning experience for the students, it is recommended teachers complete the *entire* 10-day curricular unit in sequence, because each lesson builds on the previous one. Each lesson is designed for a minimum 45-minute class and includes optional extension activities that can be incorporated if desired.

A PowerPoint of the 20 transparencies in these lessons is available for your convenience. Visit *www.nsta.org/publications/press/extras/brain.aspx* to download.

1 Numerous website links are provided throughout the unit for teacher, student, and parent use. Please note that the internet is a continually changing environment and these URLs are subject to change without notice.

FLEXIBILITY OF UNIT

Teachers can easily adapt the lessons and activities to suit a variety of grade levels and learning abilities. The suggested timeline can be modified to suit the needs of varying school schedules, curriculum maps, and individual teaching styles.

ASSESSMENT OPTIONS

This Is Your Brain includes a summative unit test (multiple-choice, short-answer, and essay questions) for use by students in paper format, as well as a multiple-choice assessment in the form of an interactive, computer-based Mouse Maze game. The unit also provides several authentic assessment options, including: creating a board game, producing an antidrug commercial, developing a school or class newspaper, and designing an informative poster. Assessment options can be used throughout the unit or at its completion to ensure effective learning.

MATERIAL SUPPLY LIST

LESSON	ACTIVITY ONE	ACTIVITY TWO	ACTIVITY THREE	ACTIVITY FOUR
1	overhead projector Transparency A Worksheet 1	Worksheet 1	overhead projector Transparency B Lesson 1 homework extension three-ring binder or folder three-hole punch	
2	overhead projector Transparencies B, C, & D Worksheets 2 & 3	Worksheet 4 Transparencies E & F	overhead projector Transparency F Steps of the scientific method bookmark Worksheet 2 Lesson 2 homework extension	
3	overhead projector Transparencies F & G Worksheet 5	overhead projector Transparencies H & I Worksheets 6, 7, & 8	overhead projector transparencies H & J Lesson 3 homework extension	
4	overhead projector Transparency J colored pencils or crayons Worksheet 9 20 small objects of 2 different colors	Worksheet 9 internet access Transparency I (optional)	overhead projector Transparency K Lesson 4 homework extension	
5	overhead projector Transparencies K & L research labels Worksheet 10	Worksheet 11	overhead projector Transparency M Lesson 5 homework extension	

MATERIAL SUPPLY LIST

LESSON	ACTIVITY ONE	ACTIVITY TWO	ACTIVITY THREE	ACTIVITY FOUR
6	overhead projector Transparency M 5 large sheets of poster paper Worksheet 12 animal cards (1 sheet per group) scissors tape	student glossary	overhead projector Transparency N Lesson 6 homework extension internet access	
7	overhead projector Transparency N Worksheet 13	overhead projector Transparency O Worksheets 13 & 14	Worksheet 13	overhead projector Transparency P Lesson 7 homework extension
8	overhead projector Transparency P scenario #1 handout scenario #2 handout Worksheet 15	scenario #1 handout scenario #2 handout Worksheet 15	overhead projector Transparency Q Lesson 7 honmework extension	
9	overhead projector Transparency Q Worksheet 16	Talking Points handout	Worksheet 17	overhead projector Transparency R Worksheet 17
10	overhead projector Transparency S 1 set of three Rs research cards per group Worksheet 18	overhead projector Transparency R Worksheet 19		

VOCABULARY TERMS INTRODUCED IN EACH LESSON

Lesson 1:

characteristic
hypothesis
profile

Lesson 2:

brain
cocaine
data
drug
ecstasy
experiment
heroin
inhalant
illicit
licit
LSD
marijuana
neuron
nicotine
scientific method
steroid

Lesson 3:

axon
axon terminals
brainstem
cell body
cerebellum
chemical message
dendrites
dopamine
electrical message
frontal lobe
GABA
myelin
neurotransmitter
occipital lobe
parietal lobe
receptors
serotonin
soma
synapse
synaptic gap
temporal lobe

Lesson 4:

abuse
addiction
chronic
craving
disease
drug abuse
drugs of abuse
limbic system
reward
tolerance

Lesson 5:

behavioral research
biological research
biomedical research
control group
experiment
genetic research
population-based research
research
THC

VOCABULARY TERMS INTRODUCED IN EACH LESSON

Lesson 6:

model

Lesson 7:

autonomy
beneficence
bioethics
compassion
ethics
explicit
implicit
justice
opinion
morals
nonmaleficence
values

Lesson 8:

protocol
Institutional Animal Care and Use Committee

Lesson 9:

animal welfare
Animal Welfare Act (AWA)
United States Department of Agriculture (USDA)

Lesson 10:

anesthesia
blood work
cell culture
chemical simulation
computer simulations
genetic alterations
genetic markers
magnetic resonance imaging (MRI)
mathematical modeling
mechanical simulation
non-mammalian models
PET scan
reduce
refine
replace
Three Rs
tissue culture

LESSON 4

HOW DO DRUGS AFFECT THE BRAIN?

Teacher Lesson Plan: Overview and Concepts

In this lesson, students build on Lesson 3's exploration of neuron structure. In addition to understanding how neurons transfer messages, students learn how drug use interferes with the normal functioning of the brain and has negative effects. Students continue to follow the story of Chris through the process of the scientific method as they gather important information about brain function and drug use. Students will also be challenged to develop an explanation of why drug addiction is considered a disease of the brain.

Students discover the process of message transfer in the brain and what happens to that process when drugs of abuse are introduced into the body. Using critical-thinking skills, students analyze the risks associated with drug use and abuse, the science of addiction, and how drug use changes the normal functioning of human body systems. This knowledge will be used in the next lesson to explore the role of scientific research in understanding drug addiction.

Objectives

After completing this lesson, students will be able to

- demonstrate the process of message transfer between specialized neuron cells;
- explain the role of neurotransmitters in message transmission;
- illustrate how drugs of abuse interfere with the communication process between neurons;
- define *disease* and formulate an explanation of why drug addiction is considered a brain disease; and
- explain the difference between drug abuse and addiction.

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National Standards Met in Lesson 4

National Science Education Standards

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Standard B: Physical Science

- Transfer of energy

Standard C: Life Science

- Structure and function in living systems
- Regulation and behavior

Standard F: Science in Personal and Social Perspectives

- Personal health
- Risks and benefits
- Science and technology in society

National Health Education Standards

- Students explain the relationship between positive health behaviors and prevention of injury, illness, disease, and premature death. (standard 1)
- Students explain how health is influenced by the interaction of body systems. (standard 1)
- Students predict how decisions regarding health behavior have consequences for self and others. (standard 6)

National Council of Teachers of English

- Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities. (standard 11)
- Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information). (standard 12)

ACTIVITY ONE
BRIDGING THE GAP

Time needed for completion:

20 minutes

MATERIALS

For the class:

- Overhead projector
- Transparency J
- Small colored objects
- Colored pencils or crayons

For each student:

- Worksheet 9
- Small identical objects in two colors

Preparation

Gather 5–10 small, identical objects of one color and one of the same object in another color (e. g., buttons, beads, geometric-shaped math counters) to demonstrate normal and interrupted neural communication.

Procedure

1. Show students Transparency J: *How Have Drugs Affected Chris's Brain?* from Lesson 3. Have students share what they already know about drug use and its impact on brain function. Ask students if they think Chris's brain or body functions have been affected by drug use. Ask for specific examples to describe possible symptoms or effects Chris might be experiencing due to drug use. Examples could be high blood pressure, red eyes, sleeplessness, irritability, seizures, distractibility, poor energy, paranoia, irregular heart rhythms, difficulty in school, memory loss, or problems getting along with family and friends.
2. Explain to students that they will be using the information from Lesson 3 to discover what happens to normal brain function when drugs are introduced into the body.
3. Choose five student volunteers to create a human neuron chain. Each person will represent a neuron: the left hand represents the dendrites, the body is the soma, the right arm is the axon, and the right hand represents the axon terminal. Have students stand in a line with arms outstretched with fingertips close but not touching.
4. To initiate the transmission, place a small object of the common color in the left hand of the first person in line. That person will transfer the object to his or her right hand (signifying the signal moving through the "neuron"), and then place the object in the

4 ACTIVITY ONE
BRIDGING THE GAP

hand of the person to the right. The next person transfers the object to his or her right hand and places it in the left hand of the person to the right. This sequence continues to the end of the chain. The person at the end of the chain should be instructed to perform an action signifying the successful communication (e.g., a wink, a laugh, saying a word). Discuss with the class each step of the process stressing the fit between neurotransmitter and receptor and that the receptor must be available for each neurotransmitter in order for the signal to continue down the chain.

5. To demonstrate an interrupted signal, start the human neuron chain again, this time inserting an object of the second color into the left hand of the person in the middle of the chain. Begin the process to demonstrate how the message (object coming down the chain) cannot be accepted by this neuron because there is already an object being used by the receptor.
6. Have the students get into their small groups. To review the concepts from Lesson 3, distribute this lesson's Worksheet 9: *Brain Function and Drug Use* (p. 85).
7. Have students complete only Worksheet 9: Part A: Bridging the Gap. (Encourage the students to review Worksheet 6: *How a Neuron Sends a Message* and Worksheet 8: *Sending the Message Across the Synapse* from Lesson 3 in their project portfolio pages.) In Worksheet 9: Part A (question 1), students are asked to make a detailed color drawing of a two-neuron chain, including neurotransmitters, showing how a message is passed between neurons. Students should label the dendrites, soma, axon, axon terminals, synaptic gap, neurotransmitters, and receptors, and show the direction of the electrical impulse. On their drawing, students should show how the shape of the neurotransmitter fits the shape of the receptor.
8. In the small groups, have students discuss and complete Worksheet 9: Part A (question 2).

ACTIVITY TWO
BREAKING THE CHAIN

Time needed for completion:

25 minutes

MATERIALS

For each student:

- Worksheet 9
- Internet access

Procedure

1. Ask students to *hypothesize* what may happen to message transmission in the brain if drugs of abuse are present. In their small groups, have students brainstorm a list of possible ways a drug of abuse (such as cocaine, marijuana, inhalants, alcohol, and so on) could interfere with message transmission between neurons. Encourage students to use both color objects and their drawing from Worksheet 9: *Brain Function and Drug Use,* Part A as a model. After students have had several minutes to brainstorm, have the groups share their lists with the class. Record the complete list on the board.
2. Consider displaying Transparency I: *Sending the Message Across the Synapse.* Using the list brainstormed by the class, lead the students in a discussion about how drugs can interfere with message transmission between neurons in the following basic ways:
   - The drug of abuse (such as PCP) may have a *similar size and shape* as the natural neurotransmitter and take its place on the receptor of the dendrite. If the natural neurotransmitter (frequently dopamine) cannot find its receptor because the drug has taken its place, the message cannot be delivered and the neurotransmitter builds up in the synaptic gap.
   - Some drugs (such as cocaine) can *block the reabsorption* of the natural neurotransmitter back into the axon terminal of the sending neuron, causing a flood of the neurotransmitter in the synapse.
   - Some drugs (such as methamphetamine) *bind into the receptors* and start an unusual chain of electrical impulses. This causes the neuron to release large amounts of the natural neurotransmitter into the synapse.

4 ACTIVITY TWO
BREAKING THE CHAIN

3. Direct students to: *www.thirteen.org/closetohome/science/html/animations.html* to view an online animation of these effects on nerve cell transmission.
4. Explain to students that when there is an unnatural amount of a neurotransmitter present in the synaptic gap, it causes the person to have significantly increased feelings of pleasure and reward. The brain may react to the excess dopamine in several ways:
   - The brain may reduce the production of natural dopamine to compensate for the excess released due to drug use.
   - The brain may decrease the number of dopamine receptors to compensate.
   - Some neurons in the brain may die from the toxicity of the drug taken.
5. Over time, excess neurotransmitter introduced through drug abuse can damage the ability to feel pleasure and the nerve cells can become dependent on the drug to function properly.
6. Have students complete question 4 of Worksheet 9, *parts A and B* in their small groups. Have students select one color to represent the natural neurotransmitter and a different color for the drug of abuse.
7. Ask students how this process can lead to a person becoming addicted to a drug. Write the terms *abuse* and *addiction* on the board and ask students to describe the difference between their meanings.
   - Drug *abuse* is the *repeated* use of illegal drugs or the *inappropriate* use of legal drugs to increase the feelings of pleasure, reduce stress, or alter reality.
   - Emphasize to students that an *addiction* is apparent when a person has a pattern of behavior in which drugs are used and sought in an uncontrolled and compulsive way—even in the face of negative health and social consequences. When a person becomes addicted to a drug, the drug craving and seeking becomes central to the person's life. Tell students that no one can know how quickly someone can become addicted to a drug, but scientific evidence has shown that exposure to drugs in young people has a more potent addictive impact than exposures later in life. This is especially important for children to understand.
8. Ask students, "Why can it be difficult for a person to stop using a drug?" Explain that through research, scientists have learned that repeated drug use fundamentally

changes the brain so that the limbic system craves the drug just as it does food and water. That is why a person may experience withdrawal symptoms when the individual stops taking the drug. When drug use is no longer voluntary, a person has become truly addicted or "dependent" on drugs.

9. Introduce the term *disease*, which is an abnormal condition that impairs the normal functioning of an organism. Using this definition and the concepts discussed, have students analyze why drug addiction can be considered a disease of the brain. (*Note:* There is some controversy in the public regarding the "disease" concept of drug addiction. However, it is widely accepted in the biomedical and science community that drug addiction becomes a chronic health condition like asthma or heart disease with biological, psychological, and social influences. Discuss with students why there are differing views on this concept.)
10. Ask students, "If drug addiction is a disease, is there a cure?" Explain there is no cure for drug addiction, but it is treatable through programs that may use behavior therapy and sometimes medications. The purpose of treatment is to restore a healthier life by regaining control over the drug craving, seeking, and use. Significant research is being done by organizations such as the National Institute on Drug Abuse to help scientists understand the effects of drug use on the human body, how addiction occurs, and how it can be more effectively treated.
11. Have students complete the remaining items in Worksheet 9: Part B.

4

ACTIVITY THREE

CLOSING TEASER—TOMORROW'S HEADLINE

Time needed for completion:

5 minutes

MATERIALS

For the class:

- Overhead projector
- Transparency K

For each student:

- Lesson 4 homework extension
- Worksheet 9

Procedure

After completing the activities, assign the homework extension, then display Transparency K: *Can Research Help Chris?* without providing additional details.

Homework Extension: The Brain Scrambler

Hand out Homework Extension: *The Brain Scrambler* (p. 88) for students to complete before the next lesson. Have students complete Worksheet 9 if they were unable to finish during class.

Optional Extensions

- Have students construct detailed 3-D models of a chain of neurons to illustrate the process of message transfer. The models should be labeled and include arrows to indicate the direction of the neural impulse.
- Assign groups of students to prepare an oral or written research report on the specific effects various drugs of abuse have on the structure and function of human body systems and particularly the brain. Selected drugs could include cocaine, marijuana, LSD, ecstasy, heroin, steroids, or methamphetamine.
- Have students create a commercial or skit illustrating the risks associated with drug use, abuse, and dependence. Students should include a scientific explanation of drug addiction and why addiction is a brain disease with biological, psychological, physiological, and social detriments. Students should include some of the negative consequences that are due to drug use and abuse, such as memory loss, chronic respiratory problems, depression, headaches, racing heart, increased blood pressure, strokes, bleeding in the brain, paranoia, aggressiveness, and sleep disorders.

Resources for Further Exploration

Websites

Centre for Neuro Skills. Brain function and deficits: *www.neuroskills.com/index.shtml?main=/tbi/brain.shtml*

HowStuffWorks. How your brain works: *http://science.howstuffworks.com/brain.htm brain.shtml*

NIDA for teens. Introducing your brain: *http://teens.drugabuse.gov/facts/facts_brain1.asp*

NIDA for teens. Mind over matter teacher's guide: *http://teens.drugabuse.gov/mom/tg_intro.asp*

Books

Friedman, D. P., S. Rusche, and J. Biswas. *False messengers: How addictive drugs change the brain*. New York: CRC Press.

Grabish, B. R. *Drugs and your brain.* Center City, MN: Hazelden.

Papa, S., and S. Miller. *Amazing brain: Addiction.* Farmington Hills, MI: Blackbirch Press.

Sylwester, R. 1995. *A celebration of neurons: An educator's guide to the human brain*. Alexandria, VA: ASCD.

4 HOW DO DRUGS AFFECT THE BRAIN?

TRANSPARENCY K

Name_____ Date_____

BRAIN FUNCTION AND DRUG USE

WORKSHEET 9

Part A: Bridging the Gap

1. **Draw a detailed diagram of a two-neuron chain, including neurotransmitters, showing how a message is sent between neurons. Label the dendrites, soma, axon, axon terminals, synaptic gap, neurotransmitters, and receptors, and draw an arrow to indicate the direction of the electrical impulse. Be sure to show how the shape of the transmitter (object) fits the shape of the receptor.**

2. **Using the terms *message, neurotransmitters, lock, key, axon terminal, receptor,* and *synaptic gap*, explain how a message is transferred between neurons.**

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Name_____ Date_____

BRAIN FUNCTION AND DRUG USE

WORKSHEET 9 (CONTINUED)

Part B: Breaking the Chain

3. Draw and label a colored diagram showing how a drug such as marijuana can interrupt message transfer between neurons. Be sure to include the axon terminal, synapse, neurotransmitters, and receptors.

4. Write a paragraph to explain why drug addiction is considered a brain disease. Describe some ways in which drug use may have negatively affected Chris's brain and body.

Name_____ Date_____

BRAIN FUNCTION AND DRUG USE

WORKSHEET 9 (CONTINUED)

5. Explain three ways a drug can interfere with natural message transmission between neurons.

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6. Do you believe scientific research can help Chris? Explain why or why not.

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Name_____ Date_____

THE BRAIN SCRAMBLER

HOMEWORK EXTENSION

Based on the material in your Project Portfolio and the Student Glossary (p. 251), follow the clues to unscramble each of these words and write the letters on the lines provided. Rearrange the shaded letters to solve the ultimate puzzle at the bottom of the page.

a. A short description of a person's characteristics — ILEROPF __ __ ■ __ __ __ __

b. Neurotransmitter that produces feelings of pleasure when released by the brain's reward system — MOPIDENA __ __ __ __ __ ■ __ __

c. Specialized branches that receive messages from other neurons and relay them to the soma — STENDDRIE __ __ __ ■ __ __ ■ __ __

d. The addictive drug in tobacco — ENOCNTII __ __ ■ __ __ __ __ __

e. The repeated use of drugs to increase pleasure or reduce stress — GUDR SEAUB ■ __ __ __ __ __ __ __ __

f. The part of the body that controls all thoughts, feelings, and other body functions. — NIRAB __ __ __ __ ■

g. Part of the neuron that contains the nucleus — OAMS __ __ __ ■

h. A fatty material that surrounds and insulates the axons of some neurons — LYMNIE __ __ __ __ ■ __

ULTIMATE PUZZLE:

Uncontrollable, compulsive drug seeking and use, even in the face of negative health and social consequences.

Answer: _____

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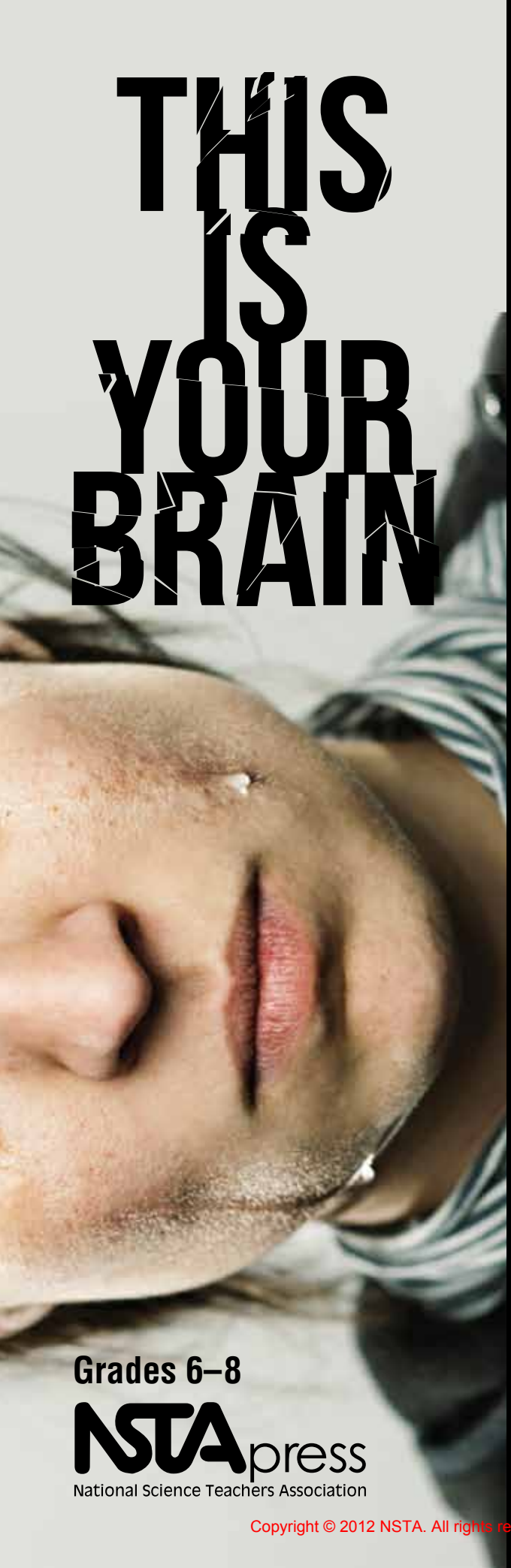
THIS IS YOUR BRAIN



TEACHING ABOUT NEUROSCIENCE AND ADDICTION RESEARCH

"The need for students' understanding of the value of the neurosciences—and the damaging effects of illicit drug use, the mechanisms of addiction, and the scientific and ethical basis of animal-based drug abuse research—is critical to creating a better future for our children."

—From the Introduction to *This Is Your Brain*

This innovative curriculum presents 10 comprehensive, ready-to-use lessons about contemporary real-world issues exploring drug use and abuse. Following scientific method principles, the 45-minute lessons guide middle school students through brain structure and function as well as the neurobiology of drug addiction. In addition, the book explores the role of biomedical research in understanding addiction and prevention, and the ethics of including animals in biomedical research.

The lessons cover:

- How the brain works
- How drugs affect the brain
- Why research is important
- Applying ethics to research
- The future of research

Supplemental material includes assessments, teacher resources, and a downloadable program that your students can use to review the material.

Filled with skill-based, multidisciplinary activities, *This Is Your Brain* includes specific lesson plans for teachers, interactive learning materials for students, and companion materials for parents. The book is ideal for middle school teachers of science, health, physical education, and family consumer science as well as guidance counselors, social workers, psychologists, and nurses.

Grades 6–8

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