# The Brain: Understanding Neurobiology Through the Study of Addiction

under a contract from the
National Institutes of Health




U.S. Department of Health and Human Services
National Institutes of Health
National Institute on Drug Abuse


Center for Curriculum Development
5415 Mark Dabling Boulevard
Colorado Springs, CO 80918

**BSCS Development Team**
Nancy M. Landes, Principal Investigator
Anne L. Westbrook, Project Director
Debra A. Hannigan, Curriculum Developer
Ann C. Lanari, Research Assistant
Carol Vallee, Project Assistant
Karen Bertollini, Project Assistant
Mary Crist, Project Assistant
Carrie Hamm, Project Assistant
Raphaela Conner, Project Assistant
Barbara Perrin, Production Manager
Ric Bascobert, Editor
Diane Gionfriddo, Photo Research
Lisa Chilberg, Graphic Designer
Sandra Matthews, Evaluator

**Videodiscovery, Inc., Development Team**
Shaun Taylor, Vice President for Product Development
Michael Bade, Multimedia Producer/Project Director/Videographer
Greg Humes, Assistant Multimedia Producer
Cathy Saum, Graphic Designer
Lucy Flynn Zuccotti, Photo Research
Michele Moore, Assistant to Project Director
Jennifer Hunt, Costumes and Makeup
Mike Commins, Gaffer (Lighting)
Chet McKnight, Sound
Lee Strucker, Script Writer

**Advisory Committee**
Andrea Baruchin, Vanderbilt University, Nashville, Tennessee
Michael Dougherty, Hampden-Sydney College, Hampden-Sydney, Virginia
David Friedman, Wake Forest University, Winston-Salem, North Carolina
Reese Jones, University of California, San Francisco, California
Kathleen Ranwez, Pomona High School, Arvada, Colorado
Cathrine Sasek, National Institute on Drug Abuse, Bethesda, Maryland
Martin Shields, James Caldwell High School, West Caldwell, New Jersey
Susan Wooley, American School Health Association, Kent, Ohio

**Writing Team**
Mary Ann Cutter, University of Colorado, Colorado Springs, Colorado
JoAnne Dombrowski, Consultant, Somerton, Arizona
Michael Dougherty, Hampden-Sydney College, Hampden-Sydney, Virginia
David Friedman, Wake Forest University, Winston-Salem, North Carolina
Paula Henderson, Newark High School, Wilmington, Delaware
Laura McNicholas, Veterans Affairs Medical Center, Philadelphia, Pennsylvania
E. Leong Way, University of California San Francisco, San Francisco, California

**Artist**
Susan Bartel

**Cover Design**
Martha Blalock, Medical Arts and Photography Branch, National Institutes of Health

**Cover Illustration**
Anna Rose Childress, Ph.D., University of Pennsylvania School of Medicine

**Design and Layout**
Angela Greenwalt, Finer Points Productions

**Photo Credits**
Carlye Calvin

**BSCS Administrative Staff**
Carlo Parravano, Chairman, Board of Directors
Rodger W. Bybee, Executive Director
Janet Carlson Powell, Associate Director, Chief Science Education Officer
Larry Satkowiak, Associate Director, Chief Operating Officer

**Videodiscovery, Inc., Administrative Staff**
D. Joseph Clark, President
Shaun Taylor, Vice President for Product Development

**National Institutes of Health**
Bruce Fuchs, Office of Science Education
Lucinda Miner, National Institute on Drug Abuse
William Mowczko, Office of Science Education
Cathrine Sasek, National Institute on Drug Abuse
Gloria Seelman, Office of Science Education

**Field-test Teachers**
Domenica Altieri, Sonora High School, La Habra, California
William Barlow, Preston High School, Kingwood, West Virginia
Gwyn Bush, McNicholas High School, Cincinnati, Ohio
Jennifer Carpio, St. Joseph's Academy, St. Louis, Missouri
Kathy Cattrell, Crestview High School, Columbiana, Ohio
Aster Chin, Lowell High School, San Francisco, California
Katy Colvin, Fort LeBoeuf High School, Waterford, Pennsylvania
Linda Dizer, Girls Preparatory School, Chattanooga, Tennessee
Karen Emery, Shady Spring High School, Shady Spring, West Virginia
Fran Enright, Evergreen Senior High School, Evergreen, Colorado
Leon Fox, Perry High School, Perry, Iowa
Charlotte Freeman, Girls Preparatory School, Chattanooga, Tennessee
Marian Gonzalez, Lowell High School, San Francisco, California
Paula Henderson, Newark High School, Wilmington, Delaware
Wade Hill, Battle Mountain High School, Minturn, Colorado
John Johnson, Creekview High School, Carrollton, Texas
Karel Lilly, Foshay Learning Center, Los Angeles, California
Marilyn Link, North Carolina School of Science and Mathematics, Durham, North Carolina
Brian McCarry, Monsignor Bonner High School, Drexel Hill, Pennsylvania
Glenn Miller, Wheaton High School, Wheaton, Maryland
Tracy Peterson, Hamilton East High School, Hamilton, New Jersey
Kathleen Ranwez, Pomona High School, Arvada, Colorado
Ruth Regent-Smith, Pius XI High School, Milwaukee, Wisconsin
Martin Shields, James Caldwell High School, West Caldwell, New Jersey
Ann Sowd, Jackson High School, Massillon, Ohio
Sandra Sundlof, Wheaton High School, Wheaton, Maryland
Kay Thornton, Perry High School, Perry, Iowa
Linda Wright, Creekview High School, Carrollton, Texas
Lois Wysocki, Radnor High School, Radnor, Pennsylvania

**Special Thanks**
BSCS and Videodiscovery thank the following individuals for providing resources or reviewing specific activities in this unit:
Dr. William Armstrong, University of Tennessee;
Dr. Richard Cannon, National Heart, Lung and Blood Institute;
Dr. Monica Skarulis, National Institute of Diabetes and Digestive and Kidney Diseases;
Dr. Michael Phelps, UCLA School of Medicine;
Dr. Johannes Czernin, UCLA School of Medicine;
David Twomey, UCLA School of Medicine; and
Jim Strommer, UCLA School of Medicine.

**Cover Image Description**
The cover shows a positron emission tomography (PET) image of a human brain. Blood flow to a particular brain area, the amygdala, increases when a person addicted to cocaine experiences cravings for the drug. The image, when compared with those taken of people who aren't addicted to cocaine, reveals that just eliciting memories of drug abuse in the addicted person is sufficient to cause changes in brain activity.

This material is based on work supported by the National Institutes of Health under Contract No. 263-98-C-0056. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the funding agency.



**Revised and reprinted March 2010**
**NIH Publication No. 09-4871 ISBN: 1-929614-05-5**

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 the *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 on Drug Abuse, and curriculum design experts from Biological Sciences Curriculum Study (BSCS) and Videodiscovery. 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. For the 2010 (fourth) printing, key sections of the supplement were updated, but the Student Lessons remain basically the same.

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 the BSCS 5E Instructional Model (page 3), 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 videos and 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.

For a complete list of curriculum supplements, updates, availability, and ordering information, or to submit feedback, please visit our Web site or write to

Curriculum Supplement Series
Office of Science Education
National Institutes of Health
6100 Executive Boulevard
Suite 3E01 700 MSC 7520
Bethesda, MD 20892-7520

We appreciate the valuable contributions of the talented staff at Biological Sciences Curriculum Study (BSCS) and Videodiscovery, Inc. 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. We welcome your feedback.

Bruce A. Fuchs, Ph.D.
Director
Office of Science Education
National Institutes of Health
*supplements@science.education.nih.gov*

[1] The National Academy of Sciences released the *National Science Education Standards* in 1996, outlining 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 biomedical and behavioral 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 and 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 into 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 $30 billion in 2009.

## 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 of treatments for 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 or behavioral 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 health 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 or behavioral sciences, determines the project's overall merit and priority in advancing the research agenda of the particular NIH funding institutes and centers.

About 38,500 research and training applications are reviewed annually throughout 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.

## The Nobelists

The roster of people who 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 hepatitis. You can learn more about Nobelists who have received NIH support.

## 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 these:

- 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 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.

## Science Education

Science education by NIH and its institutes and centers contributes to ensuring the continued supply of well-trained basic research and clinical investigators, as well as the myriad professionals in the many allied disciplines who support the research enterprise. These efforts also help educate people about scientific results so that they can make informed decisions about their own—and the public's—health.

This curriculum supplement is one such science education effort, a collaboration among four partners: the NIH National Institute on Drug Abuse, the NIH Office of Science Education (OSE), Biological Sciences Curriculum Study, and Videodiscovery, Inc.

OSE learning tools support teachers in training the next generation of scientists and scientifically literate citizens. These materials cover information not available in standard textbooks and allow students to explore biological concepts by using real world examples. In addition to the curriculum supplements, OSE provides a host of valuable resources accessible through the OSE Web site.

We welcome your comments about existing resources and suggestions about how we may best meet your needs. Feel free to write us.

For more about NIH, visit its Web site.

# About the National Institute on Drug Abuse

The National Institute on Drug Abuse (NIDA), one of the research institutes that comprise the National Institutes of Health, was established in 1974 as the Federal focal point for research, treatment, prevention and training services, and data collection on the nature and extent of drug abuse. NIDA's mission is to lead the nation in bringing the power of science to bear on drug abuse and addiction. This charge has two critical components. First, NIDA supports and conducts research across a broad range of disciplines to explore the biomedical and behavioral foundations of drug abuse. Second, NIDA ensures that the results of research are rapidly and effectively disseminated so that the scientific findings can be used to improve drug abuse and addiction prevention, treatment, and policy.

NIDA is the world's leading supporter of research on the health aspects of drug abuse and addiction. NIDA-supported science addresses the most fundamental and essential questions about drug abuse, ranging from the molecule to managed care, and from DNA to community outreach research. When NIDA was founded, many people incorrectly viewed drug abuse as a problem of people with character flaws and weak wills. Today, thanks to the research accomplishments of hundreds of scientists, those simplistic ideologies are being replaced by a better understanding of the complex biological, behavioral, social, and public health aspects of drug abuse. Scientists have shown that while initial experimentation with drugs may be voluntary, continuing drug abuse changes the brain in fundamental and long-lasting ways. These brain changes trigger the compulsive drug-seeking and drug-taking behaviors that are the hallmarks of drug addiction. NIDA's scientists have clearly shown that drug abuse is a preventable behavior and drug addiction is a treatable brain disease. Among the many and diverse accomplishments over the past three decades, NIDA-supported research has

- identified the molecular sites in the brain where every major drug of abuse—opioids, cocaine, PCP, and THC (the active ingredient in marijuana)—has its initial effect. These discoveries, together with computer-aided drug design, are paving the way to development of novel medications to break the cycle of addiction.
- produced a neurobehavioral model to explain drug-taking behavior to improve treatment and rehabilitation methods.
- supported the development of three medications, LAAM, buprenorphine, and naltrexone, through the approval process by the FDA for the treatment of opiate addiction.
- supported the development and evaluation of pharmacologic treatment for newborns withdrawing from exposure to narcotics.
- defined nicotine addiction and the scientific basis for therapy using nicotine gum and skin patches.
- pioneered innovative community-based research on AIDS prevention efforts that showed that drug users will change AIDS risk behaviors, which can reduce their susceptibility to HIV infection and AIDS.
- demonstrated that participation in methadone treatment significantly reduces HIV seroconversion rates and decreases high-risk behaviors.
- demonstrated that successful drug abuse treatment reduces criminality as well as relapse to addiction.
- demonstrated the value of treating the depression and other mental disorders of people who abuse drugs to improve the results of addiction therapy.
- measured the positive impact of comprehensive research-based community drug prevention strategies that involve the media, schools, families, neighborhoods, and the workplace.
- demonstrated that science education about drug abuse and the brain improves student achievement in science.

- used advanced imaging techniques to identify in awake humans the specific brain circuits that are involved in craving, euphoria, and other sequelae of drug addiction. These exciting studies are providing the foundation for the development of new, targeted medications to block individual aspects of drugs.
- used molecular genetic technologies to clone the genes for the major receptors for virtually every abusable drug, thus providing scientists with the tools necessary to study in fine detail how drugs of abuse exert their many behavioral effects.
- produced genetically engineered animals in which a particular drug receptor had been eliminated, or "knocked out." These animals are providing unprecedented insight into how drugs exert their many effects in the brain and produce addiction.
- demonstrated that prenatal exposure to cigarettes has long-term effects on cognitive performance.
- successfully immunized rats against the psychostimulant effects of cocaine, thus opening up the possibility of developing a vaccination against cocaine addiction.

The results of these and other achievements through NIDA-funded research offer this country's best hope for solving the medical, social, and public health problems of drug abuse and addiction.

The need for greater knowledge of drug abuse continues to grow. Ever-changing drug use patterns, the continuing transmission of HIV infection among people who abuse drugs, and the need to develop new and effective treatment and prevention methods underscore the importance of research in finding new and better ways to alleviate the pain and devastation of addiction. NIDA's goals for the future include

- to design and develop new medications for marijuana and stimulant (such as cocaine and methamphetamine) addiction by building on the recent molecular discoveries that have uncovered the basis for addiction in the brain.
- to develop techniques to detect subtle effects of drug exposure in children of drug-using parents so that early preventive or clinical interventions can be instituted.
- to broaden research on women and addiction to determine the biological and behavioral differences that need to be addressed in effective drug abuse prevention and treatment.
- to reduce the spread of HIV infection through improved drug abuse interventions and better understanding of the interactions of drugs of abuse and the body's immune system.
- to apply state-of-the-art neuroimaging techniques to the problems of drug abuse prevention and treatment.
- to design, develop, and test new behavioral therapies and promote their use for appropriate patient populations.
- to study the treatment of special clinical problems presented by people who abuse drugs and have HIV, tuberculosis, hepatitis, and other infections.
- to understand the organization and financing of drug abuse treatment and its benefits to the larger healthcare system.
- to identify the protective and resiliency factors that prevent drug use in those individuals with multiple risk factors so more effective prevention techniques can be developed.
- to strengthen the research infrastructure, by providing additional opportunities for research training and career development for clinical researchers and improved mechanisms for training and mentoring minority researchers.
- to expand the use of scientific information to educate the public about the real nature of drug abuse and addiction and the hope and promise for more effective prevention and treatment.
- to broaden the dissemination of research findings and improve drug abuse prevention and treatment practice and policy.
- to counter the growing abuse of prescription medications, including opioid analgesics (such as painkillers), stimulants (such as ADHD medications), and CNS depressants (such as sleep and anxiety medications).

# The Essence of Drug Addiction

By Nora Volkow, M.D., Director, National Institute on Drug Abuse

## What Is Addiction?

More than three decades of research supported by the National Institute on Drug Abuse (NIDA) has proven that addiction is a complex brain disease characterized by compulsive, at times uncontrollable, drug craving, seeking, and use that persist despite potentially devastating consequences. Addiction is also a developmental disease; that is, it usually starts in adolescence or even childhood and can last a lifetime if untreated. Disagreements about the nature of addiction remain: namely, whether it reflects voluntary or involuntary behavior and whether it should be punished or treated as a health issue. Even though the first time a person takes a drug, it is often by choice—to achieve a pleasurable sensation or desired emotional state—we now know from a large body of research that this ability to choose can be affected by drugs. And when addiction takes hold in the brain, it disrupts a person's ability to exert control over behavior—reflecting the compulsive nature of this disease.

The human brain is an extraordinarily complex and fine-tuned communications network made up of billions of cells that govern our thoughts, emotions, perceptions, and drives. Our brains reward certain behaviors such as eating or procreating—registering these as pleasurable activities that we want to repeat. Drug addiction taps into these vital mechanisms geared for our survival. And although not a life necessity, to an addicted person, drugs become life itself, driving the compulsive use of drugs—even in the face of dire life consequences—*that is the essence of addiction*.

## How Does Addiction Take Hold in the Brain?

The rewarding effects of drugs of abuse come from large and rapid upsurges in dopamine, a neurochemical critical to stimulating feelings of pleasure and to motivating behavior. The rapid dopamine "rush" from drugs of abuse mimics but greatly exceeds in intensity and duration the feelings that occur in response to such pleasurable stimuli as the sight or smell of food, for example. Repeated exposure to large, drug-induced dopamine surges has the insidious consequence of ultimately blunting the response of the dopamine system to everyday stimuli. Thus the drug disturbs a person's normal hierarchy of needs and desires and substitutes new priorities concerned with procuring and using the drug.

Drug abuse also disrupts the brain circuits involved in memory and control over behavior. Memories of the drug experience can trigger craving as can exposure to people, places, or things associated with former drug use. Stress is also a powerful trigger for craving. Control over behavior is compromised because the affected frontal brain regions are what a person needs to exert inhibitory control over desires and emotions.

That is why addiction is a brain disease. As a person's reward circuitry becomes increasingly dulled and desensitized by drugs, nothing else can compete with them—food, family, and friends lose their relative value, while the ability to curb the need to seek and use drugs evaporates. Ironically and cruelly, eventually even the drug loses its ability to reward, but the compromised brain leads addicted people to pursue it, anyway; the memory of the drug has become more powerful than the drug itself.

## Why Are Some People More Vulnerable Than Others?

Like many other diseases, vulnerability to addiction is influenced by multiple factors, with genetic, environmental, and developmental factors all contributing. Genetics accounts for approximately half of an individual's vulnerability to addiction, including the effects of the environment on gene function and expression. Elements of our social environments—culture, neighborhoods, schools, families, peer groups—can also greatly influence individual choices and decisions about behaviors related to substance abuse, which can in turn affect vulnerability. Indeed, addiction is a quintessential gene-by-environment-interaction disease: a person must be exposed to drugs (environment) to become addicted, yet exposure alone does not determine whether that will happen—predisposing genes interact with this and other environmental factors to create vulnerability. In fact, environmental variables such as stress or drug exposure can cause lasting changes to genes and their function, known as epigenetic changes, which can result in long-term changes to brain circuits. Genes may also mitigate the effects of environment—which is why, for example, two substance-abusing individuals growing up in the same high-risk environment may have very different outcomes.

Adding to the complexity, the contributions of environmental and genetic risk factors may also vary during the different life stages of childhood, adolescence, and young adulthood. Adolescence is the period when addiction typically takes hold. Additionally, because their brains are still undergoing rapid development in areas that contribute to decision-making, judgment, and risk-taking, adolescents tend toward immediate gratification over long-term goals. This can lead to risk-taking, including experimenting with drugs. When coupled with their increased sensitivity to social or peer influences and decreased sensitivity to negative consequences of behavior, it is easy to see why adolescents are particularly vulnerable to drug abuse.

## How Can People Recover Once They're Addicted?

As with any other medical disorder that impairs the function of vital organs, repair and recovery of the addicted brain depends on targeted and effective treatments that must address the complexity of the disease. We continue to gain new insights into ways to optimize treatments to counteract addiction's powerful disruptive effects on brain and behavior because we now know that with prolonged abstinence, our brains can recover at least some of their former functioning, enabling people to regain control of their lives.

That said, the chronic nature of the disease means that relapsing to drug abuse is not only possible but likely, with relapse rates similar to those for other well-characterized chronic medical illnesses such as diabetes, hypertension, and asthma. For all these diseases, including drug abuse, treatment involves changing deeply embedded behaviors, so lapses should not be considered failure but rather indicate that treatment needs to be reinstated or adjusted, or that alternate treatment is needed. But addicted individuals also need to do their part. Even though they are dealing with a compromised brain that affects decision-making and judgment, people with drug abuse or addiction must also take responsibility to get treatment and actively participate in it.

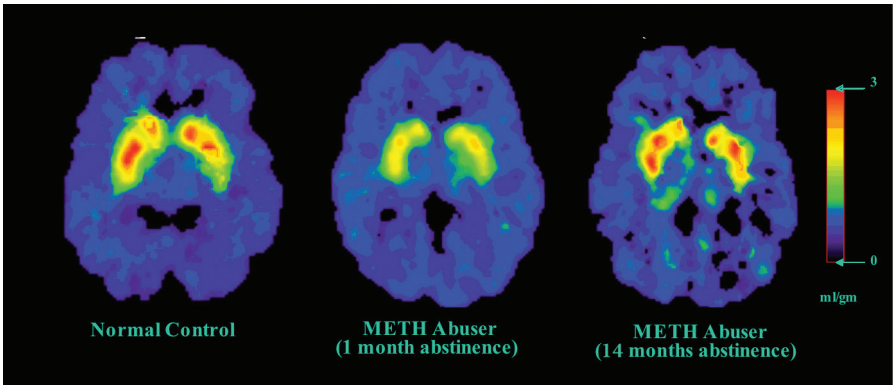
## What Is Our Best Approach to Stopping Drug Abuse in This Country?

Although we have a range of effective addiction treatment options in our clinical toolbox, we still don't have enough to address the many facets of this problem. Research continues to search for improved prevention and treatment options and to reveal promising new strategies to help people deal with their compulsive drug use.

Science-based approaches to tackling drug abuse and addiction will yield smart solutions that bring positive change. As a society, the success of our efforts to deal with the drug problem depends on having an accurate understanding of it. Education

is key. Education can impart knowledge to equip parents to be effective interveners with their children. Knowledge will also help our youth make more informed choices and perhaps think twice before they make a decision.

More information on drug abuse and addiction can be found on the NIDA homepage. Free publications can be ordered online from NIDA DRUG*PUBS*, Research Dissemination Center or by calling 1-877-NIDA-NIH or 1-877-643-2644.




*Recovery of brain dopamine transporters in methamphetamine (METH) abuser after protracted abstinence. With treatment that keeps abusers off METH, drug-altered brains can recover at least some of their former functioning, as these images illustrate. Using positron emission tomography, we can measure the level of dopamine transporters (DAT) in the striatal region of the brain as an indicator of dopamine system function. The METH abuser (center) shows greatly reduced levels of DAT (yellow and green), which return to nearly normal following prolonged abstinence (red and yellow). Source: Volkow, N.D., et al. 2001.* Journal of Neuroscience *21:9414–18.*

# Introduction to the Module

## What Are the Objectives of the Module?

*The Brain: Understanding Neurobiology Through the Study of Addiction* has several objectives. The first is to help students understand major concepts in neurobiology. The brain controls everything a person does, including regulating breathing and heart rate, movement, thought, and emotions. The module seeks to provide students with a fundamental knowledge of how the neurons in the brain convey information to regulate these diverse functions.

The second objective is to provide students with factual information on how drugs of abuse alter the function of the brain. Drugs of abuse exert their effects by altering the communication between neurons. Some of the changes resulting from drug abuse are short-term while others are long-term, and potentially permanent. At some point in drug abuse, the brain changes and the person abusing drugs becomes addicted. The addicted person has a compulsive need to continue to take drugs despite adverse physical, social, and emotional consequences. Scientists continue to investigate what changes occur in the brain when a person becomes addicted to drugs.

Science plays an important role in assisting individuals as they make choices about enhancing personal and public welfare. In this module, students see that science provides evidence that can be used to support ways of understanding and treating human disease. In addition to being the world's largest supporter of research into drug abuse and addiction, the National Institute on Drug Abuse is committed to ensuring the rapid and effective dissemination of research findings to improve drug abuse and addiction prevention, treatment, and policy. This module is one way to provide this information to the public.

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**

An additional 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?

One challenge for science teachers is to make science meaningful to high school students. Students at this age want to see the relevance of the material to their lives. This module presents fundamental principles of neurobiology in relation to drugs of abuse. This link to drugs grabs students' attention because, in today's world, drugs affect virtually all students either directly or indirectly. This real-life context engages students and makes neurobiology something more than just another topic to memorize for biology class. They can apply the information to make decisions about their lives.

*"Excellent information on drug actions and neurobiology presented in an inquiry format. Students handled difficult concepts because of the way they were presented."*
*—Field-test Teacher*

*"It appears that students really did learn the material on neurotransmission and drug addiction. I actually heard one student kidding another about their dopamine levels! Another student was in my room after school explaining to an underclassman how information gets from one part of the body to the other—complete with diagrams on the board."*
*—Field-test Teacher*

*"The topic is of interest to students. The information is current and goes beyond what is available in textbooks."*

*—Field-test Teacher*

## What's in It for the Teacher?

*The Brain: Understanding Neurobiology Through the Study of Addiction* meets many of the criteria used to assess teachers and their programs.

- 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**.
- The module includes an Internet-based **multimedia component** that features minidocumentaries, animations, and interactive activities.
- It is an **integrated** module, drawing most heavily from the subjects of science, mathematics, health, and language arts.
- Finally, the module includes built-in **assessment** tools, indicated by an assessment icon in the lessons.

In addition, the module provides a means for **professional development**. Teachers can engage in new and different teaching practices without completely overhauling their entire program. In *Designing Professional Development for Teachers of Science and Mathematics*[1], Susan Loucks-Horsley et al. write that replacement modules, such as *The Brain: Understanding Neurobiology Through the Study of Addiction*, can "offer a window through which teachers can get a glimpse of what new teaching strategies look like in action." By experiencing a short-term module 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 a replacement module like this 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 high school curriculum with the lessons presented in this module. This information is presented to help teachers make decisions about incorporating this material into their curriculum.

### Major Topics Presented in *The Brain: Understanding Neurobiology Through the Study of Addiction*

| Topics | Lesson 1 | Lesson 2 | Lesson 3 | Lesson 4 | Lesson 5 |
|---|---|---|---|---|---|
| Localization of brain function | • | | | | |
| General functions of specific brain areas | • | | | | |
| Anatomy of the neuron | | • | | | |
| Neurotransmission | | • | • | | |
| Mechanism of drug action on neurons | | | • | • | |
| Environmental, behavioral, and genetic influences on addiction | | | | • | • |
| Addiction as a chronic disease | | | | • | • |

# Implementing the Module

The five lessons in this module are designed to be taught in sequence for approximately two weeks as a replacement for part of the standard curriculum in high school biology. 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: Understanding Neurobiology Through the Study of Addiction* is designed to help students develop the following major goals associated with scientific literacy:

- to understand a set of fundamentals about neurobiology and how drugs of abuse change the brain;
- to recognize that drug addiction is a treatable, chronic brain disease;
- to experience the process of scientific inquiry and develop an enhanced understanding of the nature and methods of science; and
- to appreciate 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?

The lessons form a conceptual whole that will provide students with a fundamental knowledge of neurobiology, drug abuse, and drug addiction. Students begin by learning how different areas of the brain regulate specific functions, including feeling pleasure (Lesson 1—*The Brain: What's*

### Conceptual Flow of the Lessons

| Lesson | Learning Focus* | Major Concepts |
|---|---|---|
| Lesson 1<br>*The Brain: What's Going On in There?* | Engage/Explore | Specific brain regions control specific brain functions. |
| Lesson 2<br>*Neurons, Brain Chemistry, and Neurotransmission* | Explore/Explain | Neurons convey information using electrical and chemical signals. |
| Lesson 3<br>*Drugs Change the Way Neurons Communicate* | Explain/Elaborate | Drugs affect the biology and chemistry of the brain. |
| Lesson 4<br>*Drug Abuse and Addiction* | Explain/Elaborate | Addiction is a brain disease. |
| Lesson 5<br>*Drug Addiction Is a Disease — So What Do We Do about It?* | Elaborate/Evaluate | Drug addiction is a recurring chronic disease that can be treated effectively, similar to other chronic diseases. |

*See *How Does the BSCS 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?* on page 4.