



NEUROSCIENCE AND SOCIETY
Curriculum for High School Teachers

Unit 4: Drugs and Addiction

Center for Neuroscience & Society, University of Pennsylvania

The Franklin Institute

Acknowledgments

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NOTE TO TEACHERS

From sensing to moving to thinking to feeling, neuroscience explains how we perceive and interact with the world around us. This field provides a rich opportunity for high school students to explore fundamental science, framed within the context of everyday decisions and new challenges they will face as they enter adulthood.

Information about the intersection between neuroscience and society abounds online and in the media, yet many sources are unreliable. Meanwhile, there are few textbooks on neuroscience and its societal applications that are designed intentionally for high school students. This curriculum, therefore, is a curated collection of resources—reviewed by experts and tested by teachers—to help you bring this fascinating content into your classroom.

The curriculum is intentionally modular to provide flexibility. Each unit can stand alone, ready to be incorporated into an existing biology, psychology, or other course. Alternatively, multiple units can be linked together to create a semester-long elective course.

You can adapt the content to meet the readiness and capabilities of your class as needed. You can select certain topics and activities to match your students' interest and skip others depending on time constraints.

The goal of the curriculum is to inspire excitement about and increase knowledge of neuroscience. The suggested activities include a variety of instructional approaches, and we encourage you to ask open-ended questions and guide conversations so students are interacting instead of being passive listeners. Students often find personal relevance in these topics, so feel free to extend activities and discussions.

If you feel you have reached the limit of your knowledge about a particular subject, don't worry! Even scientists may not know the answer. Neuroscience is still a developing field and you can create opportunities for you and your students to think critically and learn together. Use the provided links and documents as a gateway to finding additional sources and evaluating their quality.

Your feedback is also welcomed, of course. Please contact the program administrator at neuroscience@fi.edu with comments and suggestions. Thank you for all your hard work!

Alignment with Next Generation Science Standards

The "Neuroscience and Society" curriculum supports Next Generation Science Standards in the following areas.

High School – Life Science

HS-LS1 From Molecules to Organisms: Structures and Processes

Disciplinary Core Ideas

LS1.A: Structure and Function

LS1.B: Growth and Development of Organisms

Science & Engineering Practices

Developing and Using Models

Crosscutting Concepts

Structure and Function

Stability and Change

HS-LS3 Heredity: Inheritance and Variation of Traits

Disciplinary Core Ideas

LS3.A: Inheritance of Traits

LS3.B: Variation of Traits

Science & Engineering Practices

Asking Questions and Defining Problems

Analyzing and Interpreting Data

Engaging in Argument from Evidence

Crosscutting Concepts

Cause and Effect

Systems and System Models

Science is a Human Endeavor

DRUGS AND ADDICTION

Illicit drug use is pervasive in our society, and teenagers are at the greatest risk for abuse and addiction. This unit focuses on the neurobiology of how reward works in the brain and how drugs can “co-opt” this system as well as affect neurotransmission in the brain. The topics throughout this unit focus on helping students develop an awareness of the dangers of illicit drug use, the difficulties of breaking an addiction, and what kind of treatments may be most effective in preventing relapse.

LEARNING OBJECTIVES:

Students will learn that...

- Give examples of the major benefits and uses of the brain’s reward system.
- Describe how drugs of abuse interact with this reward system.
- List the specific effects of various drugs on neurotransmission in the brain.
- Define drug addiction and discuss the neurobiology behind why people often continue taking a drug.
- Identify risk factors in themselves and others regarding addiction.
- Compare the strengths and weaknesses of various treatments based on what we know about neuroscience and psychology of addiction.

TABLE OF CONTENTS:

A. [Terms and Definitions](#)

B. Topics:

1. [Drugs of Abuse and the Brain](#)
2. [Drug Addiction](#)
3. [Treatment for Addiction](#)

C. [Annotated Articles by Topic \(for further reading\)](#)

TERMS AND DEFINITIONS

Dopamine – A neurotransmitter that is important to the reward system in the brain. Dopamine is released by certain neurons in response to rewarding stimuli.

Drug Abuse – Drug use that involves drugs either being taken illegally or recreationally without medical oversight.

Drug Tolerance – When the same amount of a drug produces less of a reaction or “high.” This means that *more* of a drug has to be taken to achieve the same effects as achieved with less of the drug previously. Eventually, the drug has to be taken in order to feel normal as the brain has become accustomed to the presence of the drug and is dependent on it.

Drug Withdrawal – Negative physical or emotional symptoms that result from stopping or reducing the intake of a drug.

Drug Detoxification – A medical treatment that helps to rid the body of a drug while managing withdrawal symptoms. This is typically thought of as only the first step in treatment, and often not sufficient to break an addiction.

Relapse – A condition in which a drug user who has refrained from drugs begins using again.

Triggers – Objects, situations, or people in a person’s environment that increase craving for a drug (because of learned associations).
neuron.

DRUGS OF ABUSE AND THE BRAIN

Key Points:

- Rewards are crucial to survival, because they motivate us to engage in survival behaviors, such as eating, drinking, and sex.
- While we can experience many different kinds of pleasurable stimuli, these all make use of the same reward system in the brain.
- The reward system in the brain involves key structures such as the ventral tegmentum (VTA) and the nucleus accumbens (NAcc), and a key neurotransmitter called dopamine (DA).
- Some drugs elicit a much larger dopamine release than natural rewards.
- Different drugs affect different neurotransmitter systems, which is why each drug has different biological and psychological properties.

Resources and Discussion Questions:

This McGill [website](#) has basic, intermediate, and advanced descriptions of the reward system and its anatomy.

NIDA has some basic descriptions of the reward system in a sequence of [slides](#).

This [video](#) shows some of the older research on both rats and humans using self-stimulation of the nucleus accumbens.

This [video lecture](#) from the Khan Academy gives a good overview of the reward system.

For more advanced students, a more [detailed video](#) describing the role of dopamine in reward.

While all drugs of abuse “hijack” the dopamine and reward systems, they also tap into the more general communications system in the brain (neurotransmission) and interfere with the way neurons normally send, receive, and process information. Refer back to the “Neurons and Neurotransmission” unit for resources and a basic description of synaptic transmission.

- Some drugs, such as [marijuana](#) and [heroin](#), can activate neurons because their chemical structure mimics that of a natural neurotransmitter. This similarity in structure “fools” receptors and allows the drugs to attach onto and activate the neurons.
- Other drugs, such as [amphetamine](#) or [cocaine](#), can cause the neurons to release abnormally large amounts of natural neurotransmitters or prevent the normal recycling of these brain chemicals. This disruption produces a greatly amplified message, ultimately disrupting communication channels.

[Neuroscience for Kids](#) has some good descriptions of the effects of different drugs on the nervous system.

The [website](#) for Foundation for a Drug-Free World has a lot of information about all of the major drug types, their effects on the brain, and descriptions of the psychological experience of the drug. Go to the “Get the Facts” tab.

Classroom Activities:

Activity #1 – “Mouse Party”

The University of Utah has a very engaging [website](#), where a video-game style interface teaches students how different drugs affect the brain. The user can “reach” into a glass container full of mice under the effects of various drugs and pull them out for analysis.

- This can be used in either a classroom setting or for smaller teams of students (if computers are available).
- Select students from the class to come up and pick a mouse to “grab” for study.
- As mice are selected and studied, students fill out the [accompanying worksheet](#).
- The following drugs are featured: heroin, ecstasy, marijuana, methamphetamine, alcohol, cocaine, and LSD.

Activity #2 – Neurotransmission Game

This is an active game that gets students involved in acting out the whole signal transmission process, with a supplemental element that models the effect of a drug on neurotransmission. Instructions for facilitating the activity are found [here](#).

Activity #3 – Ripple Effects

What impact does drug use have on individuals, their families and their communities? Use the “Ripple Effects” diagram (p. 27-28 of [this PDF document](#)) as students brainstorm and research the short-term and long-term effects of drugs at different levels of society. Do the activity once with marijuana and once with heroin/opioid drugs, and compare the impacts.

Assignment Ideas:

Assignment #1 – Drugs in the News

How accurately are drug use and abuse portrayed in the media? Divide students into groups and have them search for news articles about drug abuse. Use the chart on p. 29 of [this PDF document](#) to tally points.

- Each article earns the group 1 point.
- If the article discusses the impact of a drug on the brain and body, it is worth 2 points.
- If students identify an article that has imbalanced information (e.g. lacks scientific evidence or sensationalized information), it is worth 3 points.

Assignment #2 – Media Report Card

Have students identify scenes from television shows or movies that portray underage drinking and assign each example an accuracy grade. Students should justify each grade in the comments section of the Media Report Card on p. 30 of [this PDF document](#). Questions for students to consider in determining grades include:

- How often is underage drinking depicted?
- What is the tone of the scene(s) in which underage drinking is depicted? For example, is the scene comic, designed to elicit laughs? Or does it take underage drinking more seriously?
- Are the consequences of underage drinking shown?
- How are the effects of alcohol on the brain and body depicted?

DRUG ADDICTION

Key Points:

- Dopamine overstimulation causes some dopamine receptors to shut down, which is called tolerance. This means that more of the drug is needed to get the same “feeling.”
- Without the drug, the body produces less dopamine than it used to, meaning that people become anxious and depressed.
- Drug addiction is characterized by “compulsive drug seeking and use, despite harmful consequences,” [according to the National Institute of Drug Abuse](#).
- Risk factors for addiction include environmental risks (e.g. trauma, peers), genetic factors, and neurological factors (e.g. the state of the adolescent brain).

Resources and Discussion Questions:

Big Picture magazine has [an entire issue](#) dedicated to an overview of the basics of the brain and addiction.

What is addiction?

- [This video](#) discusses the differences between drug use, abuse, and addiction, with a focus on the vulnerability of the teenage brain.
- A [definition](#) from the American Society of Addiction Medicine, as well as a [broader one](#) in Psychology Today that includes drugs as only one kind of addiction.
- Teen [accounts](#) of addiction from Foundations for a Drug Free World. Here are some short [text accounts](#) from teens in a PBS documentary.
- The European Monitoring Centre for Drugs and Drug Addiction has [a short video](#) on addiction.

What does addiction look like in the brain?

- Overviews of the biology of addiction from [NIDA](#) and from [Harvard Health Publications](#).
- This McGill [website](#) has beginner, intermediate, and advanced descriptions of how the pleasure centers are affected by drugs.
- BrainFacts.org has a collection of addiction resources [here](#).
- The Genetics Science Learning Center at the University of Utah has an incredible amount of resources on its website about the science of addiction [here](#).

What are risk factors for addiction?

- A simple [list](#) of risk factors from the Mayo Clinic.
- NIDA gives an overview of some of the factors that influence young people specifically.
- The Genetics Science Learning Center has short sound bites about [environmental risk factors](#), [genetic risk factors](#), and risks due to the [adolescent brain](#).
- A [video clip](#) from an HBO interview with Dr. Kathleen Brady from the University of South Carolina about stress, mental illness, and addiction (Chapter 1).

Are there long-term effects of addiction on the brain?

- Different drugs have different kinds of long-term effects on the brain.
- A chart from NIDA detailing the health effects of a long list of drugs.
- NIDA also has more detailed health reports for [heroin](#), [hallucinogens](#), and [methamphetamine](#) (See the sidebars for all of the report sections about these drugs).

Can people get addicted to things that are not drugs?

- [An article](#) in Scientific American about gambling addictions.
- A WebMD [article](#) about shopping addiction.
- [An article](#) about video games and whether they can become an addiction.

Classroom Activities:

Activity #1: Student Anti-Drug Video / Skit

Students work in teams to film a public service announcement video with the purpose of dissuading peers from taking drugs. The PSA should include:

- a description of the neuroscience of how drugs interact with the reward system and how that effects behavior
- an explanation of why teens are an at-risk population based on their brain development
- the long term effects on the brain (and mind) of one or two specific drugs

Activity #2: Real People, Real Stories

Foundation for a Drug-Free World has [short 8-minute video documentaries](#) featuring real people sharing their experiences with different drugs, including prescription drug abuse. Note that these videos contain mature content and may trigger memories of traumatic experiences.

Assignment Ideas:

Assignment #1 – Drug Awareness Projects

Students can choose among multiple project ideas that allow them to creatively research and present on drug-related topics of interest to them. This [PDF](#) has a large list of great ideas from one teacher's assignment sheet. Projects include a board game, song lyrics, radio advertisement, children's book, and more.

Assignment #2 – Virtual Neuroscience Lab: Cocaine Study

The Mind Project contains a [module](#) with a virtual lab about rats and cocaine. There are lots of resources on the site for implementing this with the classroom. Students will learn about conducting research as well as learning more about cocaine-induced behavior.

TREATMENT

Key points:

- Treatment for addiction can involve behavioral intervention and/or medical intervention.
- One reason why breaking addiction is difficult is because of associated withdrawal symptoms. These can vary depending on the drug and can sometimes be dangerous in and of themselves.
- Detoxification is the process of ridding the body of drugs while simultaneously handling the withdrawal symptoms (this is often the first step in treatment).
- Relapse is when a drug user begins taking the drug again after a period of being “clean.”

Resources and Discussion Questions:

NIDA has an overview of types of treatments [here](#). They also have an [online book](#) called [Principles of Drug Addiction Treatment: A Research-based Guide](#), which has a huge amount of information about various kinds of treatments and answers to FAQs (the left-hand column lists all of the chapters).

The Khan Academy also has a [video lecture](#) on treatment and triggers for drug dependence.

HealthLine.com has a good [overview](#) of opiate withdrawal symptoms and treatment, and NIDA also has a good [overview](#).

NIDA has a [guide](#) to know how to look for an effective treatment program.

Here is a New York Times [article](#) and a Time [article](#), both critical of many current treatment practices in the United States.

Is addiction a choice, a brain disease, or something that has elements of both?

- [A rationale](#) for classifying addiction as a chronic disease.
- [A counter perspective](#) arguing that addiction is not a brain disease.
- There is an extremely clear and insightful book chapter on the topic from [Brainwashed: The Seductive Appeal of Mindless Neuroscience](#), by Sally Satel and Scott O. Lilienfeld (Chapter 3).

Classroom Activities:

Activity #1: Discussion of Celebrity Rehab

Students often have a poor understanding of the difficulties of recovering from addiction. In class, lead a discussion of known popular celebrities and their successes and/or failures in rehab.

- Scholastic/NIDA has an article for students [here](#), and a teacher’s guide [here](#).

Assignment Ideas:

Assignment #1 – Treatment Program Evaluation

Students pick a particular treatment program (e.g. AA/NA, Drug Court) and evaluate the methods and success of the program. Students should make sure to discuss:

- the neuroscience of withdrawal/longer-term effects of drugs on the brain and how this treatment addresses those issues.
- how the treatment program addresses risk factors for relapse.

Assignment #2 – Drugs and the Law

Students form teams to research and report on the drug laws in their city. The report could address issues such as drug possession vs. trafficking, mandatory minimum sentences, and punishment for juveniles vs. adults. Students should include a section with their recommendations on how could drug policy be altered knowing what we know about the neuroscience of drug use and addiction.

- A good primer on this topic is an article by David Eagleman and colleagues called "[Why Neuroscience Matters for Rational Drug Policy.](#)"

ANNOTATED RESOURCES

Note: Articles published by the Dana Foundation are written specifically for a wide readership and therefore the easiest to read among the below list.

Drug Use

[Paradoxical Profile: Alcohol's risks and benefits](#)

Dana Foundation/Joseph Volpicelli, Maia Szalavitz

A very good overview of the current known of effects of alcohol throughout development.

[Appraising the Risks of Reefer Madness](#)

Dana Foundation/Robin Murray

A very good review of the state of what we know regarding the risks of cannabis use, especially during adolescence. The author suggests that U.S. is not on board with many other countries in acknowledging these risks.

[Cognitive Enhancement by Drugs in Health and Disease](#)

Trends in Cognitive Sciences/Masud Husain, Mitul A. Mehta

This is a complex paper, potentially worth a scan for a few nuggets related to the effectiveness of cognitive enhancers and individual differences.

[Binge Drinking in Young Adults: Data, Definitions, and Determinants](#)

Psychological Bulletin/Kelly E. Courtney, John Polich

This review contains helpful and interesting statistics related to binge drinking. It also has sections related to the neuroscience of binge drinking.

[Less Drinking, Yet More Problems: Understanding African American Drinking and Related Problems](#)

Psychology Bulletin/Tamika C. B. Zolotor and others

This is a very long article, but includes interesting statistics and evidence-based theories about the differences in drinking behavior between European Americans and African Americans.

[Prenatal Exposure to Drugs: Effects on Brain Development and Implications for Policy and Education](#)

Nature Reviews Neuroscience/Barbara L. Thompson, Pat Levitt, Gregg D. Stanwood

This article gives an overview of the effects of legal and illegal drugs on brain development. It's not overly technical, and has a few interesting points about the implications of research on science communication to the public and policy.

Addiction

[How the Addiction Hijacks our Reward System](#)

Dana Foundation/Cynthia M. Kuhn, Wilkie A. Wilson

A broad overview of the neuroscience of addiction and treatment. The authors also offer an argument about the difference between an addiction and a habit.

[Tackling the Mysteries of Alcohol Dependence: A Decade after the Decade of the Brain](#)

Dana Foundation/Kenneth R. Warren

An interesting, brief review of some of the recent research on alcohol abuse and alcoholism.

[Challenges and Opportunities in Drug Addiction Research: A Decade after the Decade of the Brain](#)

Dana Foundation/Nora D. Volkow

A brief article on how research on brain plasticity may influence our understanding of risk factors for addiction and treatment.

[The Neurocircuitry of Impaired Insight in Drug Addiction](#)

Trends in Cognitive Science/Rita Z. Goldstein and others

A more advanced article, but it contains thoughtful ideas about the neuroscience behind the relationship between self-awareness and drug addiction.

[The Hidden Island of Addiction: the Insula](#)

Trends in Neurosciences/Nasir H. Naqvi, Antoine Bechara

The first section is a great overview of why researchers are beginning to believe the insula plays a role in addiction.

[Orbitofrontal Cortex, Decision-making and Drug Addiction](#)

Trends in Neurosciences/Geoffrey Schoenbaum and others

A more difficult read, but it describes some interesting addiction-related experiments in humans, monkeys, and rats.

Treatment

[The Impact of Modern Neuroscience on Treatment of Parolees](#)

Dana Foundation/Richard J. Bonnie and others

A great overview of the current state of naltrexone research, and thoughtful writing on the ethics of using this drug within the court system.