

Lesson IV
Alcohol and the Brain
(Estimated duration 1.5-2 hours)

Table of Contents

I.	Pre-requisite skills/knowledge	2
II.	Massachusetts Science and Technology/Engineering Frameworks Compliance	2
III.	Content to be Taught	2-3
IV.	Rationale	3
V.	Goals	3
VI.	Objectives	3
VII.	Teacher background	3-5
VIII.	Engagement	5
IX.	Exploration	5-7
X.	Explanation	7
XI.	Evaluation	7

Alcohol and the Brain

I. Pre-requisite skills/knowledge

Students should be comfortable with teamwork, conversation, and working closely with one another for this lesson. Students should have a basic understanding that alcohol consumption affects human behavior and that the brain controls human behavior.

II. Massachusetts Science and Technology/Engineering Frameworks Compliance

Bio 4.4: Explain how the nervous system (brain, spinal cord, sensory neurons, and motor neurons) mediates communication among different parts of the body and mediates the body's interactions with the environment. Identify the basic unit of the nervous system, the neuron, and explain generally how it works.

SIS1: Observe the world from a scientific perspective.

SIS1: Pose questions and form hypotheses based on personal observations, scientific articles, experiments, and knowledge.

SIS1: Read, interpret, and examine the credibility and validity of scientific claims in different sources of information, such as scientific articles, advertisements, or media stories.

SIS 4: Construct a reasoned argument and respond appropriately to critical comments and questions.

III. Content to be Taught

- A. The location and function of the following brain structures: cerebral cortex, hippocampus, cerebellum, hypothalamus/pituitary gland, and medulla oblongata.
- B. Brain regions communicate with one another via connections between neurons. Neurons consist of a soma (cell body containing nucleus), dendrites (which receive signals from other neurons) and axons (which send signals to other neurons).
- C. Neurons communicate with one another via chemical messages at their connections, the neuronal synapses. These chemicals are called neurotransmitters.
- D. Due to its continuing development, the adolescent brain is more susceptible to alcohol's harmful effects than the adult brain.
- E. Alcohol is both water and lipid soluble. Therefore, ingested alcohol crosses the blood-brain barrier and affects both the outside and inside of brain cells.

- F. Alcohol affects neurotransmission by interfering with neurons, synapses, and neurotransmitters.
- G. As blood alcohol content (BAC) increases, impairment in different brain regions is increasingly noticeable by behaviors associated with specific regions of the brain.

IV. Rationale

The adolescent brain is a developing organ, and adolescent behavior is often characterized by poor decision-making, emotional imbalance, and high risk taking. Most adolescents experiment with alcohol before the end of their high school career. Alcohol affects the adolescent brain differently than it does the adult brain. Alcohol awareness programs based in ethics have historically shown variable, often ineffective results in reducing substance abuse by adolescents. The aim of this lesson is to provide students with scientific understandings and data on which they can make informed decisions regarding alcohol use.

V. Goals

Students will understand the physiology behind alcohol's effects on the adolescent brain and behavior.

VI. Objectives

- A. Identify the major brain regions and associated functions.
- B. Identify the basic structure of a neuron (nerve cell) and explain how neurons communicate with each other and with the brain (neurotransmission).
- C. Understand the connection between varying blood alcohol contents (BAC) and alcohol's effect on the major regions of the brain.
- D. Understand that the adolescent brain is undergoing significant developmental changes and therefore alcohol has a more significant effect on the developing adolescent brain than the adult brain.
- E. Develop questions about the effects of alcohol on the brain and utilize resources to read, interpret, and suggest answers to these questions.

VII. Teacher background

This lesson addresses the Cerebral Cortex, Hippocampus, Cerebellum, Hypothalamus/Pituitary Gland, Amygdala and Medulla Oblongata. Each of these regions has a multitude of functions. However, this investigation addresses only the functions specific to alcohol's effect on human behavior.

The effects of alcohol on brain function are often observed hierarchically. The cerebral cortex is involved in decision-making, which is among the first behaviors affected by alcohol. 0.05% BAC is associated with poor judgment. The next noticeable impairment is often in the hippocampus, which is responsible for memory. Effects on the cerebellum result in poor balance, coordination, and reaction time at about 0.1% BAC. The hypothalamus and pituitary gland influence hormonal regulation. Alcohol depresses the neurons in the hypothalamus that control sexual arousal and performance. As BAC increases, sexual behavior increases, but sexual performance declines. Alcohol also inhibits the pituitary secretion of anti-diuretic hormone (*ADH*), which acts on the kidney to reabsorb water. When ADH levels drop, the kidneys do not reabsorb as much water. As a result, the kidneys produce more urine. This occurs at approximately 0.2% BAC. As alcohol levels increase to 0.45 % BAC, the medulla oblongata, which regulates breathing and heart rate, can be affected leading to unconsciousness and even death.

The brain regions communicate with one another through alternating electrical and chemical signals. The **neuron** is the basic brain cell, within which an electrical signal passes along the length of the cell. The chemical signals are the **neurotransmitters**, of which there are many types. Neurotransmitters pass from one neuron to another across a **synapse**. The synapse is the gap/space between the neurons. The neurons are named in relation to the synapse (pre- or post-synaptic cell). More specifically, the synapse is located between the **axon terminals** of the pre-synaptic cell and **dendrites** of the post-synaptic cell. Neurotransmission occurs as follows: Dendrites receive the neurotransmitters/chemical signals and subsequently pass an electrical signal down the length of the axon. The electrical signal is propagated through the release of neurotransmitters at the axon terminals. Due to the variety of neurotransmitters, this signaling pattern will have various effects (excitatory/inhibitory) on the post-synaptic cell.

Alcohol is both water and lipid soluble, allowing it to cross membrane barriers and affect neurotransmission by changing the cell's receptors as well as its ability to properly release neurotransmitters. Alcohol interferes at the synapse, blocking the receptors of the post-synaptic cell and therefore changing the normal signaling pattern of the brain.

Alcohol has a different effect on young people than it does on adults. Alcohol consumption during adolescence is correlated with lower cognitive ability, higher susceptibility to alcohol dependence, smaller hippocampus,

and relatively larger amygdala. In rats, alcohol impairs the ability to learn and remember by slowing the excitatory neurotransmission of glutamate in the hippocampus. This cellular and behavioral effect is more profound in adolescent rats than in adults. Adolescent rats' hippocampal neurotransmitters also become less responsive to the inhibitory neurotransmitter GABA, which normally helps induce calmness and sleepiness. Adolescent rats subjected to the equivalent of a 4-day binge even show greater cellular die-off in the forebrain than adults subjected to the same condition. Several functions of the forebrain are analogous between species, such as planning and impulse control. During human adolescence, these regions are heavily modified during the learning process and susceptible to disruption by alcohol.¹

VIII. Engagement

- A. Ask the students, "What are the primary functions of the brain?"
 - 1. Students can work in groups to compile a list.
 - 2. Students can create a list on the board.
 - 3. Conclude that the brain is involved in almost every aspect of human behavior and function.
- B. State that this investigation seeks to answer the question, "How does alcohol affect the brain and behavior?"

IX. Exploration

- A. Brain Stations and Brain Station Worksheet (see appendix)
 - 1. Students are told they will explore five regions of the brain by performing activities that utilize or address a particular brain region.
 - 2. Students rotate through activities 1-4, spending approx. 10 minutes at each station completing the Brain Station Worksheet as they proceed.
(Hint: High school students can get very wrapped up in Station 1 debate. If they are performing this in a small group, be sure to moderate the time and make sure they have an opportunity for individual reflection.)
 - 3. Perform Station 5 - Medulla as a class. Teacher directs the class to breath in and out using the signs, and then challenges the class to breathe out for an extended period until they have to take a breath. Discuss the involuntary control by the medulla oblongata to breathe. (Caution: Do not let student hold their breath repeatedly.)

¹Tapert, Susan F.; Caldwell, Lisa; Burke, Christina. Alcohol and the adolescent brain: Human studies. *Alcohol Research & Health*, Vol. 28(4), 2004-2005, 205-212)

B. Neurotransmission activity

1. Students are prompted with the question: Do brain regions work independently of one another, or do they communicate? How do they communicate with one another?
2. Students demonstrate neurotransmission by performing the “pass the squeeze” activity.
 - a. Students stand in a line and hold hands.
 - b. First student squeezes the hand of the next, and the squeeze gets passed down to the end of the line.
 - c. Explain that each student represents a neuron and that the “squeeze” represents a signal passed from neuron to neuron.
 - d. Invent a relevant context for the activity.

Example: A person is driving a car approaching a stop sign. The visual cortex of the brain needs to communicate with the motor cortex in order to press the brake and stop the car. First person in line is the visual cortex and last person receiving the squeeze is the motor cortex.
 - e. Explain that neurons do not physically touch each other, but transmit a signal chemically. Use a video clip such as one found at <http://www.youtube.com/watch?v=cNaFnRKwpFk&feature=vsr> to illustrate synapses.
 - f. Now have one of the students wrap their hands in a bubble wrap or something similar that will make the “squeeze” difficult to feel and repeat the demonstration.
 - g. Explain that alcohol interferes with the neurotransmission at the synapse and prevents or inhibits the communication among neurons.

C. Blood-Brain Barrier. Ask, “How does alcohol get to the synapses between the brain neurons?”

D.

Materials: alcohol colored with food dye, baby oil, water, test tubes

1. Demonstrate alcohol’s solubility in water by mixing the dyed alcohol with water, shaking, and showing the student no separation of liquids.
2. Demonstrate alcohol’s solubility in lipids by mixing the dyed alcohol with baby oil, shaking, and showing the students no separation of liquids.

What does this mean for alcohol’s affect on the brain? (Alcohol can penetrate cell membranes—get into neurons.)

3. As a comparison, mix colored water and oil to demonstrate the properties of insolubility.
4. Inform students that cell membranes, such neuron membranes, consist of lipids and proteins. Alcohol's solubility permits it to dissolve in the lipids and cross the cell membrane.

X. **Explanation**

- A. Ask again, "How does alcohol affect the brain and therefore behavior?"
 1. Answer questions the students have.
 2. Post the large brain diagram on the board.
 3. Have students post each brain region onto the diagram and review the functions of each brain region and the potential effects of alcohol on each brain region.
 4. Review neurotransmission and how alcohol interferes with neurotransmission.
 5. Review the properties of alcohol and the blood brain barrier that allow alcohol to penetrate the blood brain barrier.
- B. Have students read and write a review of the article, "Research Facts and Findings. Adolescent brain Development" (cf. Appendix: ACT for Youth Upstate Center for Excellence. (2002). Research Facts and Findings. Adolescent brain Development.)

XI. **Evaluation**

- A. The Party scenario
 1. Pass out The Party scenario (Appendix) for students to read.
 2. Instruct the students to complete the Party Chart (Appendix).
 3. Use the completed Party Chart Answer Key (Appendix) to create a rubric.

Optional: Have students read and review, "The Grim Neurology of Teenage Drinking" by Katy Butler (*The New York Times*, 4 Jul 2006). This article is best read after the brain lesson so that students will recognize some of the terms in the article. Students can read it as a class, read it for homework, answer questions about the article, hold a class discussion, or write a summary.

