Teacher Guide
Dendritic Spine Lab Activity

Lesson Summary: The brain physically changes when exposed to drugs. This activity utilizes scientific thinking and assessment without the need for laboratory equipment. Students investigate how neurons change their connectivity when exposed to the drug morphine.

Grade Level 9-12

Lesson Length
1-2 class periods

Standards Alignment: Minnesota Science Standards

- Science is a way of knowing about the natural world and is characterized by empirical criteria, logical argument and skeptical review. Benchmark codes: **9.1.1.1.1 & 9.1.1.1.4**
- Scientific inquiry uses multiple interrelated processes to investigate and explain the natural world. Benchmark codes: **9.1.1.2.1, 9.1.1.2.2 & 9.1.1.2.3**
- Natural and designed systems are made up of components that act within a system and interact with other systems. Benchmark codes: **9.1.3.1.3**
- Science, technology, engineering and mathematics rely on each other to enhance knowledge and understanding. Benchmark codes: **9.1.3.4.2, 9.1.3.4.3 & 9.1.3.4.4**
- Organisms use the interaction of cellular processes as well as tissues and organ systems to maintain homeostasis. Benchmark codes: **9.4.1.1.1 & 9.4.1.1.2**
- Cells and cell structures have specific functions that allow an organism to grow, survive, and reproduce. Benchmark codes: **9.4.1.2.2, 9.4.1.2.4 & 9.4.1.2.5**

Objectives—Students will be able to

- Understand how exposure to morphine affects neuron spine growth
- Complete the measurements for an experiment that highlights how drugs affect the brain

Assessment Options

- Evaluate the students' measurement methods and critical thinking
- Informally assess group cooperation and ability to work together
- Evaluate student lab notebook entries

Materials

- Pictures of dendrites (see attachments) - laminate these so that they can be reused.
- Rulers with millimeter markings, string, tape, etc could be useful but are not necessary to complete the project.

Procedure

Engage

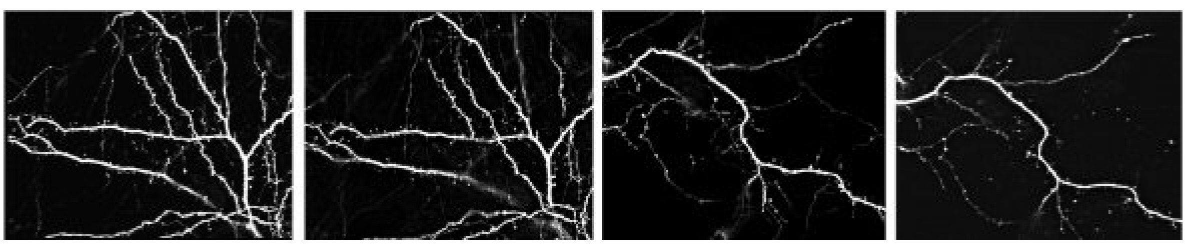
1. Review the anatomy of neurons, how synapses change with learning and how natural toxins alter synapses, using the cartoons found at: brainu.org/files/movies/synapseschange_pc.swf and brainu.org/files/movies/toxins_synapses.swf

2. Discuss with students why neuroscientists might call addiction a "disease of learning." If this were true, what changes might one expect to find in the central nervous system?

Explore

1. Break students into groups and hand out pictures 1A and 1B to student groups, and ask the students to examine the photographs of dendrites in the pictures.
2. Ask the students to hypothesize how the dendrites will change when exposed to the drug morphine.
3. Hand out pictures 2A and 2B. Explain that these are the same dendrites after 1 day of either saline treatment or morphine treatment, respectively. Ask the students to explain why both types of treatment were used, and to observe and write down the differences.
4. Instruct each group to develop a way to measure the changes observed in the dendrites from image 1 to image 2. Then ask them to use this measurement method. This is where rulers, etc. may be used. Other ways of measurement can work too, including categorizing spine morphology or other characteristics. Be sure to use the scale bars provided.
5. After all groups are done measuring, re-assemble the entire class, and have each group report out the method they used to measure the change in dendrites and their results. As a class, discuss, evaluate and highlight the positive and negative aspects of each method. What units of measurement were used? Which data are more believable? Why? Which data best reflect what you see by just looking at the pictures? If the class had to redo these measurements, what would each group do differently?

Explain



1A **1B** **2A** **2B**

Image Key

Untreated Controls
1A initial image
1B same field as 1A, image taken 1 day after image 1A

Treatment with 10µM morphine
2A initial image before morphine treatment
2B same field as 2A, image taken 1 day after image 2A and exposure to 10µM morphine

Images were kindly provided by Dr. Dezhi Liao, Dept. of Neuroscience, University of Minnesota. Dr. Liao counts the number of spines per unit length of dendrite. He classifies spines as protrusions on the dendrite (bumps on logs) or spines (spikes or mushrooms on the logs). Some neuroscientists consider mushroom shaped spines to be the most "mature."

These images are from hippocampal neurons grown in tissue culture. On the bottom of a Petri dish, neuronal axons and dendrites grow in roughly two dimensions so they are easy to photograph when labeled with a fluorescent dye. The changes observed here model the changes

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that occur in the intact brain. The hippocampus is an important brain structure involved in learning and memory.

Explore results further

1. How would neuronal circuits behave after exposure to morphine? Does this interpretation depend on the kind of neurons involved, i.e. excitatory or inhibitory? What happens if the changed neuron is in a feedback pathway?
2. Discuss what the data may mean for behaviors like learning and memory.
3. Addition of morphine to the neurons decreased the number of synaptic spines while stimulants like cocaine and methamphetamine increase synaptic spines. How could this be related to the concept of homeostasis?
4. Present the following situation to your students: The scientist who took these pictures also found dendrites with a dramatic increase in dendritic spines with very similar drugs to morphine. What does this mean for your interpretation of what's happening in the morphine experiment?

Extension

1. Introduce the physiological mechanisms of addictive drugs in a virtual neuroscience laboratory in this video. learn.genetics.utah.edu/content/addiction/drugs/mouse.html
2. Other good lessons with activities that could accompany this lesson can be found at: teach.genetics.utah.edu/content/addiction/webquest/Exploring%20The%20New%20Science%20of%20Addiction.pdf

Background Material

Question 1. How do drugs of abuse work on the human brain?

Drugs are substances that disturb the delicate biochemical balance in the brain by imitating, stimulating, or blocking the effects of certain neurotransmitters involved in the brain's circuits.

Many of these drugs' most potent effects are upon the reward circuit, the circuit that signals a positive benefit to an action or met expectation. Parts of the reward circuit use a particular neurotransmitter called *dopamine*.

All of the drugs of abuse that cause dependencies increase the amount of dopamine in the reward circuit but different drug classes do so in different ways. Sources for more information about drugs of abuse can be found at:

thebrain.mcgill.ca/flash/d/d_03/d_03_m/d_03_m_par/d_03_m_par.html and

science-education.nih.gov/supplements/nih2/Addiction/guide/lesson3-1.htm

Question 2. What is the relationship between responses to drugs at a neuronal level and homeostasis?

The brain automatically adjusts to neuroactive substances from outside the body by altering its natural responses. It thereby achieves a new state of equilibrium that is maintained until the body starts to require the external substance for normal function. At that point, the person experiences a craving that will persist until the neurons that went on vacation get back to work.

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