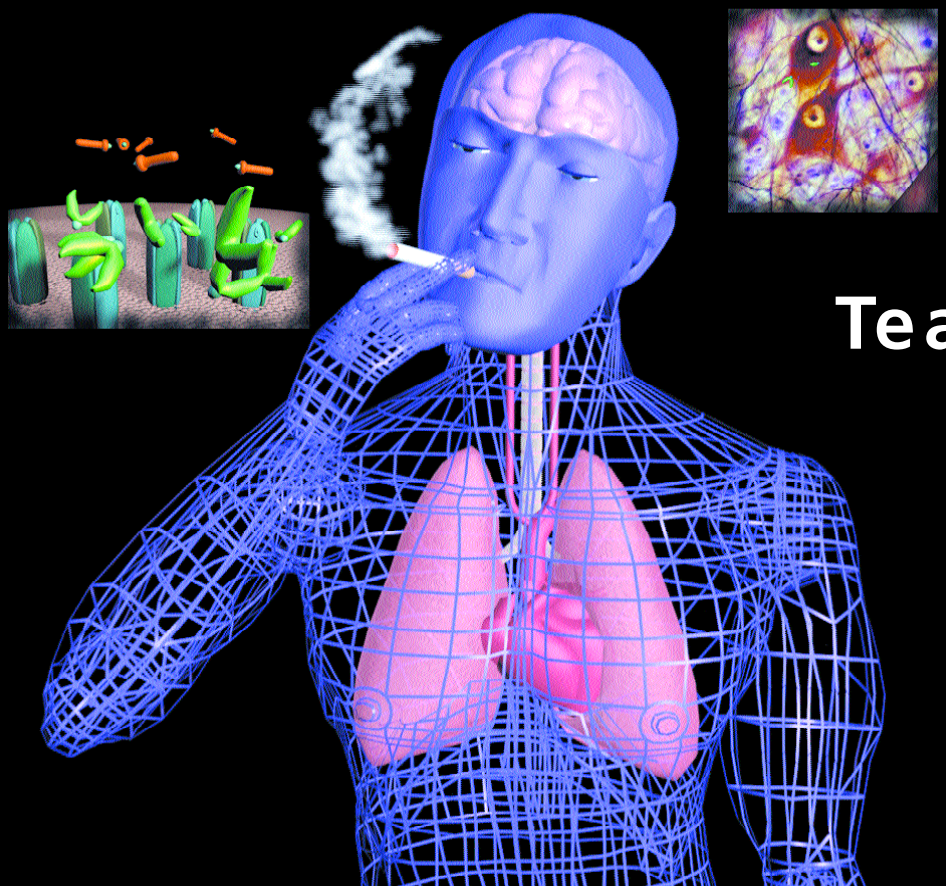
ANIMATED NEUROSCIENCE

and the Action of Nicotine, Cocaine, and Marijuana in the Brain



Teacher's Guide

Films for the Humanities & Sciences®

Background Information

This program, made entirely of 3-D computer animation, contains two parts: ANIMATED NEUROSCIENCE and THE ACTIONS OF NICOTINE, COCAINE, AND MARIJUANA IN THE BRAIN. Each part is approximately 12 minutes and may be presented in 2 different class sessions so that discussion may follow.

In part 1, the basic structure of the brain and its principal cells—neurons—are described. In addition, the communication (electrical and chemical) between neurons is explained. In part 2, the entry of nicotine, cocaine, and marijuana into the brain is shown, and the cellular actions of these drugs are described.

The contents described here are scientifically accurate. The material is suitable as an adjunct to biology classes and health classes or in any curriculum that may benefit from a scientific component to drug education/prevention programs. It is not intended that this program, by itself, be used in drug education programs; other forms of education are needed as well. This teacher's guide consists of a set of learning objectives, a glossary of terms used in the video, and additional reference material. The teacher's guide also includes a series of worksheets that students may use for self-testing. Each worksheet includes a representative still frame from the video. A set of worksheets with the answers for the teachers is provided.

Learning Objectives

After viewing this video students should understand the following concepts:

- The brain is a structure that controls many different functions; areas within the brain are highly specialized to control specific functions, but they are also interconnected.

- Neurons send information to each other using both electrical and chemical signals. Electrical information moves along a neuron, and chemical information moves between neurons. When they work together as a unit, the neurons control the function of a specific brain area.

- The communication between neurons can be disrupted by drugs; this happens specifically at the synapse, the most important control point in the process of communication.

- Regardless of their method of intake, drugs of abuse, such as nicotine, cocaine and marijuana, reach the brain through the bloodstream. When drugs are smoked they reach the brain as fast as if they were injected, and even faster than if snorted or taken by mouth. The faster a drug reaches the brain, the more likely it will be abused.

- Drugs interact with neurons at the synapse. Their targets can be receptors (e.g. for nicotine and marijuana) or uptake pumps (e.g. for cocaine).

- By acting at the synapse, drugs change the way the brain functions and can affect behavior, thinking and learning, movement and sensations. Sometimes this is beneficial, as in the treatment of a disease, and sometimes this is detrimental, especially when drugs are abused.

Copyright © 2007 Films for the Humanities & Sciences® A Films Media Group Company • P.O. Box 2053 • Princeton, NJ 08543-2053

Vocabulary

Acetylcholine--A major neurotransmitter in the brain. Acetylcholine is synthesized in and released from neurons into the synaptic space. It then binds to an acetylcholine receptor.

Acetylcholine receptor—A protein with five subunits to which acetylcholine binds. Upon binding, the acetylcholine receptor changes shape to open a channel through which sodium ions flow into the neuron, producing a current across the membrane.

Acetylcholinesterase—The enzyme that destroys acetylcholine by hydrolyzing or "cutting" it into two parts, choline and acetate.

Axon—A long portion of the neuron that leaves the cell body (or soma) and carries chemicals and proteins to the terminal.

Caudate nucleus—An area of the brain involved in voluntary movement, and drug addiction.

Cerebral cortex—The largest part of the brain. It is subdivided into several parts, including the frontal cortex (motor), parietal cortex (sensory), temporal cortex (hearing) and occipital cortex (vision). The sensory cortex receives sensory information coming from the spinal cord, and the motor cortex sends motor information back down the spinal cord.

Cocaine—The active ingredient found in the coca plant. It binds to the dopamine uptake pump and prevents the pump from bringing dopamine back into the terminal. It is a central nervous system stimulant.

Current—The flow of ions (charged atoms such as sodium, potassium, calcium or chloride) across the neuron membrane.

Cyclic AMP (Adenosine monophosphate)—A nucleotide that is generated by the action of the enzyme, adenyl cyclase. It directs other proteins to regulate the movement of ions into and out of the cell, producing membrane currents.

Dendrite—A short portion of the neuron that leaves the cell body. Each cell body has many dendrites which are covered with little spines containing receptors to which neurotransmitters bind.

Dopamine—A neurotransmitter released from neurons in parts of the brain especially involved in drug addiction (i.e. the reward pathway).

Electrical Impulse—The movement of an ion current along the neuron membrane. It is generated in the cell body and moves along the axon to the terminal.

Exocytosis—When an impulse arrives at the terminal, the vesicles fuse with the terminal membrane and release the neurotransmitters within them into the synaptic cleft (space).

G Proteins—Proteins that help receptors such as dopamine or THC receptors to activate or inhibit the enzyme adenyl cyclase and the generation of cyclic AMP.

Hippocampus—An area of the brain beneath the cerebral cortex involved in learning and memory. It lies beneath the cerebral cortex.

Neuron—The major cell type in the brain and spinal cord. It consists of the soma, axon and dendrites. There are billions of neurons in the brain.

Neurotransmitter—A chemical such as acetylcholine or dopamine that is stored in vesicles within a nerve terminal and released into the synaptic space. It binds to receptors to cause currents to flow in the postsynaptic neuron. Neurotransmitter action is terminated either by enzymes or by the uptake of the neurotransmitter into the terminal.

Nicotine—The active compound in the tobacco plant. It binds to acetylcholine receptors in the brain and causes the release of many neurotransmitters.

Postsynaptic—Pertaining to the membrane of the receiving neuron (containing the receptors) at a synapse.

Presynaptic—Pertaining to the membrane of the axon terminal at a synapse.

Receptor—A special protein to which neurotransmitters, hormones, and drugs bind. Receptors are found on the membranes of the neuron dendrites, soma, and even the terminal.

Reward pathway—A specific network of neurons that become activated by pleasurable or rewarding behaviors such as use of cocaine, heroin, nicotine, and alcohol. Many addictive behaviors activate this pathway which originates in the midbrain, and travels through the nucleus accumbens and up to the frontal cortex.

Soma—The cell body and largest part of the neuron. Proteins are synthesized in the cell body and transported to other parts of the neuron. The electrical impulse is generated in the cell body and travels down the axon.

Spinal cord—A bundle of long neurons that travel up and down the vertebral column. The neurons form synapses with sensory neurons from the periphery to carry sensory information up to the brain. Neurons leaving the brain travel down the spinal cord and form synapses with neurons that direct muscle movement.

Synapse—The connection between two neurons; it consists of the terminal of one neuron, the membrane of the neighboring neuron and the space between them (synaptic cleft). It is here that chemical information is passed from one neuron to another.

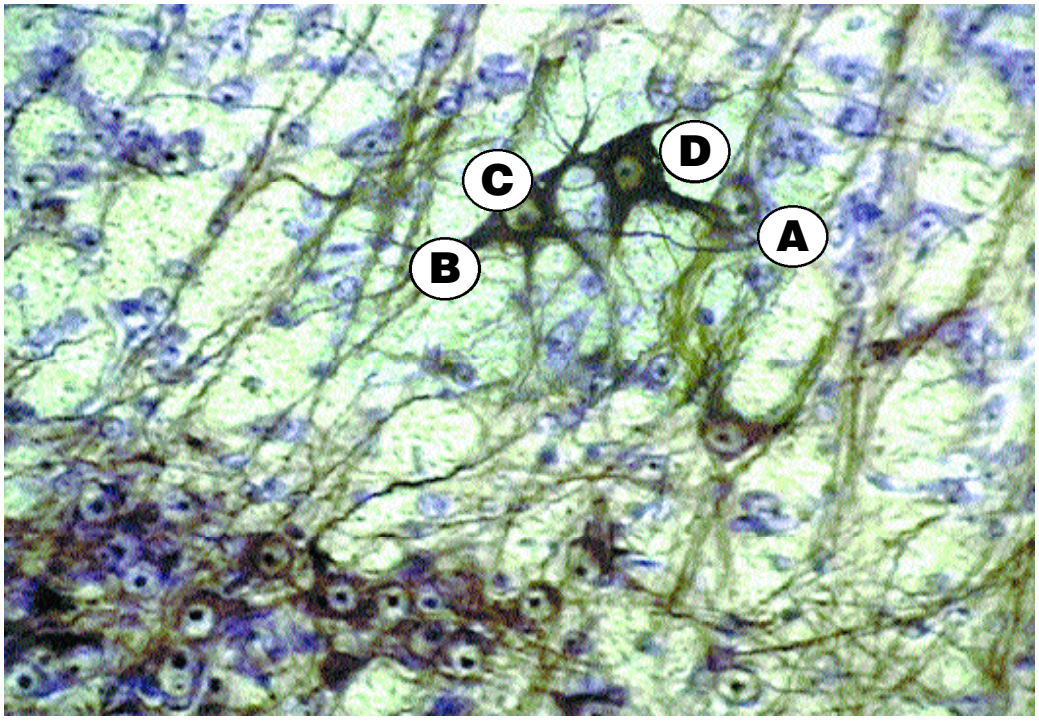
Tetrahydrocannabinol (THC)—A major active compound in the cannabis (marijuana) plant. It binds to THC receptors that are concentrated in areas such as the hippocampus.

Uptake pump—A special protein to which neurotransmitters such as dopamine bind so that they can be transported back inside the terminal. Drugs such as cocaine bind to dopamine uptake pumps and prevent them from functioning.

Vesicles—Small sacs found within the axon terminal. They contain neurotransmitters which are released into the synaptic cleft when an impulse arrives at the terminal.

Student Worksheets/Self Test

The following pages contain a set of worksheets that students can use as a self-test after viewing the video. Sets may be copied for the students as needed. The worksheets are designed to reinforce information already presented in the video and to provide new information not found in the video. Each worksheet contains a representative frame from the video that serves as reference for the questions. A set of worksheets with the answers provided is included for the teacher.



1. Neurons are the major cells in the brain and spinal cord (the central nervous system). They have several parts. Indicate the name of the parts that are labeled in the picture by filling in the blanks below:

A._____ B. _____

C. _____ D. _____

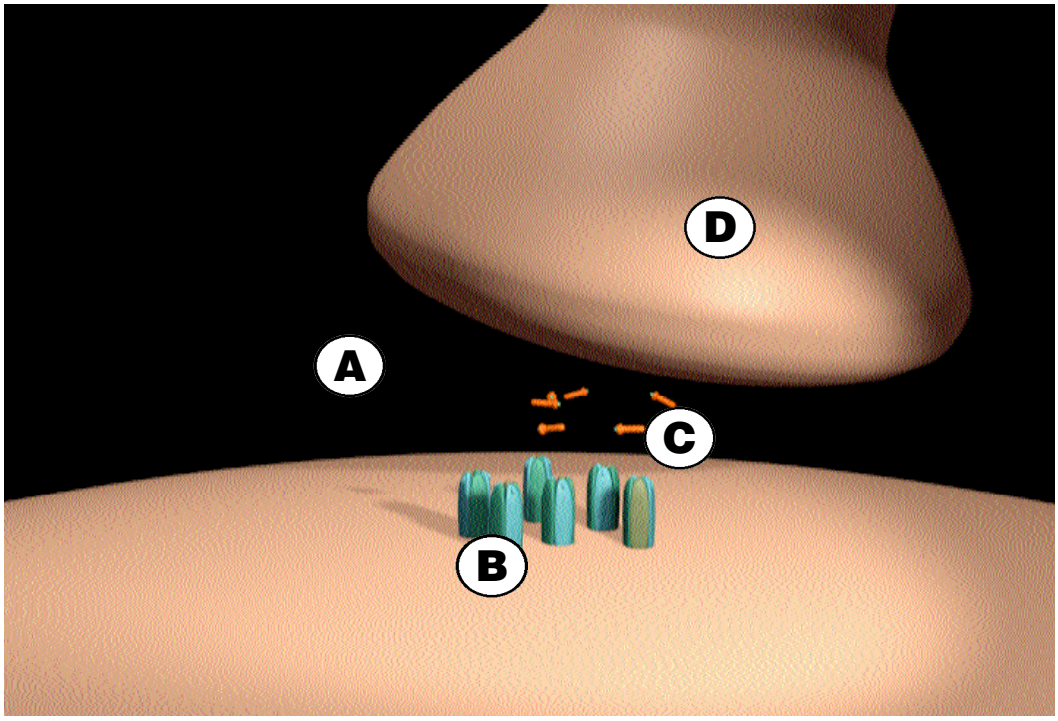
Each part of the neuron serves a special function. For each part that you have labeled above, match it to its function in the blanks below.

The _____ is the largest part of the cell. It has a nucleus which contains the genetic material to direct the production of proteins. The electrical impulse is formed here.

Electrical impulses travel along the _____ toward the nerve _____. This long structure carries more than just electrical messages; it also carries many nutrients to the _____, especially those that help make the neurotransmitters.

When an electrical impulse reaches the nerve _____ neurotransmitters are released into the synaptic space.

A neuron has many _____ that form branches like trees. Each _____ has millions of receptors on its membrane so that many synapses can be formed with other neurons. The more synapses that can transmit chemical information at a time, the more likely the receiving cell will generate the electrical impulse.



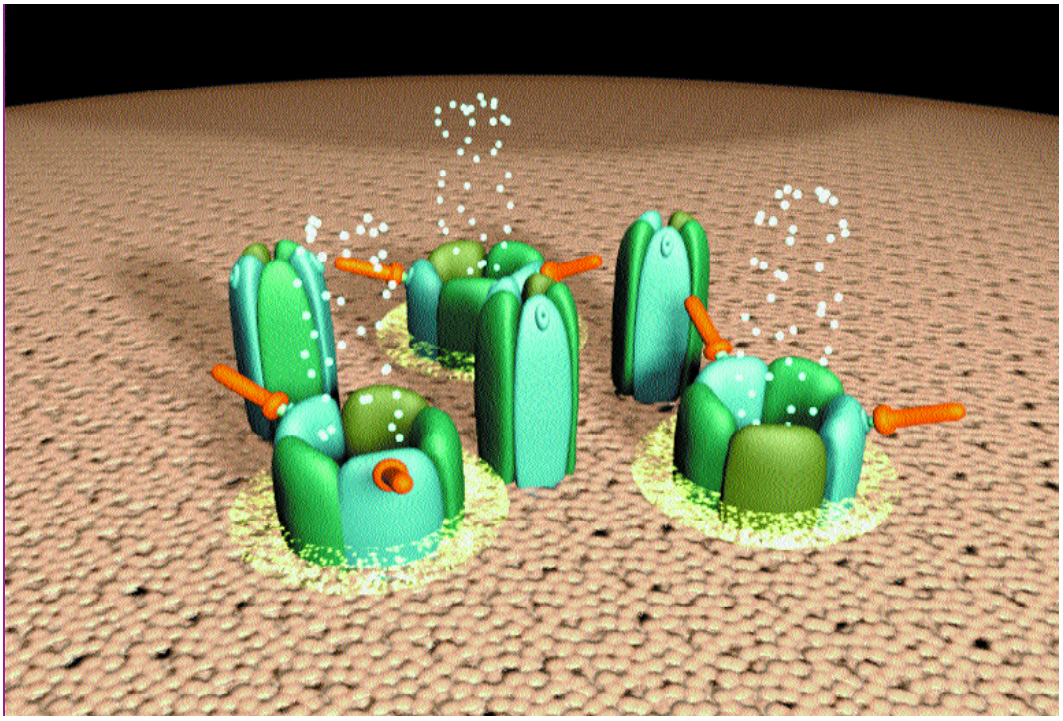
2. Electrical information is converted into chemical information at the nerve terminal. The terminal forms a connection with another neuron very nearby. This connection is called a _____.

Inside the terminal are small sacs or vesicles that contain neurotransmitters. Although there are many kinds of neurotransmitters, there is only one kind found in each neuron's terminal. When an electrical impulse reaches the nerve terminal, the vesicles move toward the membrane and fuse to it. Then the neurotransmitters are released into the _____ cleft, or space. This process is called _____.

In the picture shown above, several components of the _____ are marked. Indicate below the name of the components.

A. _____ B. _____

C. _____ D. _____



3. Acetylcholine is an important neurotransmitter in the brain. It is synthesized in neurons and released from the terminals. Once in the synaptic space, acetylcholine binds to _____ _____.

Once acetylcholine binds to its _____, several things happen. Below is a list of the steps that take place. Arrange the steps in order by placing a number in the space provided.

_____ An electrical current flows across the membrane.

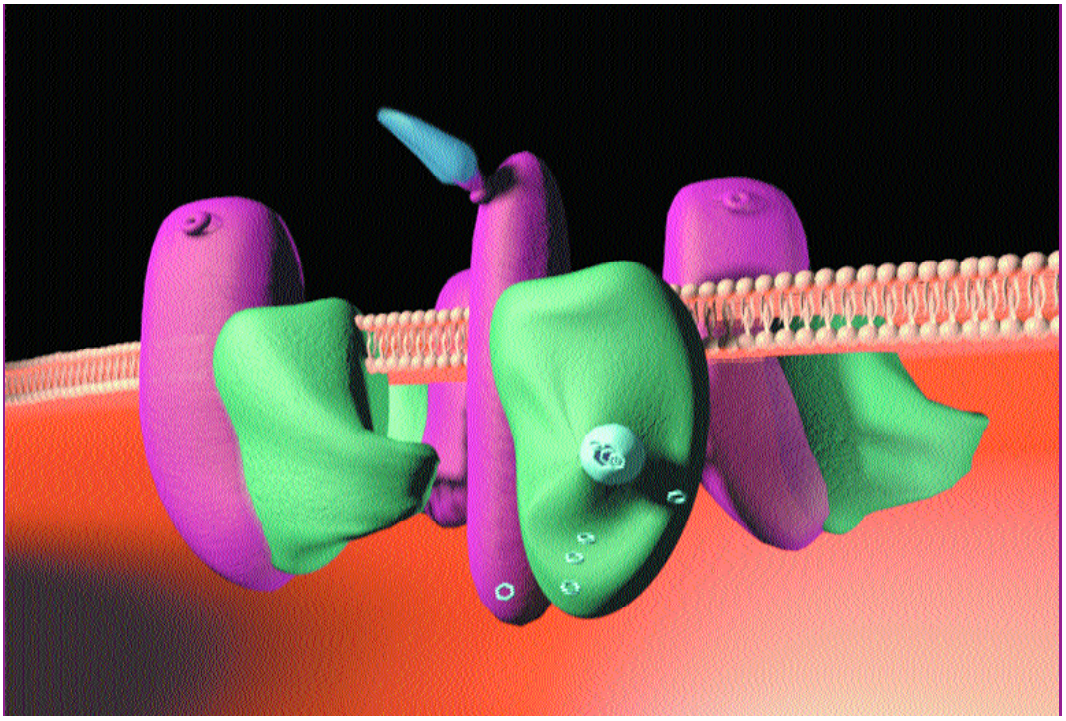
_____ Sodium ions (Na+) flow into the cell through the ion channel.

_____ The electrical current stops flowing across the membrane.

_____ Acetylcholine molecules come off of the _____.

_____ The _____ changes its shape to open a channel within its structure.

_____ The _____ changes its shape to close the ion channel.



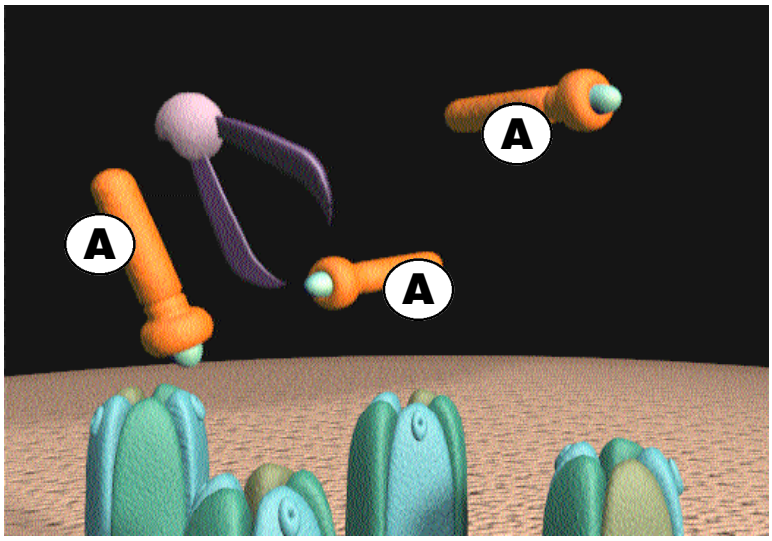
4. Dopamine is a neurotransmitter that binds to a dopamine receptor. In order for dopamine to produce its effect, it requires a series of events. Below, put these events in order by placing a number in the blank.

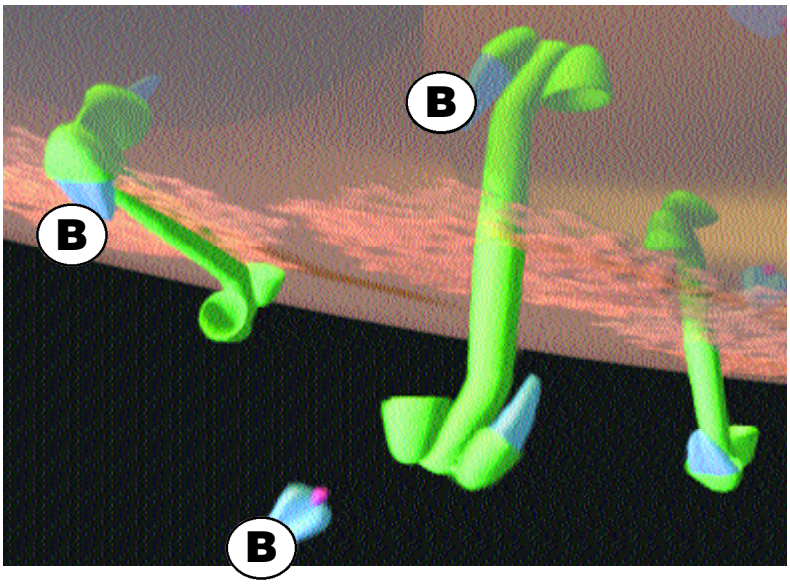
_____ The G protein activates an enzyme (adenylate cyclase) to generate cyclic AMP.

_____ Dopamine binds to its receptor.

_____ As cyclic AMP builds up inside the cell, it causes a change in the membrane currents to increase neuron firing.

_____ When dopamine is bound to its receptor, the helper G protein becomes activated.





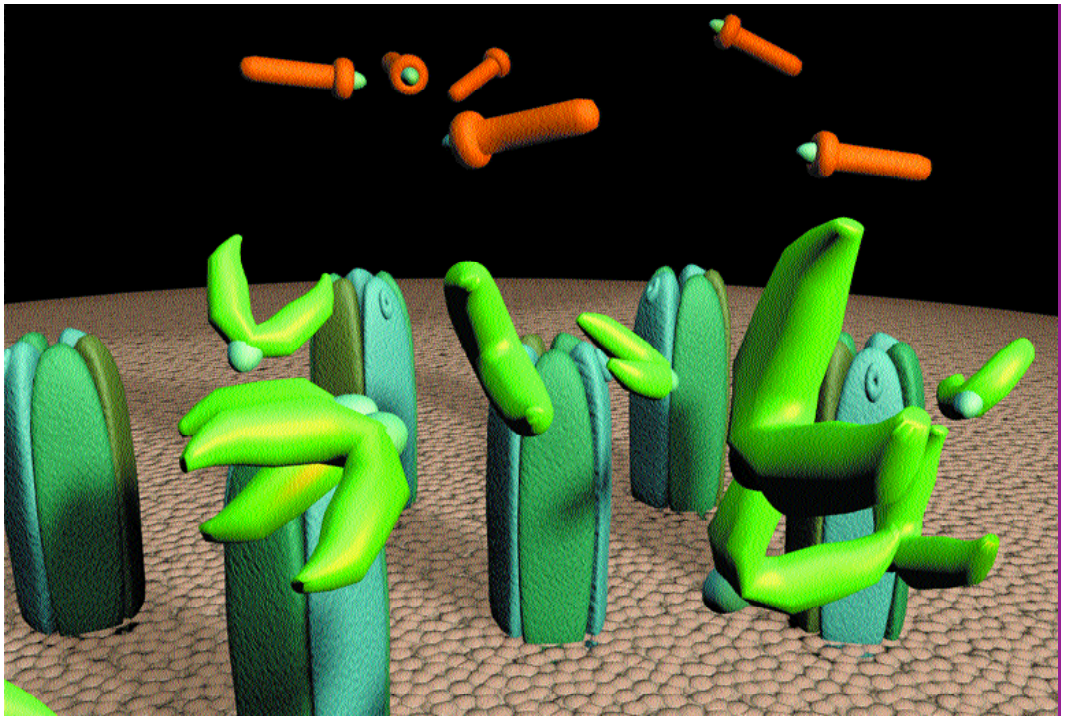
5. There are two basic ways that the actions of neurotransmitters are terminated. Once they come off of their receptors, neurotransmitters can be inactivated by enzymes or taken back up into nerve terminals by uptake pumps. Consider the two neurotransmitters, acetylcholine and dopamine. Below, fill in the blanks to indicate the termination process for each neurotransmitter; then name the labeled structures in each picture above.

Acetylcholine _____ _____

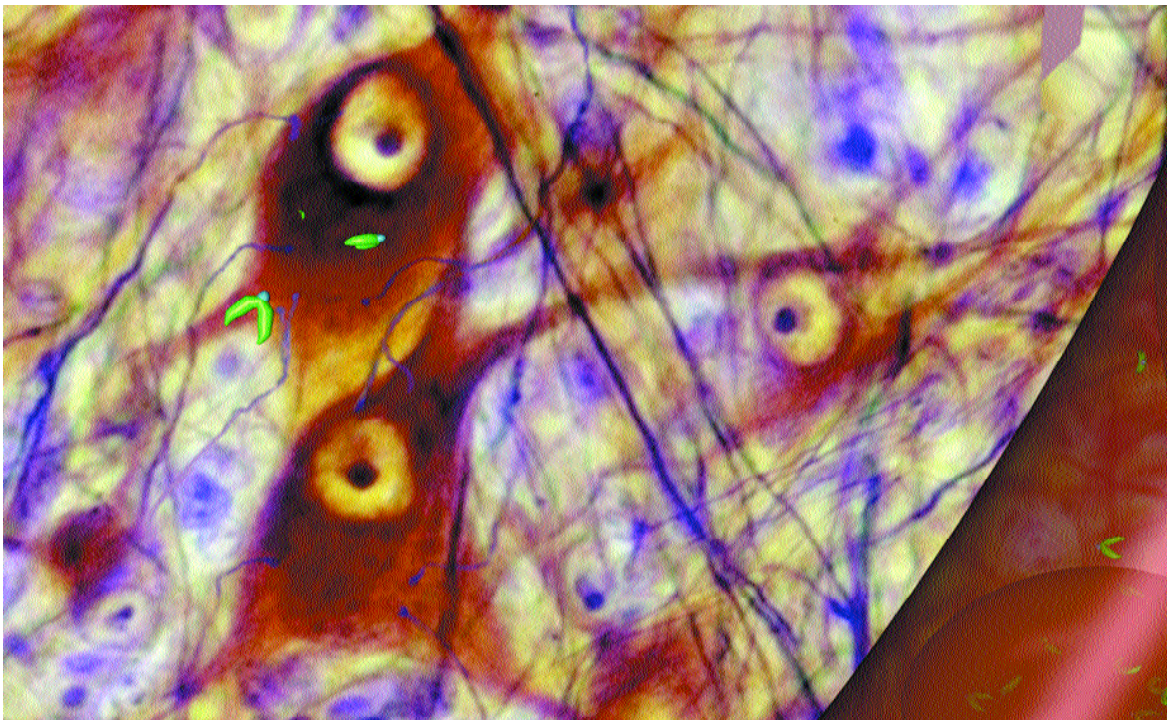
Dopamine _____ _____ _____

A: _____

B: _____



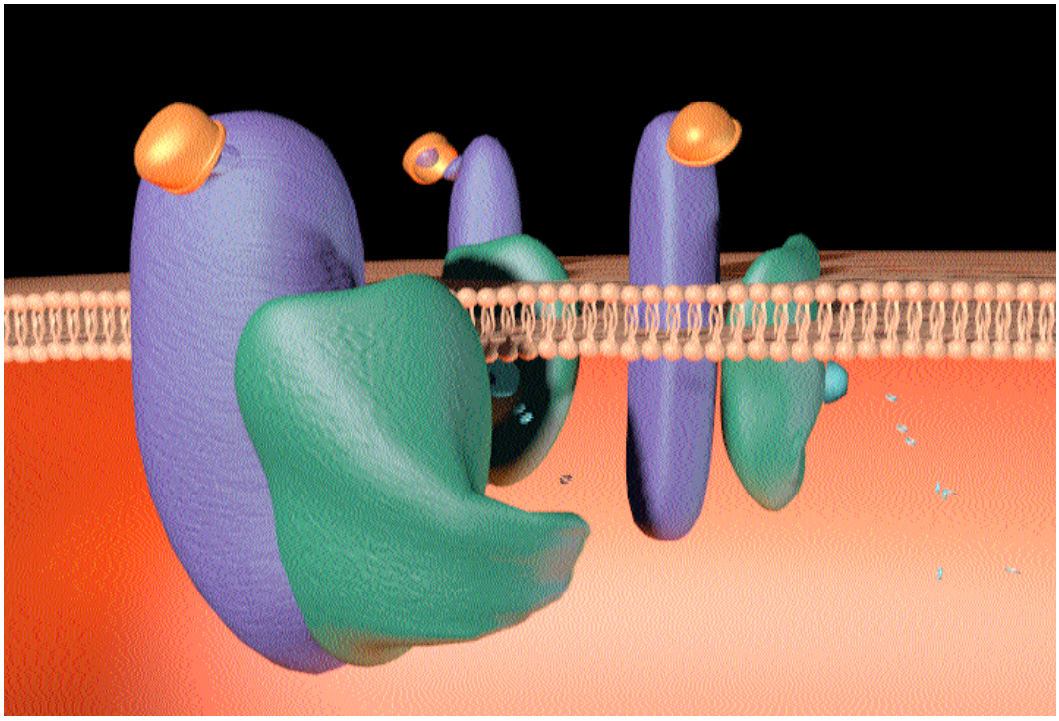
6. Nicotine and _____ bind to the same _____. The drug and the neurotransmitter compete for the same binding site. When a person smokes a cigarette, the _____wins the competition because there are more _____ molecules compared to _____ molecules present in the synaptic space.



7. Drugs such as nicotine, cocaine and THC have special chemical properties that allow them to diffuse across biological membranes very easily (this is called passive diffusion). If they are smoked, the drugs enter the bloodstream by diffusing through _____ membranes in the lungs.

Cocaine, which is also snorted, enters the bloodstream by diffusing through _____ membranes in the nose.

Once in the bloodstream, these drugs travel to the heart and then to the brain. There is a special arrangement of capillary cells in the brain itself called the blood-brain-barrier. This barrier excludes from the brain many compounds that are potentially harmful to the brain. But the chemical structure of nicotine, cocaine, and THC allows them to diffuse easily across the _____ that are part of the blood-brain-barrier, and then they enter the brain itself.



8. In many cases, scientists have discovered receptors to which drugs bind before they have discovered the natural substance in the body that binds to the receptors. Some examples include opiate receptors (to which opiates such as morphine bind) and THC receptors. We now know that endorphins and enkephalins found in our central nervous system bind to opiate receptors to help alleviate pain. Most recently, scientists have found chemicals made in our bodies that bind to THC receptors. One of these, called anandamide (from the Sanskrit word meaning bliss), has received much attention. Now that it has been identified, scientists can determine its function within the brain.

THC, or tetrahydrocannabinol, is the active ingredient in the _____ plant. Once it binds to a THC receptor, a series of events takes place inside the cell. Number the blanks below to put the series of events in order.

____ When THC binds to its receptor, it signals the helper G protein to become inactive.

____ THC binds to a cannabinoid receptor.

____ Nerve impulses in the hippocampus are reduced, causing a loss in short-term memory.

____ The loss of cyclic AMP inside the cell causes a change in membrane currents to decrease neuron firing.

____ Cyclic AMP, which is normally generated inside cells, is no longer generated.

9. There is a pathway in the brain that is activated by addictive drugs. This is called the reward pathway because anything that activates the pathway produces rewarding feelings that may lead to a repetitive behavior. For example, food, water and sex are natural rewards that activate this pathway. Without these, our species would not survive. When drugs activate this pathway, the user often finds more reward in the drugs than in natural rewards. The powerful control that drugs exert on this pathway produces addictive behavior.

Which of the following drugs activate the reward pathway? (Write either "yes" or "no".)

_____ cocaine
_____ heroin
_____ THC (in marijuana)
_____ nicotine
_____ aspirin
_____ LSD
_____ alcohol
_____ penicillin

Dopamine is the major neurotransmitter released by the neurons in the reward pathway. Addictive drugs all increase neurotransmission at dopamine synapses within the reward pathway in a variety of different ways. For example, cocaine increases dopamine in the synaptic space by blocking _____ _____ on the terminals of dopamine neurons. Nicotine binds to _____ receptors that are located on dopamine neurons and increases dopamine release from those neurons. The ability of these drugs to increase dopamine neurotransmission within the reward pathway explains their _____ liability.

Answers

1) A = axon
B = dendrite
C = soma
D = terminal

soma or cell body
axon; terminal; terminal
terminal
dendrites; dendrite

2) synapse
synaptic; exocytosis
synapse

A = synaptic space
B = receptors
C = neurotransmitters
D = axon terminal

3) acetylcholine receptors
receptor
3; 2; 6; 4, receptor; 1, receptor; 5, receptor

4) 3; 1; 4; 2

5) enzyme inactivation
reuptake into terminal
A = acetylcholine (in orange)
B = dopamine (in blue)

6) acetylcholine; receptor; nicotine; nicotine; acetylcholine

7) capillary; capillary; capillaries

8) marijuana
2; 1; 5; 4; 3

9) yes,; yes; maybe; yes; no; no; yes; no; uptake pumps; acetylcholine; addictive

Additional Resources

National Institute on Drug Abuse for Teens: The Science Behind Drug Abuse
http://teens.drugabuse.gov

BrainSource.com
www.brainsource.com (click on "Brain on Drugs")

National Families in Action
www.nationalfamilies.org (click on "NFIA's Guide to Drugs and the Brain")

NCADI: US Dept of Health and Human Services and
SAMHSA's National Clearinghouse for Alcohol and Drug Information
http://ncadi.samhsa.gov

The Partnership for a Drug-Free America
www.drugfree.org

How Stuff Works: How Your Brain Works
www.howstuffworks.com/brain.htm

Live Science: Your Brain Works Like the Internet
www.livescience.com/humanbiology/050104_brain_internet.html

ThinkQuest: Library
www.thinkquest.org/library (type "brain" into search engine)

Additional Resources at www.filmsmediagroup.com

Available from Films Media Group • www.filmsmediagroup.com • 1-800-257-5126

Drugs and the Brain

- **Preview clip online**
- **Close captioned**
- **5-part series, 51 minutes each**
- **DVD/VHS**
- **Order #36364**

"This is your brain on drugs," may be an effective sound bite, but the reality of drug use and abuse is more complicated. As this five-part series shows, the brain can be affected by drugs and alcohol in many different ways, depending on the substance consumed. The effects of stimulants, painkillers, tobacco and alcohol, cannabis, and hallucinogens are analyzed in detail, using the latest research and computer graphics. Each program demonstrates the elaborate and frequently dangerous ways in which various drugs alter brain chemistry. Scientific histories and case studies are clearly illustrated in each program. The series includes *Stimulants: The Mechanics of Pleasure; Painkillers: Numbing the Mind; Legal Drugs: Still Addictive, Still Deadly; Cannabis: Satanic Herb or Healing Potion?; Designer Drugs: Uncertain Borders.* © 2003.

Messing with Heads: Marijuana and Mental Illness

- **Preview clip online**
- **Close captioned**
- **DVD/VHS/Digital On-Demand**
- **Correlates to educational standards**
- **Order #34954**

For decades, heavy marijuana use has been linked to impaired judgment and mental ability. This program explores new research into another link—this time between marijuana and mental illnesses, specifically schizophrenia and paranoid psychosis. Citing a wealth of clinical evidence and observations by neurologists, psychiatrists, and psychologists, the program delves into the frightening effects of THC on young brains: psychotic delusions and behavior that may not appear until years after drug abuse has ended. This program is essential viewing in any anti-drug education campaign. (46 minutes) © 2005.

Drugs: Uses and Abuses

- **Preview clip online**
- **Close captioned**
- **8-part series, 17-39 minutes each**
- **DVD/VHS/Digital On-Demand**
- **Correlates to educational standards**
- **"Attention-grabbing, informative programs." —*School Library Journal***
  "Well-paced to keep teens' interest. Good overview." —*The Book Report*
  Recommended by *Today's Librarian*.
- **Order #9286**

A veritable encyclopedia of pharmacological facts, this outstanding series thoroughly examines the therapeutic uses and dangerous abuses of drugs. Moving beyond the "Just Say No" mentality, each program gives a general overview of a particular class of drugs, then moves on to closely examine specific drugs in that group. These programs promote discussion, explore myths, and provide information delivered in accessible language by a wide range of concerned professionals and recovering users. Review questions are provided with each program to test viewers' knowledge, along with provocative discussion questions that address some of the sensitive issues concerning the use and abuse of drugs. A Cambridge Educational Production. The series includes *Sedatives; Narcotics; Stimulants; Psychedelics and Hallucinogens; Inhalants; THC; PCP and Ketamine; Steroids.* © 1999.

The Addicted Brain

- **Preview clip online**
- **DVD/VHS/Digital On-Demand**
- **Correlates to educational standards**
- **CINE Golden Eagle, 1988**
  "...this fascinating production mounts its case with stunning cinemicrography, three-dimensional models, expert interviews, and live-action sequences." —*Booklist*
- **Order #1363**

This documentary takes viewers on a tour of the world's most prolific manufacturer and user of drugs—the human brain. The biochemistry of the brain is responsible for joggers' highs, for the compulsion of some people to seek thrills, for certain kinds of obsessive-compulsive behavior, even for the drive to achieve power and dominance. The program explores developments in the biochemistry of addiction and addictive behavior. (26 minutes) © 1987.

Young Addicts: Drugs, Alcohol, and America's Future

- **Preview clip online**
- **Close captioned**
- **3-part series, 11-21 minutes each**
- **DVD/VHS/Digital On-Demand**
- **Correlates to educational standards**
- **Recommended by *The New York Times, The Boston Globe, Washington Post, New York Magazine, Booklist, Video Librarian,* and *JAMA (Journal of the American Medical Association)***
- **Order #36282**

Drug and alcohol addiction is stronger than ever among America's teens and young adults. This three-part series of ABC News programs investigates disturbing new trends: teenage methamphetamine abuse, binge drinking among college-age women, and the alarmingly open access that many underage Americans now have to prescription drugs. For vital information about the dangers facing an emerging generation, this is a must-see group of programs. The series includes *Hooked: America on Meth; Women and Alcohol; Pharm Country.* © 2006.

Close to Home: Moyers on Addiction

- **Preview clip online**
- **Close captioned**
- **5-part series, 57-81 minutes each**
- **DVD/VHS/Digital On-Demand**
- **Correlates to educational standards**
- **Recommended by *The New York Times, The Boston Globe, Washington Post, New York Magazine, Booklist, Video Librarian,* and *JAMA (Journal of the American Medical Association)***
- **Order #7679**

In this critically acclaimed five-part series, Bill Moyers puts a human face on an American public health crisis: drug and alcohol addiction. Each program takes on a different facet of addiction and recovery—from studies of brain pathology and genetic risk, to various prevention and treatment approaches, to a look at our public policy. The intimate experience of addiction is shared by the addicts themselves, their parents, children, and those helping them toward recovery. The DVD version of this series also includes a special video introduction by Mr. Moyers. 5-part series, 57-81 minutes each. The DVD version can be viewed using a DVD player or computer DVD-ROM drive.The series includes *Portrait of Addiction; The Hijacked Brain; Changing Lives; The Next Generation; The Politics of Addiction.* © 1989.

Created by
Rochelle D. Schwartz-Bloom, PhD and Gayle Gross de Núñez,, PhD
SAVANTES
Durham, NC
© 1998 SAVANTES and Gayle Gross de Núñez,, PhD

Films for the Humanities & Sciences
A Wealth of Information. A World of Ideas.
PO Box 2053, Princeton, NJ 08543-2053
CALL 800-257-5126 • FAX 609-671-0266

8352