

BRAIN CHEMISTRY  
EXPLORATIONS**A. TEA**

These plants are used by people around the world. Each plant (or plant part) contains one or more chemicals that stimulate or depress certain aspects of the nervous system. Match each plant to its common uses. The first one (tea) has been done for you.

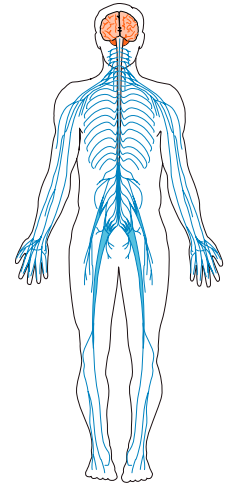
- A. Leaves from this tree, native to Southeast Asia, are brewed to make a stimulating hot drink.
- B. Once used in cough medicines, the seeds of this tropical tree are used in soft drinks and have a stimulatory effect.
- C. The fermented beverage made from this fruit acts as a depressant.
- D. Originating in the Andes, these leaves have been chewed as stimulants for more than 3,000 years.
- E. This grain is fermented to make a beverage which acts as a depressant.
- F. Ground seeds from this Central American tree are used to flavor drinks and candies, and have a mild stimulatory effect.
- G. The seeds inside the berries of this shrub are used to make a stimulating hot drink.
- H. Smoked or chewed leaves from this flowering plant can act as a stimulant or a tranquilizer, and they contain one of the most addictive substances in common use.

**COFFEE****TOBACCO****KOLA****BARLEY****COCA****CACAO****GRAPES**

# BRAIN TO BODY

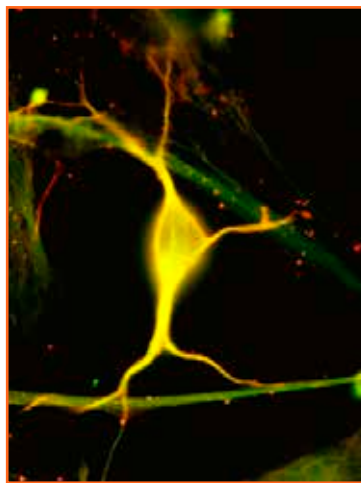


tissue), is the largest part of the brain. It sits above the brainstem and cerebellum, and covers most of the remaining brain structures. It is divided into left and right hemispheres, which are connected. Different parts of the hemispheres handle sensations, hearing, speech, decision making, memory and long-term planning. Although the hemispheres look similar, some functions are handled more by one hemisphere than the other.



**Central Nervous System**

Our emotions are governed by a region of the brain known as the limbic system. Buried under the cerebrum, the limbic system is involved in many emotions and motivations, especially those related to survival, such as anger, fear, and the fight-or-flight response. The limbic system plays a large role in feelings of pleasure, such as those experienced through eating and sex.



**Neuron from the hippocampus, part of the limbic system**

No doubt, the brain is pretty incredible, but the cells that make it up—especially the nerve cells, or neurons—are just as amazing. In fact, all functions of the brain and nervous system—and thus, the whole body—are based on electrical and chemical communications inside

and among neurons. These cells are specialized to receive and transmit information. Different types of neurons vary in appearance, but they all collect information from inside our bodies, from our senses or from other neurons. All neurons also transmit information to other neurons or other kinds of cells (such as muscle cells). Some neurons can receive messages from several thousand different cells at once!

A typical neuron has a central cell body and several branches, or nerve fibers. The branches that receive information are known as dendrites. Most neurons have many dendrites and a longer, tail-like branch called the axon, through which information travels out to the next cell.

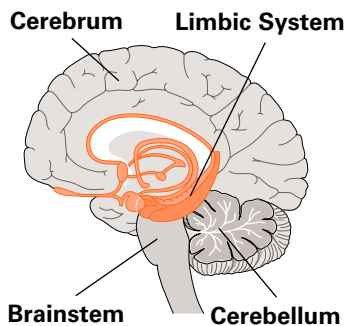
**Y**our amazing brain is the command center of your body. It receives and processes information from the world around you and controls your emotions, thoughts, movements and automatic body functions. Made up of more than 100 billion nerve cells with 100 trillion connections, the brain is our most complex organ. In fact, it is the most complicated arrangement of matter in the known universe.

The brain can be divided into several regions, each with a specific function. These include the brainstem, cerebellum, limbic system and cerebrum.

The brainstem connects directly with the spinal column and is responsible for automatic functions of the body, including

heart rate, breathing, digestion, sneezing and swallowing.

The cerebellum is located near the back of the brainstem. About the size of a tennis ball, it is responsible for skilled repetitive movements, controls balance and helps you learn information, such as the multiplication tables, by rote.



## **BRAIN FLASH**

**The cerebral cortex consists of a thin sheet of nerve cells, about 5 mm thick, that forms the uppermost layers of the cerebrum.**

**The cerebral cortex contains two-thirds of the 100 billion neurons in the human brain.**

The cerebrum, covered by the cerebral cortex (surface



# WORD SEARCH

Find the hidden words in the puzzle to the right. Some of the words refer to parts of the brain. Others include things that may affect how the brain or body works. Circle each word you find. Words may intersect, and may be hidden horizontally or vertically.

**Hint.** There are 30 words. The answers can be found on page 6.

X V N C N U B R A I N S T E M E T C  
 R I T H E N F E R M E D I C I N E E  
 D T N E U R O T R A N S M I T T E R  
 I A N M R A O P B R A I N E I M L E  
 N M T I O P D A S I L T C T N O E B  
 H I O C N R I H E J E L I M B I C R  
 A N B A X O N A L U R H I E L T T U  
 L E A L G T D O P A M I N E A L R M  
 A O C S T E E X O N I C U A S C I H  
 N A C P E I N A R A M C S Y T A C E  
 T A O E A N D A R I N O S C I F A S  
 P I R E C E R E B E L L U M M F L I  
 L B O D N M I N E R A L G O U E N G  
 T R E C E P T O R A T L A M L I E N  
 S Y N A P S E A C D A B R E A N B A  
 T R A H E A L T H S T A C G N E I L  
 C A R B O H Y D R A T E E C T A R N



**A neuron network**

The axon of one neuron usually is separated from the next cell by a tiny gap called a synapse. The space between neurons is about 20

nanometers. Messages traveling from neuron to neuron must cross the synapse for the signal to continue along its path. This is called neurotransmission.

How does information get across the synapse? Chemical changes cause an electrical signal, or impulse, to move from one end of a neuron to the other. This movement along a neuron resembles a line of dominoes in which each domino causes the next one to fall. Once the impulse reaches the end of the neuron, it triggers the release of different kinds of neurotransmitters (chemicals) that cross the synapse and attach to matched receptors on another neuron.

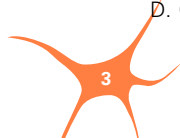
Many drugs have powerful influences on the movement of impulses through the nervous system. They can interfere with or mimic the action of neurotransmitters in the brain and nervous system. Some drugs limit, or even stop, communication between specific neurons by preventing neurotransmitters from being made or released. Others cause an excessive transfer of impulses by telling the cells to create and release massive amounts of neurotransmitters.

**BRAIN FLASH**

“Nano” means one billionth. A nanometer is one billionth (or 0.000,000,001 of a meter). Just imagine how tiny a synapse is if the width of a single hair is 50,000 nanometers!

**Answers to Cover Activity (Scientific name is in parentheses.)**

- A. Tea (*Camellia sinensis*)
- B. Kola (*Cola acuminata*)
- C. Grapes/wine (*Vitis vinifera*)
- D. Coca (*Erythroxylum coca*)
- E. Barley/beer (*Hordeum vulgare*)
- F. Cacao/cocoa (*Theobroma cacao*)
- G. Coffee (*Coffea arabica*)
- H. Tobacco (*Nicotiana tabacum*)







# Fueling the Signals

A healthy brain and nervous system require many different kinds of raw materials that come from food. Glucose (a kind of sugar) is the main source of energy for the brain. Under normal conditions, the brain requires a continuous supply of glucose provided by the blood. *Have you ever felt cranky after missing a meal or had trouble concentrating on a test when you skipped breakfast?* Your brain probably was running low on glucose.

High carbohydrate foods such as bread, pasta and potatoes are important sources of glucose. Your body also can manufacture glucose from proteins and other energy-rich foods. The best kinds of carbohydrates are digested slowly and provide an even supply of energy. Breads, cereals and pastas, when made from whole grains, are examples of good carbohydrates. Candy and other sugary foods actually deprive your brain of fuel because they cause glucose levels in the bloodstream to rise rapidly and then crash.

*Remember the electrical signals that are carried along neurons?* These signals travel through the outer membrane (covering) of nerve cells. The cell membrane is made of fats. Certain kinds of fats and oils are healthier than others. Try to avoid saturated fats and fats that are solid at room temperature (such as shortening, butter and lard). Instead, choose healthier oils such as olive, flax or canola. Some people call fish “brain food” because oily, cold-water fish like mackerel, salmon and trout supply a kind of fat needed to

build cell membranes in the brain.

Proteins from food provide the amino acids used to make neurotransmitters (chemical messengers between neurons). Meat, fish, poultry, dairy products, eggs and beans are good sources of protein. In addition, choline, a substance found in egg yolks, whole wheat products and leafy vegetables, is the basis for the neurotransmitter acetylcholine, which carries signals to muscles and also is important for memory.

The Nutrition Facts labels on food packages can help us make better choices. Check out the label to the right. *Is this a good brain food?*

## Whole Wheat Bread

### Nutrition Facts

Serving Size 1 Slice (43g/1.5 oz)  
Serving Per Container 16

Amount Per Serving		
<b>Calories</b>	100	Calories from Fat 0
<b>% Daily Value*</b>		
<b>Total Fat</b>	1.5g	<b>2%</b>
Saturated Fat	0g	
Trans Fat	0g	<b>0%</b>
<b>Cholesterol</b>	0mg	<b>0%</b>
<b>Sodium</b>	240mg	<b>10%</b>
<b>Total Carbohydrate</b>	21g	<b>7%</b>
Dietary Fiber	3g	<b>12%</b>
Sugars	3g	<b>0%</b>
<b>Protein</b>	5g	<b>16%</b>
Vitamin A		<b>0%</b>
Vitamin C		<b>0%</b>
Calcium		<b>4%</b>
Iron		<b>8%</b>

\* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:		
	2,000	2,500	
Total Fat	Less than 65g	80g	
Sat Fat	Less than 20g	25g	
Cholesterol	Less than 300mg	300mg	
Sodium	Less than 2,400mg	2,400mg	
Total Carbohydrate	300g	375g	
Dietary Fiber	25g	30g	

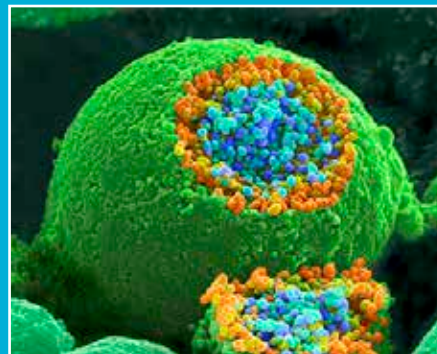
Start here

Limit these nutrients

Get enough of these nutrients



## Did You Know?



Neurotransmitters inside a nerve ending.

The brain contains more than 100 kinds of chemical messengers, called neurotransmitters.

Research on how chemical messengers work within the nervous system is helping scientists answer questions about the causes of many diseases, and is leading to more effective treatments.

Neurotransmitters, for example, are thought to be involved in schizophrenia, a chronic and disabling brain disease. Scientists believe schizophrenia results

from a combination of genetic and environmental factors. This means that even if the disorder appears to run in families, genes alone are not sufficient to cause schizophrenia. Other risk factors, such as exposure to infection or stressful environmental conditions, also may play a role. Persons with schizophrenia may hear voices that no one else can hear or feel like someone else is controlling their thoughts. The disease also can hinder a person’s abilities to manage emotions, interact with others and think clearly. Symptoms typically appear between the late teens and early 30s. Researchers are developing better medications to treat schizophrenia, but there is not yet a cure.

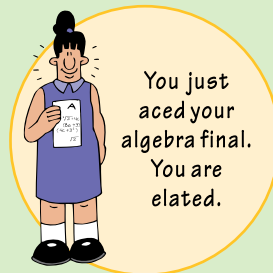
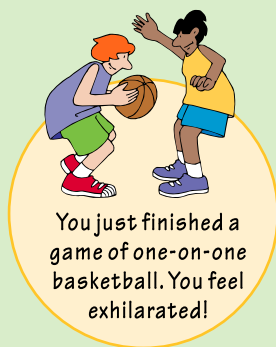
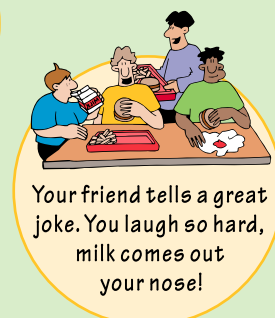
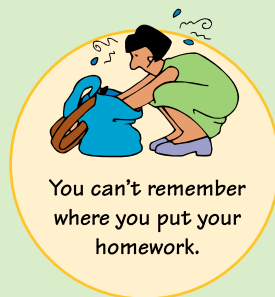
Most medicines or drugs that affect the brain work by changing the release, uptake or manufacture of specific neurotransmitters. For example, some medications used to treat depression, another brain disorder, act on chemical messengers that also are involved in regulating sleep.

Photo of nerve ending courtesy of Tina Carvalho, released into the public domain.



# CHEMISTRY CONNECTIONS

Which of these behaviors, reactions and feelings involve chemicals in the brain? Draw a line from each "scenario" you believe involves brain chemistry to the drawing of the neuron.



**BRAIN FLASH**

Scientists are finding that physical exercise, such as jogging, actually helps the brain perform better.

How can you tell if your feelings or reactions are okay? Feeling nervous before a big game or sad about a death in the family is normal. Needing a doctor's assistance to handle some kinds of problems also is normal. If you learn to pay attention, you may be able to identify when you or a friend needs to ask for help. These are some signs to consider.

- Restless behavior or trouble concentrating
- Weight loss or gain
- A drop in grades
- Feelings of sadness that don't go away
- Not caring about people and things
- Feeling exhausted all the time
- Low self-esteem
- Having trouble falling asleep at night

**Answer.** Actually, all of these behaviors, reactions and feelings involve chemicals and pathways in the brain. Surprised? To learn more about health topics for teens or children, visit the National Institutes of Health web site at [www.nlm.nih.gov/medlineplus/childandteenhealth.html](http://www.nlm.nih.gov/medlineplus/childandteenhealth.html).

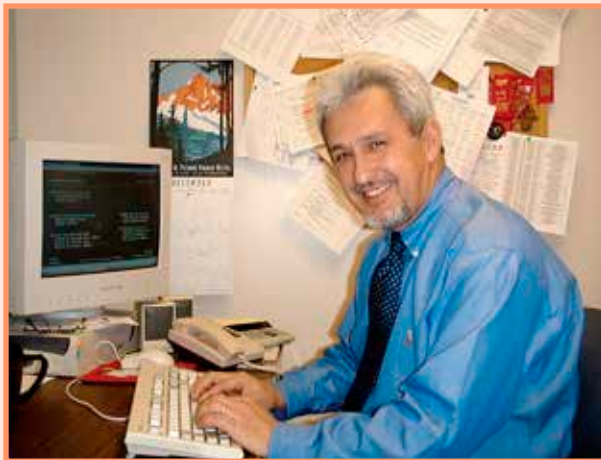
\* ADHD stands for Attention Deficit Hyperactivity Disorder.

**Answers to Think About It (page 8):** Alcohol (1, 2, 4, 5, 6, 7, 13, 16, 18); Cocaine (4, 5, 8, 9, 11, 12); Codeine (1, 4, 5, 9, 13, 17); Ecstasy (7, 8, 10, 11); Heroin (1, 2, 4, 5, 9, 13, 17); Inhalant (2, 7, 8, 9, 11, 13, 15, 16, 18); LSD (8, 9, 10); Marijuana (1/2, 3, 4, 5, 7)



# CAREERS FOR NEUROEXPLORERS: CHEMICAL DEPENDENCY COUNSELOR

Has anyone you know, or anyone your friends know, had a problem with alcohol or other drugs? Abuse of drugs, including alcohol, can damage the body (including the brain and the rest of the nervous system), hurt families and friends, and even cause death. Fortunately, there are teams of professionals specially trained to help people who can't stop drinking or taking drugs on their own. They help to break the cycle of abuse. Meet one of these important professionals, a chemical dependency counselor at Ben Taub General Hospital in Houston, Texas.



## Ricardo Castillo

Licensed Chemical Dependency Counselor  
Coordinator for Substance Abuse Services  
Ben Taub General Hospital  
Houston, Texas

### BRAIN FLASH

Drug abuse is the misuse or overuse of any medication or drug, including alcohol.

*Mr. Castillo, what do you do?*

I am part of a team of health care providers, including physicians, medical residents, nurses, counselors and others. We

work with people who abuse drugs, including alcohol. We try to educate, encourage and support these patients and their families, and to provide the best possible treatment. Our goal is not only to teach people how dangerous substance abuse is, but also to show them how to get off drugs, and how to move forward in their lives. We see people of all ages, but many of our patients are young people.

*What do you find most interesting or rewarding about your work?*

It is very interesting to work with different families and patients, and to learn about cultures and beliefs. I learn as much from my patients as they learn from me. When one of our team's patients gets off drugs and/or alcohol and makes a new start in life, I feel we really made a difference.

*What advice do you have for future chemical dependency counselors?*

Get as much education as you can. You must have at least an Associate's Degree to enroll in a college or university program to become a licensed chemical dependency counselor. It takes about three years to get licensed, which includes 4,000 hours of work experience. You also must be prepared and have a passion for this work. It is very rewarding, but it also is a tough job. You must be strong and supportive for your patients and their families. When a patient recovers, it is the best feeling you can have.

### BRAIN FLASH

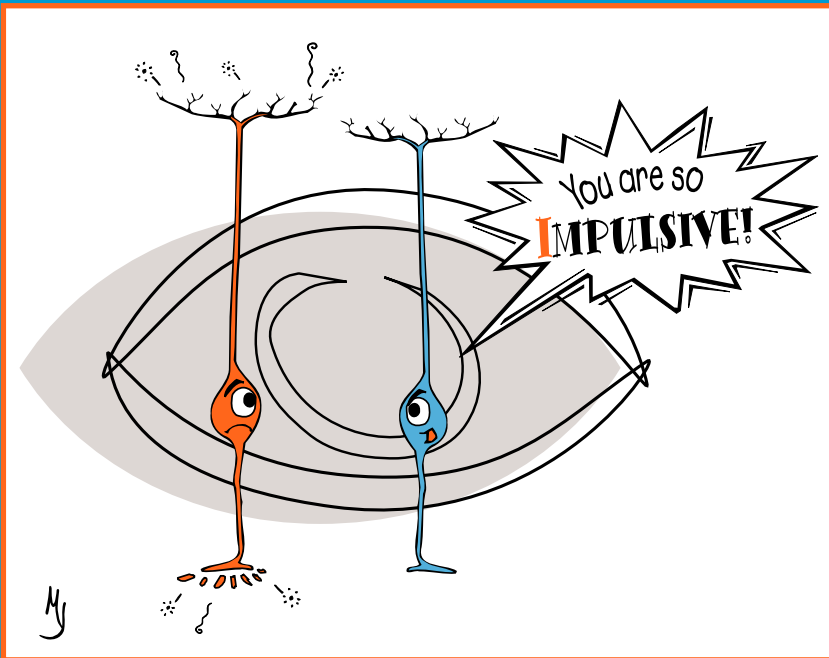
The pufferfish, eaten as a delicacy in Japan, contains a very strong poison in its skin, liver and other parts.

The poison prevents electrical signals from being sent along neurons.

Answers to "Word Search" (page 3). Axon, Brain, Brainstem, Caffeine, Carbohydrate, Cerebellum, Cerebrum, Chemical, Dendrite, Dopamine, Electrical, Food, Health, Inhaled, Limbic, Marijuana, Medicine, Mineral, Neuron, Neurotransmitter, Protein, Receptor, Signal, Speed, Stimulant, Sugar, Synapse, Tea, Tobacco, Vitamin



# Brain Busters!

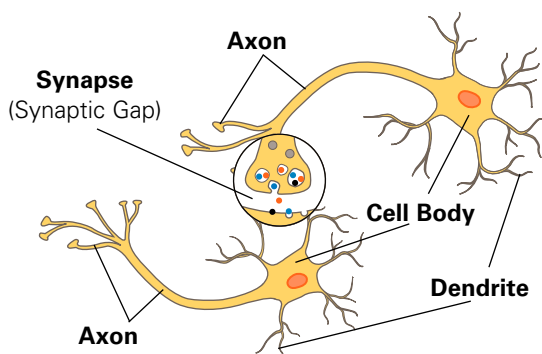


These neurons from the retina of the eye remind us that electrical signals are important for transmitting information in the nervous system. Impulses travel as electrical charges along the outer membranes of nerve cells (neurons). Ordinarily, living cells would not be good conductors of electricity. However, the membrane of a neuron is adapted to transmit an electrical charge rapidly along the length of the cell. This is called "firing."

For a message to continue, signals must be carried across the gap (synapse) between one neuron and the next. Special chemicals, called neurotransmitters, carry the messages. Neurotransmitters can trigger the next cell to fire or prevent a new impulse from being generated.

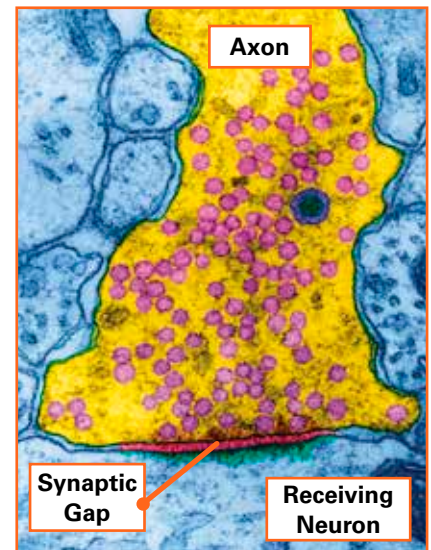
## SENDING SIGNALS

Neurons send signals to other neurons by releasing neurotransmitters. The drawing below illustrates how neurotransmitters are released, and how they cross a synapse to another neuron.



Neurons can be seen through special microscopes. The photograph of an actual neuron (to the right) is

colored to show the different parts involved in the transmission of messages. The pink dots are packets, called vesicles, containing neurotransmitters. The blue dot inside the yellow area also is a vesicle, but it contains a different kind of neurotransmitter. Each vesicle holds many molecules of neurotransmitter (on the order of 10,000s). The yellow background highlights the neuron sending the message.



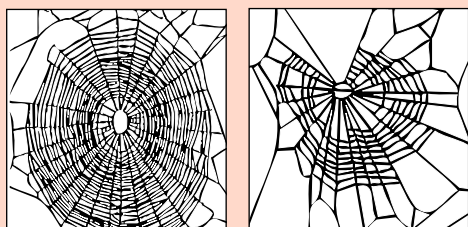
The thin magenta color shows the synapse, or synaptic gap. The green area beneath the magenta color is a portion of the receiving neuron. Notice how close the neurons are to each other!




# THINK ABOUT IT

Many abused substances have side effects that people don't think about. Look at the substances listed in the white boxes and study the numbered list of Effects (1–18).

Write the numbers for all corresponding effects in each substance box. Keep in mind that each substance can cause more than one effect and that each effect may go with more than one substance. The effects of Tobacco are given. Complete answers are on page 5. *Were there any surprises?*



NASA Tech Briefs, 19(4): 82, 1995

 NASA scientists have used spider web patterns to investigate the effects of possibly toxic chemicals. The web on the left represents a normal pattern. The web on the right was created by a spider after being exposed to marijuana. *What happened?*

Alcohol

Cocaine

Codeine

Ecstasy

Heroin

Inhalant

LSD

Marijuana

Tobacco **4, 8, 11, 14**

## EFFECTS

1. Slowed thinking or confusion
2. Poor balance and coordination
3. Panic attacks
4. Addiction
5. Short-term feeling of well-being
6. Liver disease
7. Memory loss or poor learning
8. Abnormal heart rate or heart failure
9. Nausea
10. Seeing or hearing things that are not real
11. Temporary feeling of energy
12. Ulcers inside nose
13. Unconsciousness
14. Heart disease
15. Sudden death
16. Lowered inhibitions
17. Pain relief
18. Slurred speech

**For more information about addictive substances, visit <http://drugabuse.gov>.**

## How Risky Is It?

People often take medicines or drugs prescribed by a doctor to help them recover from an illness or maintain good health. Sometimes, people also take legal or illegal drugs to make themselves feel good temporarily.

This temporary feeling of pleasure is a powerful biological force. However, the brain quickly gets used to a drug, so that more and more is needed to recreate the original feelings. Eventually, dangerous quantities of a drug are needed just to feel normal. When someone uses drugs at the cost of his or her health, safety or friendships, he or she is said to be addicted.

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