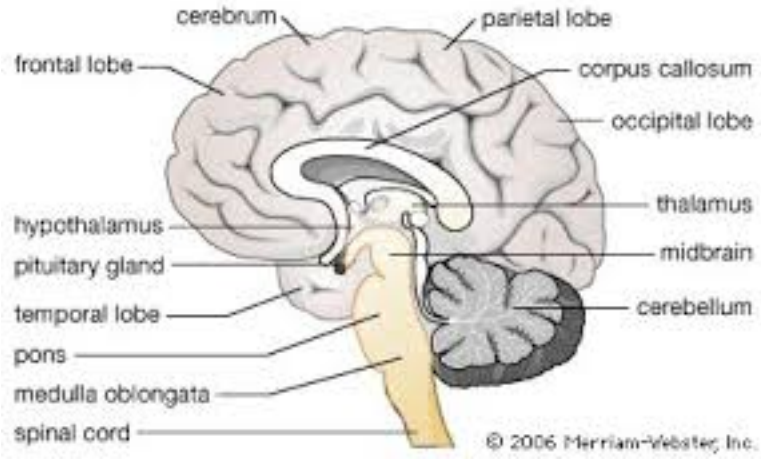
Drugs, The Brain, and Behavior: The Science of Addiction

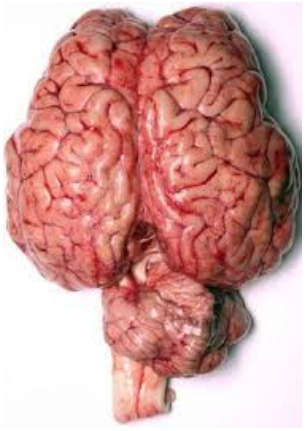
- Nearly 23 million Americans—almost one in 10—are addicted to alcohol or other drugs.
- More than two-thirds of people with addiction abuse alcohol.
- The top three drugs causing addiction are marijuana, opioid pain relievers, and cocaine.
- Abuse of, and addiction to, alcohol, nicotine, and illicit and prescription drugs costs Americans more than $700 billion a year in increased health care costs, crime, and lost productivity.
- Every year, illicit and prescription drugs and alcohol contribute to the death of more than 90,000 Americans, while tobacco is linked to an estimated 480,000 deaths per year.

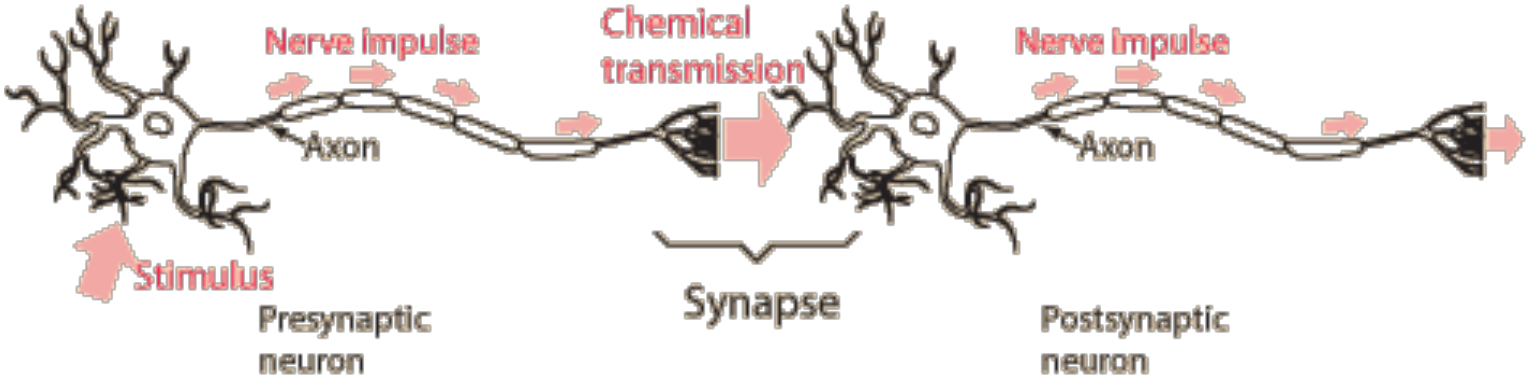
The Brain

The brain is made up of many parts that all work together as a team. Different parts of the brain are responsible for coordinating and performing specific functions.

The brain is a communications center consisting of billions of neurons, or nerve cells. Networks of neurons pass messages back and forth among different structures within the brain, the spinal cord, and nerves in the rest of the body (the peripheral nervous system). These nerve networks coordinate and regulate everything we feel, think, and do.







To send a message, a brain cell (neuron) releases a chemical (neurotransmitter) into the space (synapse) between it and the next cell. The neurotransmitter crosses the synapse and attaches to proteins (receptors) on the receiving brain cell. This causes changes in the receiving cell—the message is delivered.

- ***Neuron to Neuron***

  Each nerve cell in the brain sends and receives messages in the form of electrical and chemical signals. Once a cell receives and processes a message, it sends it on to other neurons.

- ***Neurotransmitters - The Brain's Chemical Messengers***

  The messages are typically carried between neurons by chemicals called neurotransmitters.

- ***Receptors - The Brain's Chemical Receivers***

  The neurotransmitter attaches to a specialized site on the receiving neuron called a receptor. A neurotransmitter and its receptor operate like a “key and lock,” an exquisitely specific mechanism that ensures that each receptor will forward the appropriate message only after interacting with the right kind of neurotransmitter.

- ***Transporters - The Brain's Chemical Recyclers***

  Located on the neuron that releases the neurotransmitter, transporters recycle these neurotransmitters (that is, bring them back into the neuron that released them), thereby shutting off the signal between neurons.

What are the Most Common Neurotransmitters

Serotonin

Regarded as the “master neurotransmitter,” serotonin plays key roles in relaxation, happiness, anxiety, aggression, and more. It is often targeted in

therapies for depression. Although it is produced in the brain, most of the body's serotonin is made in the digestive tract, using tryptophan as a raw material. Serotonin pathways connect to different parts of the brain and perform different functions.

Dopamine

A feel-good neurotransmitter that's the "reward" in reward-motivated behavior, dopamine drives our pursuit of gratifying activities including eating and sex. As a result, it is a contributing factor to various addictions. Dopamine is also a key brain chemical for mental performance and mind-body movement. Besides functioning as a neurotransmitter, dopamine helps form & coordinate other neurotransmitters and hormones. Dopamine is synthesized in the brain and hypothalmus, primarily from L-DOPA, and is a precursor that's used to make norepinephrine.

Norepinephrine

Also known as noradrenaline, norepinephrine is the primary neurotransmitter of the sympathetic nervous system. Stressful events trigger the release of norepinephrine and activate the "region of the brain where norepinephrine pathways are most densely clustered. Norepinephrine release signals for "fight-or-flight" responses in mind and body while sharpening focus, attention, vigilance and arousal.It also plays a role in regulating hunger and mood balance.

Epinephrine

Better known as adrenaline, Epinephrine is the main neurotransmitter of the adrenals. Emotional stressors like fear, anger and danger trigger its release. Epinephrine works with norepinephrine to promote "fight-or-flight" states — constricting blood vessels, priming muscles, opening airways, and accelerating heart rate in preparation for immediate action.

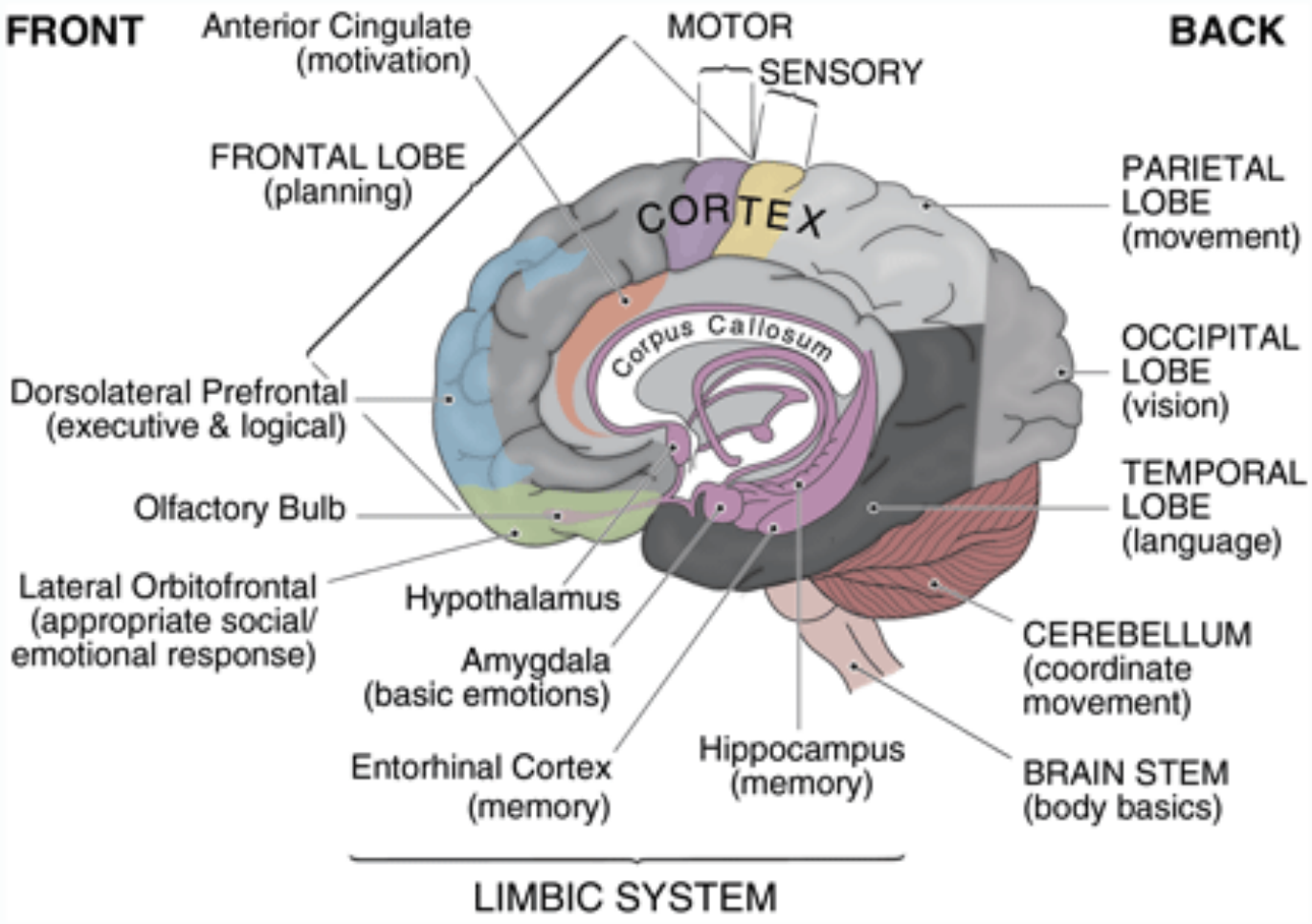
GABA

Gamma-aminobutyric acid, or simply GABA, is a "calming" neurotransmitter; it works by settling the nervous system and reducing the activity of other brain chemicals. GABA has also been shown to promote alpha brainwaves while decreasing beta brainwaves. GABA's effects are most commonly associated with relaxation, mood and sleep benefits.

Affect of Drug Abuse on Neurotransmitters

The amount of any given neurotransmitter in the brain's circuits is precisely controlled by numerous feedback mechanisms, somewhat the same way that a thermostat keeps a room around a certain temperature.

Drugs are substances that disturb this delicate balance, because they have "passkeys" that let them open certain "locks" located between the neurons. The brain automatically adjusts to these substances from outside the body by producing fewer of its own natural "keys". It thereby achieves a new state of equilibrium that is maintained until the body starts to miss the external substance. At that point, the person experiences a craving that will persist until the neurons that went on vacation get back to work.



How Do Drugs Work in the Brain?

Drugs affect the brain by tapping into its communication system and interfering with the way neurons normally send, receive, and process information. 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. Although these drugs mimic the brain’s own chemicals, they don’t activate neurons in the same way as a natural neurotransmitter, and they lead to abnormal messages being transmitted through the network.

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.

How Do Drugs Work in the Brain to Produce Pleasure?

Most drugs of abuse directly or indirectly target the brain’s reward system by flooding the circuit with dopamine. Dopamine is a neurotransmitter present in regions of the brain that regulate movement, emotion, motivation, and feelings of pleasure. When activated at normal levels, this system rewards our natural behaviors. Overstimulating the system with drugs, however, produces euphoric effects, which strongly reinforce the behavior of drug use—teaching the user to repeat it.

How Does Stimulation of the Brain's Pleasure Circuit Teach us to Keep Taking Drugs?

Our brains are wired to ensure that we will repeat life-sustaining activities by associating those activities with pleasure or reward. Whenever this reward circuit is activated, the brain notes that something important is happening that needs to be remembered, and teaches us to do it again and again without thinking about it. Because drugs of abuse stimulate the same circuit, we learn to abuse drugs in the same way.

Why Are Drugs More Addictive Than Natural Rewards?

When some drugs of abuse are taken, they can release 2 to 10 times the amount of dopamine that natural rewards such as eating and sex do. In some cases, this occurs almost immediately (as when drugs are smoked or injected), and the effects can last much longer than those produced by natural rewards. The resulting effects on the brain's pleasure circuit dwarf those produced by naturally rewarding behaviors. The effect of such a powerful reward strongly motivates people to take drugs again and again. This is why scientists sometimes say that drug abuse is something we learn to do very, very well.

How is Addiction Defined?

The word "addiction" is derived from a Latin term for "enslaved by" or "bound to."

Addiction is defined as a chronic, relapsing brain disease that is characterized by compulsive drug seeking and use, despite harmful consequences. It is considered a brain disease because drugs change the brain—they change its structure and how it works. These brain changes can be long-lasting, and can lead to the harmful behaviors seen in people who abuse drugs.

Addiction exerts a long and powerful influence on the brain that manifests itself in three distinct ways: **craving** for the object of addiction**, loss of control** over its use, and **continuing involvement** with it despite adverse consequences.

Tolerance Defined

Tolerance refers to a physiological state where the effectiveness of a drug has decreased due to chronic administration. This means that more of the drug will be required to achieve the same effect in the future. One of the reasons for why this occurs is that any organism can build up a resistance against the effects of some drugs. There are said to be two mechanisms involved in tolerance: **pharmacokinetic tolerance and pharmacodynamic tolerance**. With **pharmacokinetic tolerance** there is a decreased quantity of the substance reaching the target area. There are

different reasons for why this can occur but a common example is that there has been an increase in enzymes that lead to degradation of the drug. **Pharmacodynamic tolerance** occurs because there is a decreased response to the drug by the cellular mechanism. A common way that this happens is that there has been a reduction in the number of receptors. Some people will assume that increased tolerance means that over time those individuals who are regularly using a drug will need more of it to get the same effect. This is not necessarily the case. In the case of opiates there are four main effects to this drug – pain reduction, sedation, nausea, and constipation. Tolerance only really develops in relation to sedation and nausea – the effects of pain and constipation remain roughly the same for most people. This means that there is no often no need to increase the dosage of the medication over time because pain remains well controlled. The reason for why opiate abusers do need more of the drug to get the same effect is that they are chasing the euphoric effects – the brain develops a tolerance to this quickly.

Physical Dependence Defined

Physical dependence refers to how the body experiences physiological adaptation in response to chronic use of a drug. Humans adapt so well to having these substances in their system that they suffer negative consequences if the drug is stopped abruptly – these are referred to as withdrawal symptoms. These withdrawal symptoms do not only occur with recreational drugs – they can also occur with other medications such as antidepressants. Those who develop a physical dependence will often usually develop tolerance to the drug as well. It differs from addiction because it is a physiological state and not a dysfunctional behavioral syndrome. It would be correct to say that most addicts will have developed a physical dependence on their drug.