

This resource provides basic information on the underlying biology of drug use and drug dependence. It supports one of the competencies related to understanding substance use.

### What Is Pharmacology?

Pharmacology is the study of the nature, effects and uses of drugs. The basic processes that pharmacology studies include how drugs get into the body, what they do in the body, how they do it, and the ways in which the body breaks down and gets rid of them. In other words, how a drug interacts with the body and how the body interacts with the drug.

This resource focuses on the pharmacology of **psychoactive drugs**.

People use this type of drug for the effect they have on the brain and how it changes the way they feel and experience things. Such drugs can also act on areas of the brain that control different parts of the body, affecting liver function, hormone levels, heart rate, breathing and more. It is also possible that the way the liver breaks down a drug (metabolism) can damage other tissues and organs and affect their functioning. Using drugs can result in serious health outcomes, both short-term or acute (e.g., stroke linked to cocaine use) and long-term or chronic (e.g., liver problems linked to regular, heavy alcohol use).

### How Does It Work?

#### The Brain Reward System

The use of psychoactive drugs can lead to addiction or a substance use disorder because they affect the brain's reward system in a powerful way. It is likely that the reward system naturally evolved because it encourages behaviours that help people and animals survive. Typically, behaviours related to survival, such as eating, sex and social interaction, act on an area of the brain known as the ventral tegmental area. Activation of the ventral tegmental area leads to a release of dopamine, an important brain chemical or neurotransmitter in the reward system. Dopamine then affects other parts of the brain (see Figure 1), which results in feelings of pleasure and encourages the individual to repeat the behaviours that produced that pleasure in the first place. This process is called reinforcement. In this way, the reward system reinforces behaviours that are important to survival. For example, a hungry individual wandering in the woods might discover some berries. Eating the berries activates the ventral tegmental area, which releases dopamine into other areas of the brain. The release of dopamine leads to feelings of

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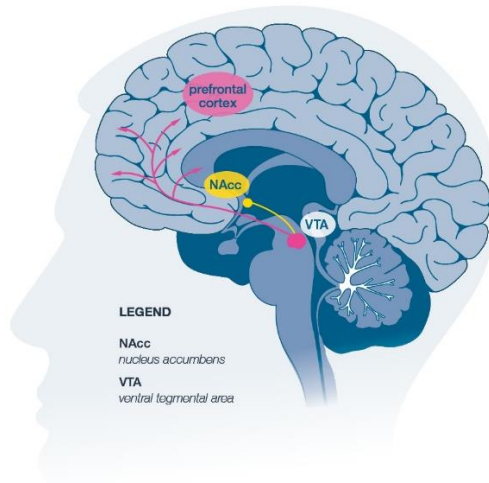
**Psychoactive drugs** are chemical substances that, when taken, affect how the brain works, and changes thinking, mood, and behaviour.

Common psychoactive drugs include:

- caffeine
- alcohol
- cocaine
- cannabis
- opioids

pleasure and reinforces the behaviours that produced the feeling. That is, the individual will be more likely in the future to wander down the same path to find and eat the same berries.

Drugs act on the brain's reward system in a similar way, producing a release of dopamine that leads to feelings of pleasure. People often use drugs for these feelings of pleasure and repeat the behaviour that leads to these rewards. In this way, the reward system reinforces behaviours that support drug use. Drugs often turn on the reward system even more strongly than behaviours such as eating or sex. Addiction can happen when drugs hijack or take control of the reward system.



**Figure 1: The Brain Reward System**

Both drugs and behaviours such as eating, sex and social interaction act on the ventral tegmental area (VTA) in the brain. It produces dopamine and sends it to two other areas of the brain. One area is the nucleus accumbens (NAcc), the pleasure centre of the brain that leads to rewarding feelings. The second area is the prefrontal cortex. This part of the brain is responsible for emotions, learning and impulse control. It helps the individual learn and repeat behaviours that lead to rewarding feelings.

Unfortunately, substance use disorders do not result from simple drug actions on one neurotransmitter or on one part of the brain. Many other chemicals are involved, and there are many ways that drugs can act on the brain. Some drugs, for example, act to block, mimic or increase the activity of natural chemicals in the body.

### How Drugs Act Differently on the Brain

Psychoactive drugs can be categorized into several groups based on how they affect the brain:

- **Depressants** slow down brain function and lead to calmness or drowsiness. Depressants include alcohol, opioids (e.g., heroin, fentanyl, oxycodone, hydromorphone, morphine, etc.), sedatives and medications for anxiety and sleep (e.g., lorazepam, diazepam, diphenhydramine, etc.). Depressants have this slowing effect because they affect certain neurotransmitters that act as the brakes in the brain.
- **Stimulants** increase brain activity, especially in areas that are part of the reward system (see Figure 1). Because of this activity, stimulants lead to pleasurable and rewarding effects. They include drugs such as cocaine, methamphetamine, methylphenidate, pseudoephedrine and caffeine. Some medications in this class, for example methylphenidate, are prescribed for the treatment of attention deficit hyperactivity disorder (ADHD).
- **Hallucinogens** produce their effects by acting on several areas of the brain, and can result in major changes in mood, experiences and thinking. They include drugs such as LSD (lysergic acid diethylamide), PCP (phencyclidine), cannabis and jimson weed.
- **Psychotherapeutic agents** are medications used to treat psychiatric disorders and some types of pain and include antidepressants, antipsychotic medications and mood stabilizers. Most of these medications do not lead to addiction or substance use disorder, although it is sometimes possible with medications used for anxiety and sleep.

## Factors that Modify a Substance's Pharmacology

The effect that drugs have on the brain and body depends on how they are used, the types of chemicals in the drug and what other drugs are being taken at the same time. Sometimes these conditions can make a drug's effect stronger and more harmful.

- **How they are used (route of administration):** The way in which a drug is consumed (e.g., orally, inhaled, injected, etc.) will determine how quickly the drug enters the body, reaches the brain and produces its effects. People who use drugs often prefer a route that produces a rewarding effect very quickly. Drugs that are intended to enter the body slowly (e.g., pills to be swallowed, patches with drugs that are gradually absorbed through the skin) can be altered by snorting, smoking or injecting the drugs to speed up its entry into the body and brain. Changing the route of a drug can increase the amount of the drug that reaches the brain and so increase the risk of harm and death (by overdose) to the user.
- **What they are made of (chemical composition):** The chemical composition of a drug can increase the risk and harm to the user. A major issue with street drugs is the lack of quality control: drugs vary in strength and chemical makeup in unpredictable ways. Sometimes illegal drugs are manufactured to resemble legal, prescription medications, but their content and strength are not known. Because prescription and over-the-counter medications have known content, are legal and provoke less stigma, they are appealing to many users. Although they are perceived to be less dangerous because of their legal status that, unfortunately, is not the case. In recent years, the non-medical use of prescription opioid medications has become a significant public health concern and resulted in a string of deaths related to overdose.
- **What else is being used (polysubstance use):** Frequently, the use of two or more substances at the same time — polysubstance use — is a reality for people who use drugs, and poses some additional challenges and health risks. People might have a specific drug of choice, but will also use other drugs to intensify the drug's effect or to help them deal with side effects or withdrawal symptoms. Sometimes a different substance is used when a drug of choice is unavailable, unaffordable or both. Interactions between drugs are complex and can be concerning. For example, taking several depressants at the same time — alcohol and anxiety medication — can lead to an overdose or death. This effect might be unexpected if a person has experience taking a regular dose of one or the other drug, but the combined effect is something entirely different and dangerous.

## Tolerance, Dependence and Withdrawal

Many psychoactive drugs, especially when used regularly over time, can result in features of substance use disorder that include **tolerance**, **dependence** and **withdrawal**.

- **Tolerance** means that over time an increasing amount of the drug is needed to produce the same effect. With repeated exposure to the drug over time, the body becomes better at breaking the drug down and flushing it out of the blood stream. The body can also become less responsive to the presence of the drug. Indeed, many people who have used a drug for long periods of time and have developed tolerance are unable to recapture the “high” or feeling of well-being they had when they first used the drug. Overdose is a danger when tolerance is lost or reduced, such as after medical detoxification. If the individual uses the same amount of drug they used prior to detoxification, with tolerance lost the body cannot break down and get rid of the drug as quickly as it did before, which can result in overdose.
- **Dependence** can also occur after long-term or chronic use of a drug or medication. While tolerance is building, an individual needs increasing levels of a drug in their bodies to reach the level of pleasure they desire. However, over time the body becomes used to functioning with

the drug in the system. In other words, the body recognizes the presence of the drug as the new normal. In certain circumstances, the body can no longer function properly without the drug. The individual becomes physically dependent on the presence of the drug to function normally. This condition is referred to as dependence.

- **Withdrawal** is when an individual becomes physically dependent on a drug and their bodies become less capable of functioning normally without it. If the drug cannot be found, then a dependent individual will begin showing symptoms of withdrawal. Withdrawal effects are, in many cases, opposite to the effects of the drug itself. Withdrawal symptoms include feelings of fatigue and depression in cocaine withdrawal or aches and pains with opioid withdrawal. Withdrawal symptoms can be directly life threatening, as in the case of severe alcohol use disorder. They can also be indirectly life-threatening, as in the case of opioid withdrawal, during which symptoms can be so troubling that the individual might consider suicide. Insomnia is a common symptom of withdrawal from many psychoactive drugs. People who use opioid or alcohol, for example, might continue using them to prevent withdrawal and to feel normal.

### Implications for Substance Use and Allied Professionals

A basic understanding of how drugs affect the brain and act in the body can help practitioners work more effectively with people who use drugs and alcohol. For example, pharmacology can help us understand why people use drugs or alcohol and why it can be hard to stop. That is, there are biological changes in the brain and body that make drugs very rewarding (e.g., effects on the reward system) and stopping very undesirable (e.g., withdrawal symptoms). It also explains the biology behind people's drug of choice (e.g., depressants, stimulants, hallucinogens) and behaviours that increase the risk of harm (e.g., how drugs are taken, type of drug, polysubstance use). There are, of course, many reasons why people use drugs and why some go on to develop a substance use disorder while others do not. In addition to the biological effects in the brain, there are also social and psychological reasons (e.g., connect with others, relieve stress, experience new things). People can also be at greater risk for drug use and substance use disorder because of their genetics and how it interacts with the environment. The environment includes both childhood and adult life experiences. The pharmacology of drugs is only one important part of understanding addiction. Practitioners also need to consider how pharmacology and these other factors work together to influence drug use and substance use disorders. This will lead to a fuller understanding of addiction and how to help individuals who are struggling with drug or alcohol use.

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### Selected Resources

*Goodman and Gilman's The pharmacological basis of therapeutics* (12<sup>th</sup> ed., 2010)

An authoritative and widely used medical textbook that describes the basic science and clinical application of drugs. Chapter 24, Drug Addiction, provides a good overview of pharmacology related to addiction. Written by Laurence Brunton, Bruce A. Chabner, & Bjorn Knollman.

Source: McGraw-Hill

Available at [www.mhprofessional.com/9780071624428-usa-goodman-and-gilmans-the-pharmacological-basis-of-therapeutics-twelfth-edition-group](http://www.mhprofessional.com/9780071624428-usa-goodman-and-gilmans-the-pharmacological-basis-of-therapeutics-twelfth-edition-group)

*How drug addiction works* (2016)

A simple engaging two-minute video overview of how drug addiction works.

Source: AJ+

Available at [www.youtube.com/watch?v=rJSDgvWQSYI](http://www.youtube.com/watch?v=rJSDgvWQSYI)

*Mechanism of drug addiction in the brain* (2014)

A four-minute video overview of how drug addiction works by affecting the reward system. Includes animation of brain and chemical processes. Available in English, French, Portuguese and Spanish.

Source: Alila Medical Media

Available at [www.youtube.com/watch?v=NxHNxmJv2bQ](http://www.youtube.com/watch?v=NxHNxmJv2bQ)

*Dr. Nora Volkow: How drug addiction hijacks the brain* (2013)

Dr. Volkow, from the U.S. National Institute on Drug Abuse, explains in a short speech on video how drugs take over the reward system.

Source: FORA.tv

Available at [www.youtube.com/watch?v=cL97QKupu1g](http://www.youtube.com/watch?v=cL97QKupu1g)

*Generation Rx videos on drug addiction* (2016)

A series of educational videos on drug addiction, particularly prescription drugs. The focus is on the pharmacology, toxicology and neuroscience behind drug addiction. Presented lecture style with slides.

Source: Generation Rx

Websites: [vimeo.com/generationrx/videos](http://vimeo.com/generationrx/videos)

