The Role of Neurotransmitters

A neurotransmitter is a chemical messenger that carries, boosts, and balances signals between [neurons](https://www.verywellmind.com/what-is-a-neuron-2794890) (also known as nerve cells) and target cells throughout the body. These target cells may be in glands, muscles, or other neurons.

Billions of neurotransmitter molecules work constantly to keep our brains functioning, managing everything from our breathing to our heartbeat to our learning and concentration levels. They can also affect a variety of psychological functions such as fear, mood, pleasure, and joy.

How Neurotransmitters Work

In order for neurons to send messages throughout the body, they need to be able to communicate with one another to transmit signals. However, neurons are not simply connected to one another. At the end of each neuron is a tiny gap called a synapse and in order to communicate with the next cell, the signal needs to be able to cross this small space. This occurs through a process known as neurotransmission.

In most cases, a neurotransmitter is released from what's known as the axon terminal after an [action potential](https://www.verywellmind.com/what-is-an-action-potential-2794811) has reached the synapse, a place where neurons can transmit signals to each other.

When an electrical signal reaches the end of a neuron, it triggers the release of small sacs called vesicles that contain the neurotransmitters. These sacs spill their contents into the synapse, where the neurotransmitters then move across the gap toward the neighboring cells. These cells contain receptors where the neurotransmitters can bind and trigger changes in the cells.

After release, the neurotransmitter crosses the synaptic gap and attaches to the receptor site on the other neuron, either exciting or inhibiting the receiving neuron depending on what the neurotransmitter is.

Receptors and neurotransmitters act like a lock-and-key system. Just as it takes the right key to open a specific lock, a neurotransmitter (the key) will only bind to a specific receptor (the lock). If the neurotransmitter is able to work on the receptor site, it triggers changes in the receiving cell.

Sometimes neurotransmitters can bind to receptors and cause an electrical signal to be transmitted down the cell (excitatory). In other cases, the neurotransmitter can actually block the signal from continuing, preventing the message from being carried on (inhibitory).

Inactivation of Neurotransmitters

So what happens to a neurotransmitter after its job is complete? Once the neurotransmitter has had the designed effect, its activity can be stopped by three mechanisms:

* Degradation: An enzyme changes the structure of the neurotransmitter so it can't be recognized by the receptor
* Diffusion: The neurotransmitter drifts away from the receptor
* Reuptake: The whole neurotransmitter molecule is taken back up by the axon of the neuron that released it

Criteria

The actual identification of neurotransmitters can actually be quite difficult. While scientists can observe the vesicles containing neurotransmitters, figuring out what chemicals are stored in the vesicles is not quite so simple.

Because of this, neuroscientists have developed a number of guidelines for determining whether or not a chemical should be defined as a neurotransmitter:1﻿

* Presence of the chemical within the cell. The chemical is either synthesized in the neuron or otherwise found in it.
* Stimulus-dependent release. It is released in appropriate quantities by the neuron upon stimulation.
* Action on postsynaptic cell. The chemical must be released by the presynaptic neuron, and the postsynaptic neuron must contain receptors that the chemical will bind to.
* Mechanism for removal. A specific mechanism exists to remove the chemical from its site of activation after its work is done.

Classification

Neurotransmitters play a major role in everyday life and functioning. Scientists do not yet know exactly how many neurotransmitters exist, but more than 60 distinct chemical messengers have been identified.2﻿

Neurotransmitters can be classified by their function:3﻿

* Excitatory neurotransmitters: These types of neurotransmitters have excitatory effects on the neuron, meaning they increase the likelihood that the neuron will fire an action potential. Some of the major excitatory neurotransmitters include epinephrine and norepinephrine.
* Inhibitory neurotransmitters: These types of neurotransmitters have inhibitory effects on the neuron; they decrease the likelihood that the neuron will fire an action potential. Some of the major inhibitory neurotransmitters include serotonin and gamma-aminobutyric acid (GABA).
* Modulatory neurotransmitters: These neurotransmitters, often referred to as neuromodulators, are capable of affecting a larger number of neurons at the same time. These neuromodulators also influence the effects of other chemical messengers. Where synaptic neurotransmitters are released by axon terminals to have a fast-acting impact on other receptor neurons, neuromodulators diffuse across a larger area and are more slow-acting.

Some neurotransmitters, such as [acetylcholine](https://www.verywellmind.com/what-is-acetylcholine-2794810) and dopamine, can create both excitatory and inhibitory effects depending upon the type of receptors that are present.

Types

There are a number of different ways to classify and categorize neurotransmitters. In some instances, they are simply divided into monoamines, amino acids, and peptides.4﻿

Neurotransmitters can also be categorized into one of six types:

Amino Acids

* Gamma-aminobutyric acid (GABA): This naturally occurring amino acid acts as the body's main inhibitory chemical messenger. GABA contributes to vision, motor control, and plays a role in the regulation of anxiety. Benzodiazepines, which are used to help treat anxiety, function by increasing the efficiency of GABA neurotransmitters, which can increase feelings of relaxation and calm.
* Glutamate: The most plentiful neurotransmitter found in the nervous system, glutamate plays a role in cognitive functions such as [memory](https://www.verywellmind.com/what-is-memory-2795006) and [learning](https://www.verywellmind.com/what-is-learning-2795332). Excessive amounts of glutamate can cause excitotoxicity resulting in cellular death. This excitotoxicity caused by glutamate build-up is associated with some diseases and brain injuries including Alzheimer's disease5﻿ , stroke, and epileptic seizures.

Peptides

* Oxytocin: This powerful hormone acts as a neurotransmitter in the brain. It is produced by the hypothalamus and plays a role in social recognition, bonding, and sexual reproduction.6﻿ Synthetic oxytocin such as Pitocin is often used as an aid in labor and delivery. Both oxytocin and Pitocin cause the uterus to contract during labor.
* Endorphins: These neurotransmitters than inhibit the transmission of pain signals and promote feelings of euphoria. These chemical messengers are produced naturally by the body in response to pain, but they can also be triggered by other activities such as aerobic exercise.7﻿ For example, experiencing a "runner's high" is an example of pleasurable feelings generated by the production of endorphins.

Monoamines

* Epinephrine: Also known as adrenaline, epinephrine is considered both a hormone and a neurotransmitter. Generally, epinephrine is a stress hormone that is released by the adrenal system. However, it functions as a neurotransmitter in the brain.8﻿
* Norepinephrine: This naturally occurring chemical is a neurotransmitter that plays an important role in alertness is involved in the body's [fight or flight response](https://www.verywellmind.com/what-is-the-fight-or-flight-response-2795194). Its role is to help mobilize the body and brain to take action in times of danger or stress. Levels of this neurotransmitter are typically lowest during sleep and highest during times of stress.
* Histamine: This organic compound acts as a neurotransmitter in the brain and spinal cord.9﻿ It plays a role in allergic reactions and is produced as part of the immune system's response to pathogens.
* Dopamine: Commonly known as the feel-good neurotransmitter, dopamine is involved in reward, motivation, and additions.10﻿ Several types of addictive drugs increase dopamine levels in the brain. This chemical messenger also plays an important role in the coordination of body movements. Parkinson's disease, which is a degenerative disease that results in tremors and motor movement impairments, is caused by the loss of dopamine-generating neurons in the brain.
* Serotonin: A hormone and neurotransmitter, serotonin plays an important role in regulating and modulating mood, sleep, anxiety, sexuality, and appetite. [Selective serotonin reuptake inhibitors](https://www.verywellmind.com/how-are-ssris-used-in-the-treatment-of-panic-disorder-2583979) (SSRIs) are a type of antidepressant medication commonly prescribed to treat depression, anxiety, panic disorder, and panic attacks. SSRIs work to balance serotonin levels by blocking the reuptake of serotonin in the brain, which can help improve mood and reduce feelings of anxiety.11﻿

Purines

* Adenosine: This naturally occurring chemical acts as a neuromodulator in the brain and is involved in suppressing arousing and improving sleep.
* Adenosine triphosphate (ATP): Considered to be the energy currency of life, ATP acts as a neurotransmitter in the central and [peripheral nervous systems](https://www.verywellmind.com/what-is-the-peripheral-nervous-system-2795465).12﻿ It plays a role in autonomic control, sensory transduction, and communication with glial cells. Research suggests it may also have a part in some neurological problems including pain, trauma, and neurodegenerative disorders.

Gasotransmitters

* Nitric oxide: This compound plays a role in affecting smooth muscles, relaxing them to allow blood vessels to dilate and increase blood flow to certain areas of the body.
* Carbon monoxide: This colorless, odorless gas can have toxic and potentially fatal effects when people are exposed to high levels of the substance. However, it is also produced naturally by the body where it acts as a neurotransmitter that helps modulate the body's inflammatory response.13﻿

Acetylcholine

* Acetylcholine: This is the only neurotransmitter in its class. Found in both the central and peripheral nervous systems, it is the primary neurotransmitter associated with motor neurons.14﻿ It plays a role in muscle movements as well as memory and learning.

When Neurotransmitters Do Not Work Right

As with many of the body's processes, things can sometimes go awry. It is perhaps not surprising that a system as vast and complex as the human nervous system would be susceptible to problems.

A few of the things that might go wrong include:

* Neurons might not manufacture enough of a particular neurotransmitter
* Neurotransmitters may be reabsorbed too quickly
* Too many neurotransmitters may be deactivated by enzymes
* Too much of a particular neurotransmitter may be released

When neurotransmitters are affected by disease or drugs, there can be a number of different adverse effects on the body. Diseases such as Alzheimer's, epilepsy, and Parkinson's are associated with deficits in certain neurotransmitters.

Health professionals recognize the role that neurotransmitters can play in mental health conditions, which is why medications that influence the actions of the body's chemical messengers are often prescribed to help treat a variety of [psychiatric conditions](https://www.verywellmind.com/a-list-of-psychological-disorders-2794776).

For example, dopamine is associated with such things as addiction and schizophrenia. Serotonin plays a role in mood disorders including depression and OCD.11﻿ Drugs, such as SSRIs, may be prescribed by physicians and psychiatrists to help treat symptoms of depression or anxiety.

Medications are sometimes used alone, but they may also be used in conjunction with other therapeutic treatments including [cognitive-behavioral therapy](https://www.verywellmind.com/what-is-cognitive-behavior-therapy-2795747).

Drugs That Influence Neurotransmitters

Perhaps the greatest practical application for the discovery and detailed understanding of how neurotransmitters function has been the development of drugs that impact chemical transmission. These drugs are capable of changing the effects of neurotransmitters, which can alleviate the symptoms of some diseases.

* Agonists vs Antagonists: Some drugs are known as agonists and function by increasing the effects of specific neurotransmitters. Other drugs and referred to as antagonists and act to block the effects of neurotransmission.15﻿
* Direct vs Indirect Effects: These neuro-acting drugs can be further broken down based on whether they have a direct or indirect effect. Those that have a direct effect work by mimicking the neurotransmitters because they are very similar in chemical structure. Those that have an indirect impact work by acting on the synaptic receptors.

Drugs that can influence neurotransmission include medications used to treat illness including depression and anxiety, such as SSRIs, tricyclic antidepressants, and [benzodiazepines](https://www.verywellmind.com/the-benzodiazepines-378909).

Illicit drugs such as heroin, cocaine, and marijuana also have an effect on neurotransmission. Heroin acts as a direct-acting agonist, mimicking the brain's natural opioids enough to stimulate their associated receptors. Cocaine is an example of an indirect-acting drug that influences the transmission of dopamine.16﻿