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Neurotransmitters: Types, Function and Examples

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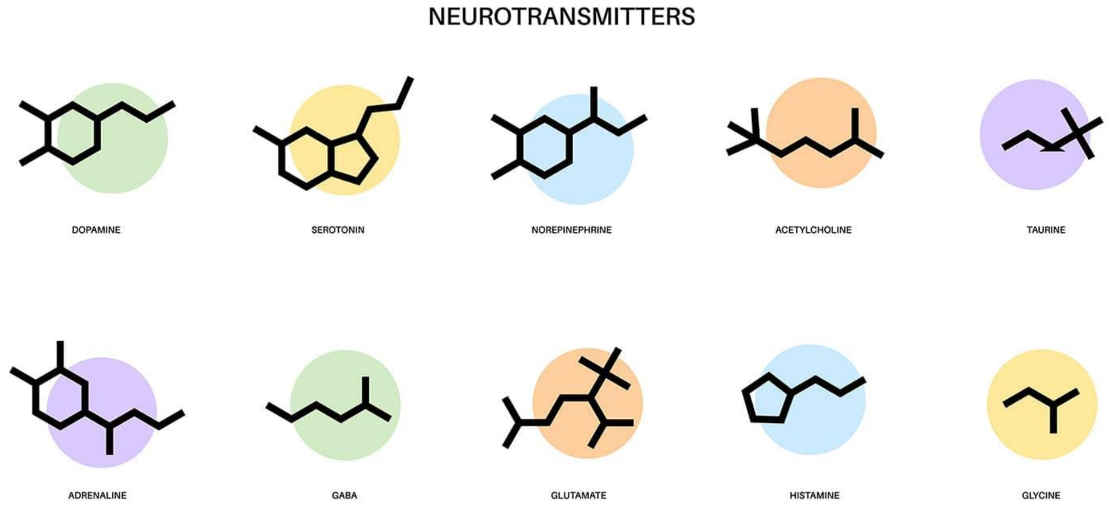
Key Points

- Neurons do not make direct contact. There is a very small gap between neurons called a synapse. The signal needs to cross this gap to continue on its journey to, or from, the CNS. This is done using chemicals which diffuse across the gap between the two neurons. These chemicals are called neurotransmitters.
- Neurotransmitters are chemical messengers that are released from a synaptic vesicle into the synapse by neurons.
- Some neurotransmitters act by making the neuron more negatively charged so less likely to fire. This is an inhibitory effect. This is the case for serotonin. Inhibitory neurotransmitters are generally responsible for calming the mind and inducing sleep.
- Other neurotransmitters increase the positive charge so make the neuron more likely to fire. This is the excitatory effect. Adrenalin is which is both a neurotransmitter and a hormone has an excitatory effect.



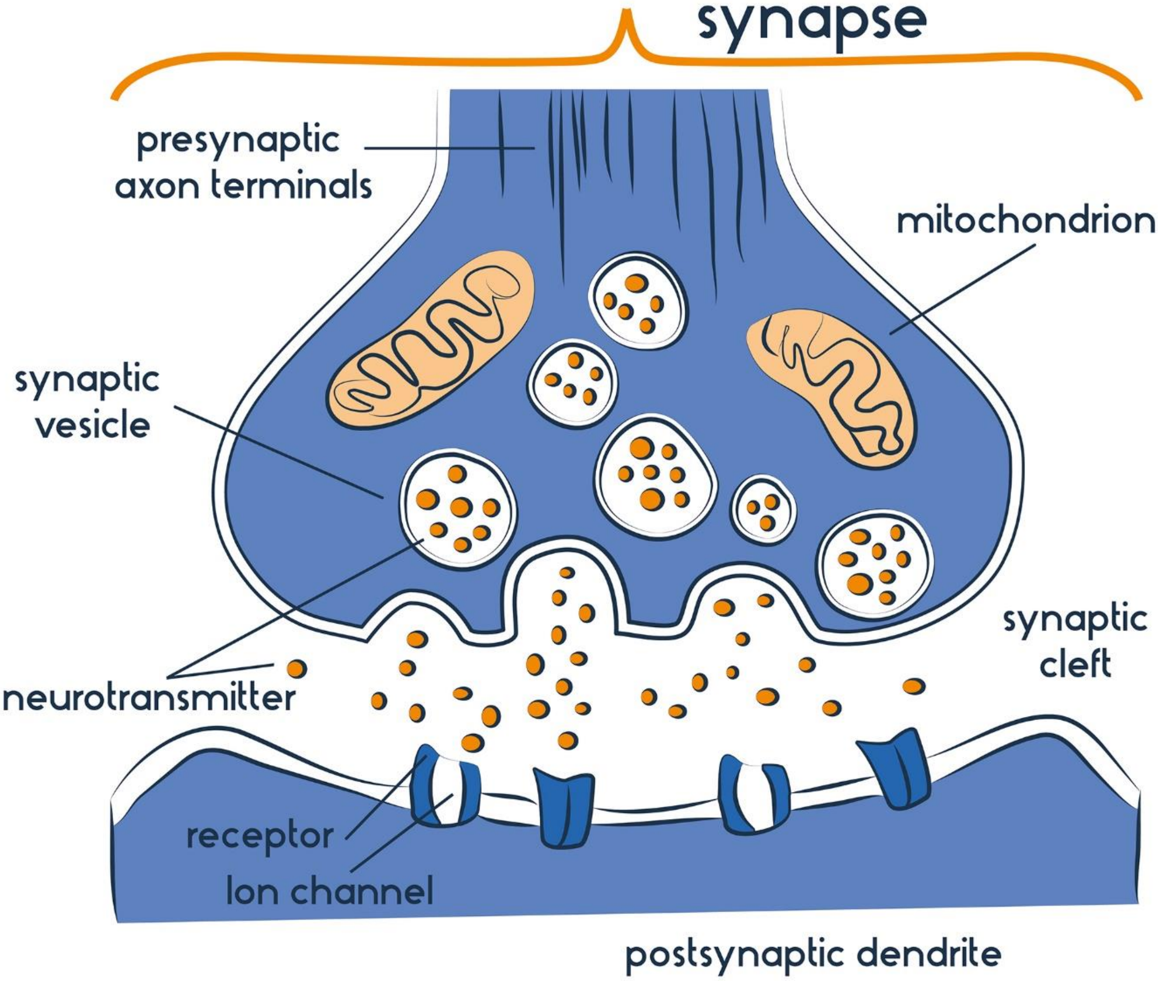
A neurotransmitter is a chemical messenger that allow nerve cells to communicate with each other. A neurotransmitter signal travels from a neuron, across the synapse, to the next neuron. The synapse is the name given to the space between the two neurons.

Neurotransmitters are important in boosting and balancing signals in the brain and for keeping the brain functioning. They help manage automatic responses such as breathing and heart rate, but they also have psychological functions such as learning, managing mood, fear, pleasure, and happiness.

How Neurotransmitters Work

In order for neurons to send messages via neurotransmitters, they need to communicate with each other, which they do through synapses.

When signals travel through a neuron and reach the end of that neuron, they cannot simply travel through to the next one. Instead, the neuron must trigger the release of neurotransmitters, which then carry signals across the synapses with the goal of reaching the next neuron.



During synaptic transmission, the action potential (an electrical impulse) triggers the synaptic vesicles of the pre-synaptic neuron to release neurotransmitters (a chemical message).

These neurotransmitters diffuse across the synaptic gap (the gap between the pre and post-synaptic neurons) and bind to specialised receptor sites on the post-synaptic neuron.

The neuron which released the neurotransmitters is called the presynaptic neuron. The neuron which receives the neurotransmitters is called the postsynaptic neuron.

The end of each neuron has presynaptic endings and vesicles, which are sacks containing neurotransmitters.

When a nerve impulse (or action potential) triggers the release of neurotransmitters, these chemicals are then released into the synapse and then is taken up by the receptors on the next neuron. This process is known as neurotransmission.

For Example

Packets of serotonin molecules are released from the end of the presynaptic cell (the axon) into the space between the two nerve cells (the synapse). These molecules may then be taken up by receptors of the postsynaptic nerve cell (the dendrite) and thus pass along their chemical message. Excess molecules are taken back up by the presynaptic cell and reprocessed.

After Neurotransmission

The neurotransmitters released from the presynaptic neuron may either excite or inhibit the postsynaptic neuron, telling it to either release neurotransmitters, slow down the release, or stop signaling completely.

After neurotransmission, the signal is terminated, allowing the neurons to return to a resting state.

When neurotransmitters get released into the synapse, not all are able to be attached to the receptors of the postsynaptic neuron. However, the gap between the neurons needs to be clearer of neurotransmitters at signal termination.

Therefore, the neurotransmitters either get broken down by enzymes, diffused away, or re-uptake occurs.
Re-uptake is a process whereby neurotransmitters get reabsorbed back into the presynaptic neuron they came from.

After this process, they either get restored back into the synaptic vesicles until needed again, or they get broken down by enzymes.

Classification

A neurotransmitter can influence neurons in one of three ways: it can excite, inhibit, or modulate them.

- **Excitatory neurotransmitters** – these types have an excitatory/stimulating effect on the neurons. If a neurotransmitter is excitatory, it will increase the likelihood that the neuron will fire action potential. Examples of these types of neurotransmitter are epinephrine and norepinephrine.
- **Inhibitory neurotransmitters** – in contrast to excitatory neurotransmitters, inhibitory neurotransmitters have the opposite effect, inhibiting/hindering the neurons. If a neurotransmitter is inhibitory, it makes the likelihood of the neuron firing action potential will be decreased. Examples of these types of neurotransmitter are GABA and endorphins.
- **Modulatory neurotransmitters** – these are often called neuromodulators. If a neurotransmitter is a neuromodulate, this means it can affect a large number of neurons at the same time, as well as being able to influence the effects of other neurotransmitters. Neuromodulators do not directly activate the receptors of neurons but work together with neurotransmitters to enhance the excitatory or inhibitory responses

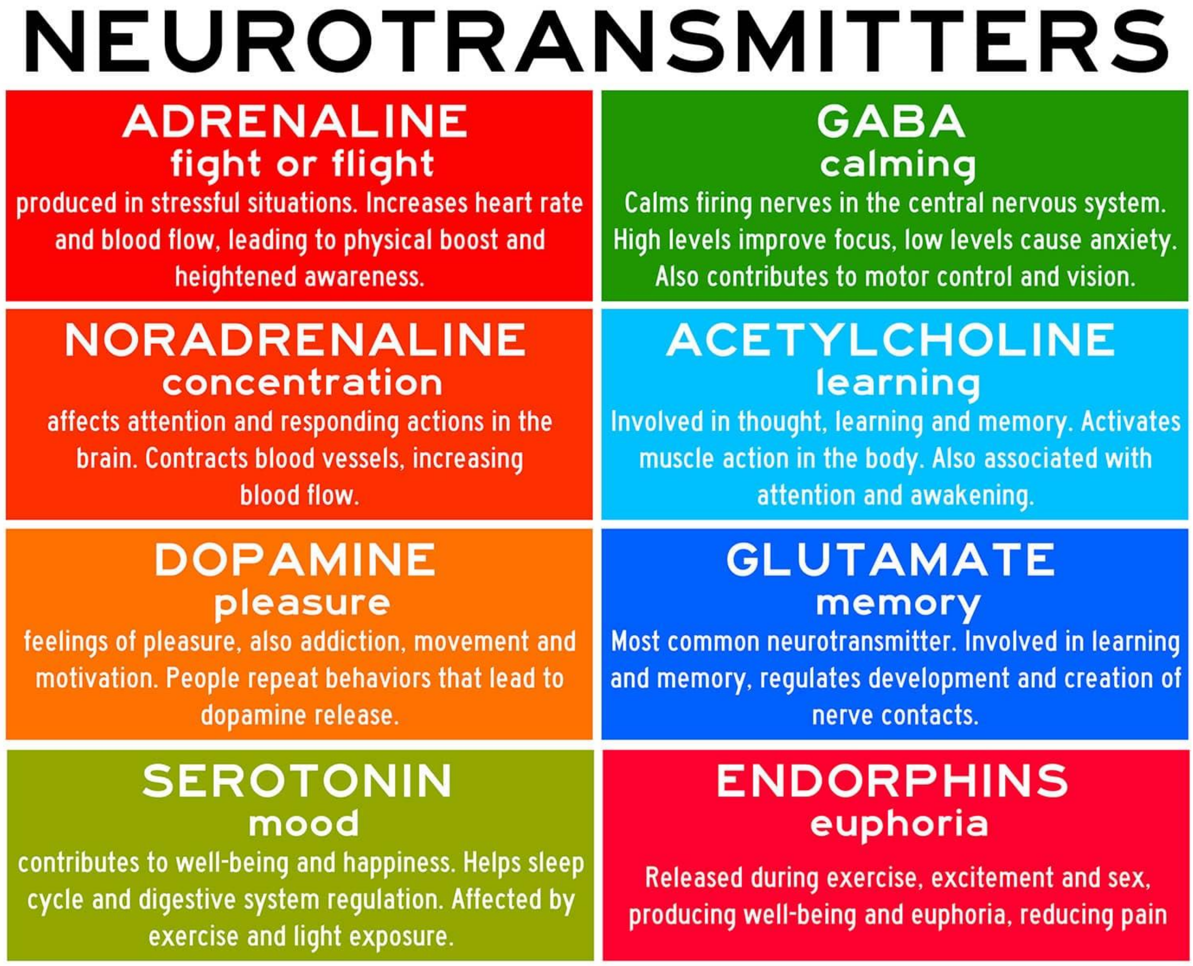
of the receptors.Examples of these types of neurotransmitter are serotonin and dopamine.

Whether a neurotransmitter is excitatory or inhibitory is dependent on the receptor it binds to on the postsynaptic neuron.

Some neurotransmitters can be both excitatory and inhibitory depending on the context. Some can activate multiple receptors as there is not just one receptor for each type of neurotransmitter.

Types

There are over 50 known types of neurotransmitters. Some of the main classifications are described below in a few categories: monoamines, amino acids, peptides, purines, and acetylcholine.



Monoamines

The monoamine group of neurotransmitters is especially important for psychologists as they are involved in a number of behaviors such as decision-making, emotional response, happiness, depression, and reward response.

Type of monoamines are serotonin, epinephrine, norepinephrine, and dopamine.

Serotonin

Serotonin plays a role as a neurotransmitter, as well as a hormone. It is important in controlling mood and can therefore affects the happiness levels of an individual. Serotonin is also important for regulating anxiety, appetite, pain control, and sleep cycles.
Serotonin is found in the enteric nervous system in the gastrointestinal tract (the gut) but is also produced in the central nervous system in an area of the brain stem, called the raphe nuclei. Serotonin is of the inhibitory class of neurotransmitters as it does not stimulate the brain.

Instead, it balances out the excessive excitatory neurotransmitter effects. A deficit in serotonin can be linked to depression, sadness, fatigue, suicidal thoughts, and anxiety. It therefore plays a role in the underlying cause of many mental health issues.

Serotonin syndrome is a condition whereby there is too much serotonin in the brain. This could be caused by a reaction to drugs, leading to symptoms of restlessness, hallucinations, and confusion, and could be fatal.

Epinephrine

This neurotransmitter and hormone are also known as adrenaline. This is a stress hormone which is released into the blood stream via the adrenal glands. This is an excitatory class of neurotransmitter as it stimulates the central nervous system. If there is too much adrenaline in the blood stream, this could lead to high blood pressure, anxiety, insomnia, and increased risk of a stroke. If there were too little adrenaline, however, this can lead to diminished excitement and not being able to react appropriately in stressful situations, diminishing the stress response.

Norepinephrine

Also produced in the adrenal glands, this neurotransmitter is a naturally occurring chemical, also known as noradrenaline. This is an excitatory neurotransmitter as it stimulates the brain and body, also produced within the brainstem and hypothalamus.
This chemical helps in activating the body and brain to take action during time of stress or when in dangerous situations.

It is especially prevalent during the fight-or-flight response, aiding in alertness. Noradrenaline is at its peak during times of stress, but lowest during sleep cycles.

If levels of noradrenaline are too high, this can lead to high blood pressure, excessive sweating, and anxiety. Low levels of this chemical could mean that energy levels are lower, concentration is lacking, and could also contribute to depressed feelings.

Dopamine

Dopamine is produced in areas of the brain called the substantia nigra, ventral tegmental area, and the hypothalamus, projecting to the frontal cortex and the nucleus accubens (responsible for reward and pleasure) among other areas.
Dopamine is both an excitatory and inhibitory neurotransmitter, as well as a neuromodulator, involved in reward, motivation, and addictions. A surplus of dopamine can result in competitive behaviors, aggression, poor control over impulses, gambling, and addiction.

As such, addictive drugs can increase levels of dopamine, encouraging the individual to continue using these drugs to get that pleasure reward. A deficiency in dopamine could result in feelings of depression.

It is thought that dopamine can also play a role in the coordination of body movements and a shortage can be seen in those with Parkinson's disease – resulting in tremors and motor impairments.

Amino Acids

Gamma-aminobutyric acid (GABA)

GABA is a naturally occurring neurotransmitter which is known as the body's primary inhibitory messenger. GABA is located in many brain regions: hippocampus, thalamus, basal ganglia, hypothalamus, and brain steam.
Its main functions are to regulate anxiety, vision, and motor control. People who do not have enough GABA may find they have poor impulse control and could lead to seizures in the brain.

Lack of GABA may also result in mental health issues such as bipolar disorder and mania. If there is too much GABA, however, this could result in hypersomnia (oversleeping) and a lack of energy.

Glutamate

Another amino acid is glutamate, which supports cognitive functions such as memory formation and learning. This is known as the most abundant neurotransmitter, which is found in the central nervous system.
Glutamate is an excitatory neurotransmitter, with receptors found in the central nervous system in the neurons and the glia. If there is an excess amount of glutamate, this could result in excitotoxicity – meaning that neurons are killed due to overactivations of glutamate receptors.

If these neurons are destroyed, this could lead to conditions such as Alzheimer's disease, stroke, and epilepsy.

If there are not enough glutamate, this could result in psychosis, insomnia, concentration problems, mental exhaustion, or even death.

Peptides

Endorphins

This is an inhibitory type of neurotransmitter which works in lowering the transmission of pain signals to the brain and promotes feelings of euphoria. In terms of structure, endorphins are similar to opioids, and work in similar ways.
Endorphins are primarily made within the hypothalamus and pituitary glands in response to pain but can also be released when completing physical activity (contributing to a 'runner's high').

There are not many known symptoms of having too many endorphins, but it could lead to an addiction to exercise. If there were a deficit in endorphins, this could result in feelings of depression, headaches, anxiety, mood swings, and a condition called fibromyalgia (chronic pain).

Purines

Adenosine

Adenosine is a neuromodulator type of neurotransmitter which functions in suppressing arousal and improving sleep cycles. Adenosine is commonly found in the presynaptic regions of the hippocampus and acts as a central nervous system depressant.
Consistently high levels of this neurotransmitter can cause hypersensitivity to touch and heat.

If there is too little adenosine, this can cause anxiety and trouble sleeping. Caffeine is what is known as an adenosine blocker which causes the adenosine receptors to be blocked. This is why caffeine can cause issues with sleeping and is not recommended to drink too late in the day.

Adenosine triphosphate (ATP)

Another type of purine, found in the central nervous system and the peripheral nervous system. ATP has a role in autonomic control, sensory transduction, and communication with glia cells.
It essentially carries energy between cells through being released by activated neurons and passed onto other active neurons in the brain. ATP is excitatory in several brain regions such as the hippocampus and somatosensory cortex.

Acetylcholine

Acetylcholine is the only known neurotransmitter of its kind, found in both the central nervous system and the parasympathetic nervous system. The main function of this type is focused on muscle movements, memory, and learning, associated with motor neurons.

Too much acetylcholine is linked with increased salivation, muscle weakening, blurred vision, and paralysis.

Too little acetylcholine is linked to learning and memory impairments, as well as being shown to have links to dementia and Alzheimer’s, according to research (Haam & Yakel, 2017; Tabet, 2006).

Disorders Associated with Neurotransmitters

Symptoms associated with mental health conditions such as mood and anxiety disorders and schizophrenia are believed to be the result in part from an imbalance of neurotransmitter levels in the brain.
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In depression, there is evidence of abnormalities in noradrenergic, dopaminergic, and serotonergic transmission. Overall, serotonin has been shown to play a role in mood disorders as well as obsessive compulsive disorder (OCD).

Finally, dopamine levels have been shown to be associated with addictions and schizophrenia. The sensitivity of dopamine receptors or too much dopamine is suggested to be associated with schizophrenia (Martin, Ressler, Binder, & Nemeroff, 2009).

The Effects of Drugs

Different types of drugs can affect the chemical transmission and change the effects of neurotransmitters. This can include medications used to alleviate the symptoms of certain mental health conditions, such as SSRIs, benzodiazepines, and anti-psychotics. Neurotransmission can also be affected by illicit drugs such as cocaine, marijuana, and heroin.

Medication

- Selective Serotonin Re-uptake Inhibitors (SSRIs) are a type of antidepressant used to relieve symptoms of conditions such as depression, anxiety, posttraumatic stress disorder, panic disorder, obsessive compulsive disorder, and phobias.

  SSRIs work by blocking the reuptake of the neurotransmitter serotonin into the neuron that released it. This means that there will be a build up of serotonin in the synaptic cleft, making it more likely that serotonin will reach the receptors of the next neurons.

- Benzodiazepines work by reducing the excitability of nerve signals in the brain, mainly for individuals who are suffering from insomnia, anxiety, panic disorder, and certain types of epilepsy.

  These medications work by enhancing the brain's response to GABA, having a relaxing and calming effect on individuals. Benzodiazepines are typically only prescribed for a couple of weeks as it can have adverse side effects of causing more anxiety or altering mood and behavior.

- Antipsychotic medications are usually used to treat the positive symptoms associated with psychosis (e.g. delusions, hallucinations, and paranoia), primarily in those with diagnosed schizophrenia.

  As those with schizophrenia usually have too much dopaminergic activity, antipsychotics work to antagonise dopamine receptors. Antipsychotics can also be used for individuals with dementia, bipolar disorder and major depressive disorder.

Illicit Drugs

Depending on the type, illicit drugs can either slow down or speed up the central nervous system and autonomic functions. Marijuana contains the psychoactive chemical tetrahydrocannabinol (THC) which interacts with, and binds to cannabinoid receptors. This produces a relaxing effect and can also increase levels of dopamine.

Heroin binds to the opioid receptors and triggers the release of extremely high levels of dopamine. The more that heroin is used, the more likely a tolerance will develop from it, meaning that the brain will not function the way it did before starting the drug.

This can cause levels of dopamine to drop when the drug is stopped, which can ultimately lead to this drug being addictive so the user can feel the 'high' from the dopamine again.

Cocaine is a stimulant drug as it speeds up the central nervous system, increasing heart rate, blood pressure, alertness, and energy. Cocaine essentially gives the brain a surge of dopamine with quick effects. The effects of cocaine do not typically last very long and can make a person irritable or depressed afterwards, leading to a craving of more.

Cocaine can be highly addictive due to the way it affects the dopamine levels and reward system of the brain. Ecstasy is a psychoactive drug, which works as a stimulant as well as a hallucinogenic. Ecstasy works by binding to serotonin receptors and stimulating them, as well as influencing norepinephrine and dopamine.

Ecstasy can bring about feelings of pleasure and warmth, overall decreasing anxiety in the moment. However, regular use and aftereffects can increase anxiety, irritability, sleep difficulties, and depressed feelings.