Neurotransmitters

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- Communication of information between neurons is accomplished by movement of chemicals across a small gap called the **synapse**.
- Chemicals, called **neurotransmitters**, are released from one neuron at the presynaptic nerve terminal.
- Neurotransmitters then cross the synapse where they may be accepted by the next neuron at a specialized site called a receptor.

- The action that follows activation of a receptor site may be either depolarization (an excitatory postsynaptic potential) or hyperpolarization (an inhibitory postsynaptic potential).
- A depolarization makes it MORE likely that an action potential will fire; a hyperpolarization makes it LESS likely that an action potential will fire.

Neurotransmitter : Criteria

- The chemical must be produced within a neuron.
- The chemical must be found within a neuron.
- When a neuron is stimulated (depolarized), a neuron must release the chemical.
- When a chemical is released, it must act on a post-synaptic receptor and cause a biological effect.

- After a chemical is released, it must be inactivated.
- Inactivation can be through a reuptake mechanism or by an enzyme that stops the action of the chemical.
- If the chemical is applied on the post-synaptic membrane, it should have the same effect as when it is released by a neuron.

Synaptic Transmission

- Synaptic transmission refers to the propagation of nerve impulses from one nerve cell to another.
- This occurs at a specialized cellular structure known as the synapse, a junction at which the axon of the presynaptic neuron terminates at some location upon the postsynaptic neuron.

- The end of a presynaptic axon, where it is juxtaposed to the postsynaptic neuron, is enlarged and forms a structure known as the **terminal button**.
- An axon can make contact anywhere along the second neuron: on the dendrites (an axodendritic synapse), the cell body (an axosomatic synapse) or the axons (an axo-axonal synapse).

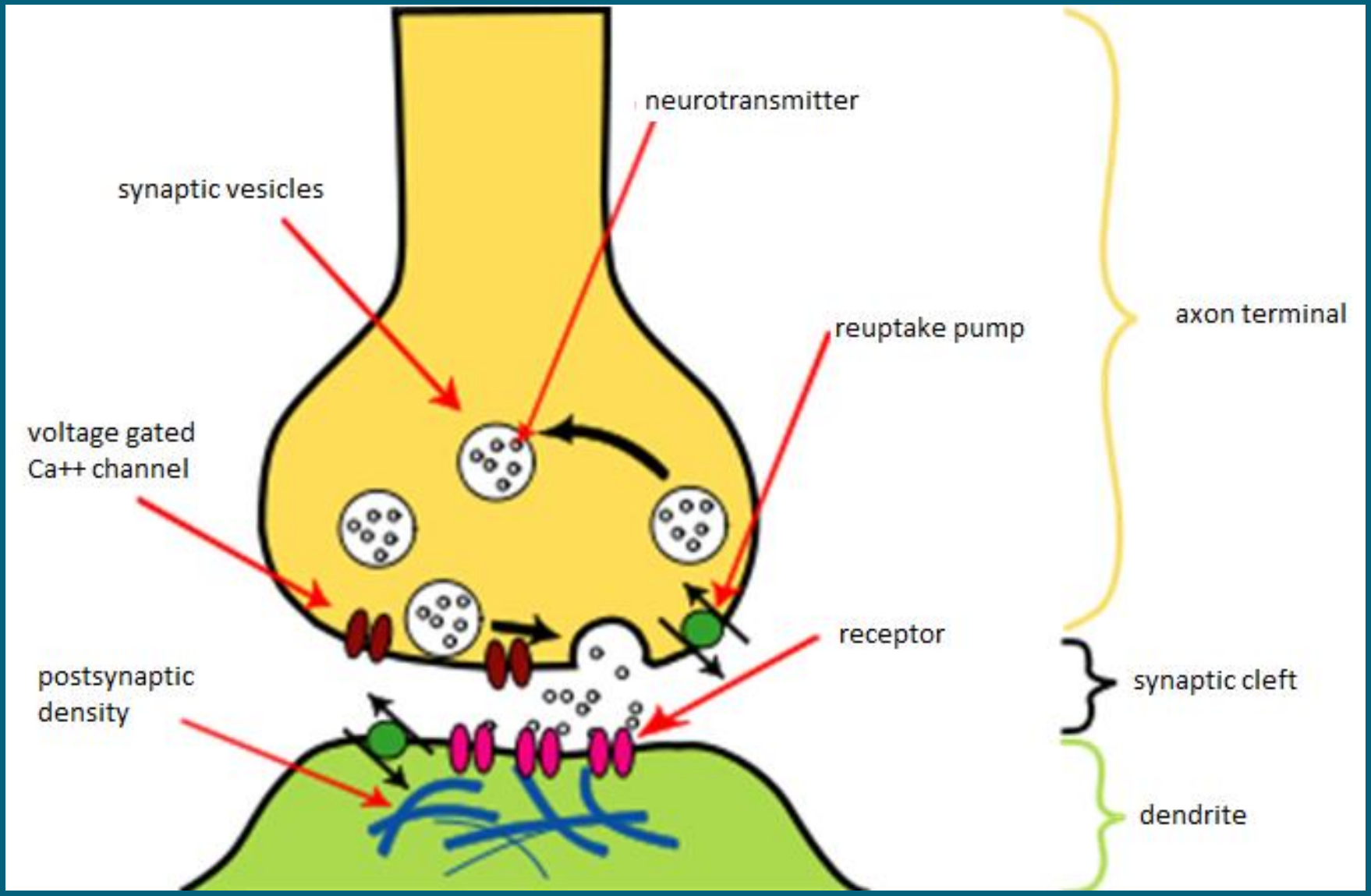
- Nerve impulses are transmitted at synapses by the release of chemicals called neurotransmitters.
- As a nerve impulse, or action potential, reaches the end of a presynaptic axon, molecules of neurotransmitter are released into the synaptic space.

What is the process?

- Chemicals play a vital role in the transmission of signals.
- The impulse (**action potential**) arrives at the terminal button.
- Gated Ca^{2+} (calcium ion) channels open due to the electrical impulse, causing an influx of the ions.
- This influx causes **synaptic vesicles** to diffuse to the terminal button membrane and release the neurotransmitters inside.
- Once in the **synaptic cleft**, the neurotransmitters diffuse over to **receptors** on the **post-synaptic neurone**.

- The neurotransmitters then bind with the receptors. Only the correct neurotransmitters can bind to the receptors (much like a lock and key). The action potential is transferred to the post-synaptic neurone.
- The neurotransmitter is then destroyed with enzymes and recycled; it is reabsorbed into the **pre-synaptic neurone**, which is facilitated with **uptake pumps.** This allows the neurotransmitters to be used again next time.

Structure of a typical chemical synapse



- The neurotransmitters are a diverse group of chemical compounds ranging from simple amines such as dopamine and amino acids such as γ-aminobutyrate (GABA), to polypeptides such as the enkephalins.
- The mechanisms by which they elicit responses in both presynaptic and postsynaptic neurons are as diverse as the mechanisms employed by growth factor and cytokine receptors.

- A neuron affects other neurons by releasing a neurotransmitter that binds to chemical receptors.
- The effect upon the target neuron is determined not by the source neuron or by the neurotransmitter, but by the type of receptor that is activated.
- A neurotransmitter can be thought of as a key, and a receptor as a lock: the same type of key can here be used to open many different types of locks.

- Receptors can be classified broadly as *excitatory* (causing an increase in firing rate), *inhibitory* (causing a decrease in firing rate), or *modulatory* (causing long-lasting effects not directly related to firing rate).
- The two most common neurotransmitters in the brain, glutamate and GABA, have actions that are largely consistent. Glutamate acts on several different types of receptors.

- Since well over 90% of the neurons in the brain release either glutamate or GABA, these labels encompass the great majority of neurons.
- There are also other types of neurons that have consistent effects on their targets, for example "excitatory" motor neurons in the spinal cord that release acetylcholine, and "inhibitory" spinal neurons that release glycine.

- The distinction between excitatory and inhibitory neurotransmitters is not absolute, however. Rather, it depends on the class of chemical receptors present on the target neuron.
- In principle, a single neuron, releasing a single neurotransmitter, can have excitatory effects on some targets, inhibitory effects on others, and modulatory effects on others still.

Types of neurotransmitters

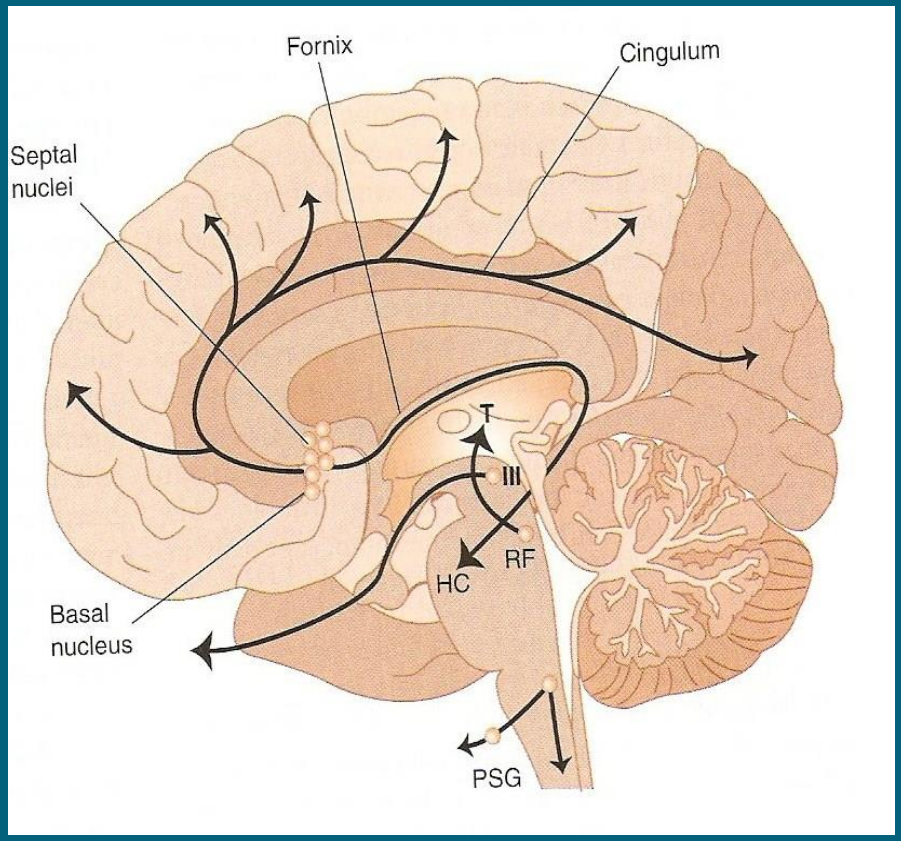
- Neurotransmitters are classified into three main groups namely, amino acids, peptides, and monoamines.
- Amino acids: glutamate, aspartate, D-serine, γ-aminobutyric acid (GABA), glycine
- Monoamines and other biogenic amines: dopamine (DA), norepinephrine (noradrenaline; NE, NA), epinephrine (adrenaline), histamine, serotonin (SE, 5-HT), melatonin
- Others: acetylcholine (ACh), adenosine, anandamide, nitric oxide, etc.

- *Acetylcholine:* This was one of the first neurotransmitters discovered.
- It's main purpose is the stimulation or inhibition of movement in skeletal muscle.
- This neurotransmitter is usually found in the brain and peripheral nervous system. It has also been found to have impact on memory and learning.
- Other uses include slowing of the heart, contraction of the gut area and stimulation of mucus and saliva production.

Acetylcholine (ACh)

Release through the brain via cholinergic pathways. Plays role in:

- cognition (memory)
- sleep/wake cycle
- parasympathetic nervous system
- regulation of heart rate, digestion, production of saliva, bladder function.
- smooth muscle contraction



(Boyd, 2002)

Monoamines

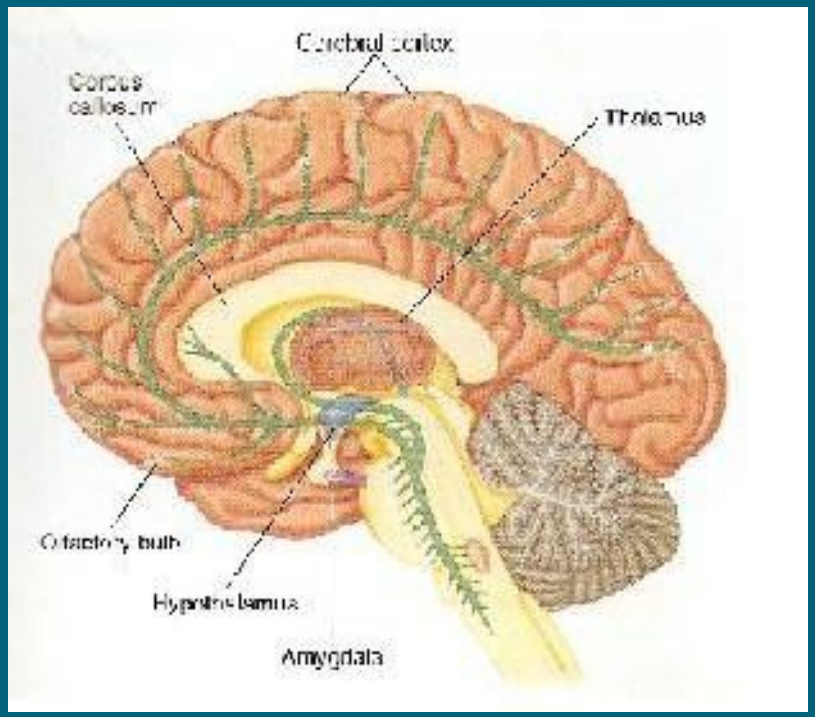
- **<u>Norepinephrine</u>** (NE)

Found mainly in 3 areas of the brain; the locus coeruleous, the pons and reticular formation. Main role;

- attention, alertness, arousal

-sleep/wake cycle

- regulating mood/anxiety



(Barlow and Durand ,2005)

- *Noradrenaline (Norepinephrine):* This is involved in the regulation of mood.
- In Psychology, this is important as low levels of this can be a contributory factor of depression. Very high levels of this can cause stress and aggression;
- it is released in response to short-term stress and therefore causes the heart rate and blood pressure to increase.

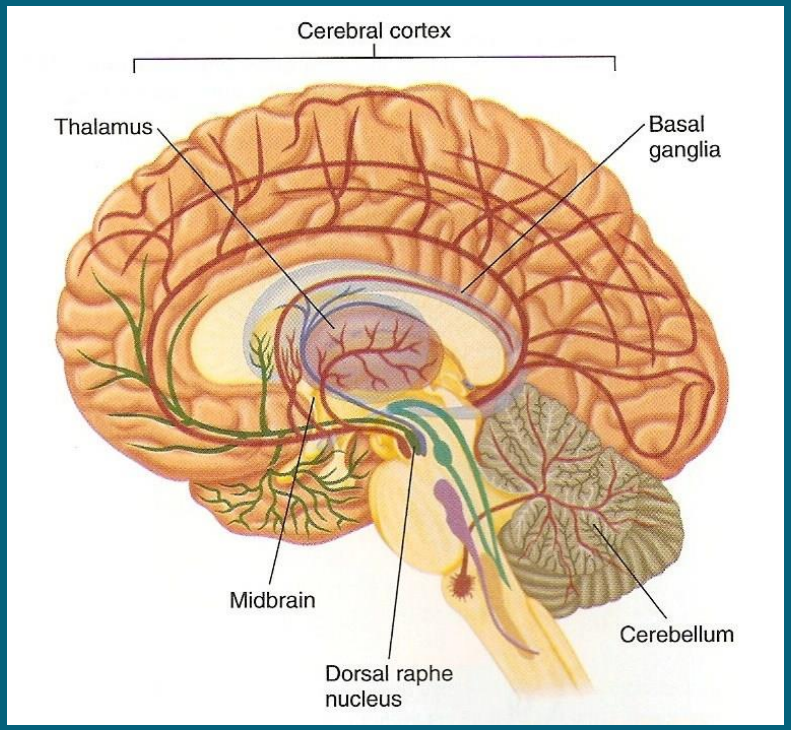
- High levels of this, mixed with high levels of dopamine and phenylethalimine have actually been found to cause the infatuation emotion.
- Biologically, it increases levels of glycogen conversion in the liver, and conversion of fats to fatty acids. It also relaxes bronchial muscles, allowing easier breathing.

- *Serotonin:* This is the prime neurotransmitter regulating mood, sleep, emotion and appetite.
- A large amount causes inhibition of appetite, small amounts cause cravings for food.
- Serotonin in low levels has been linked to depression, and violent/aggressive behaviour.

- **<u>Serotonin</u> (5HT)**

Believed to be one of the great influences on behaviour. Complex neurotransmitter. Surprisingly only 2% of serotonin is found in CNS. Roles include

- Vasoconstriction, gastrointestinal regulation.
- Low serotonin associated with aggression, suicide, impulsive eating, anxiety and low mood.
- regulates general activity of the CNS, particularly sleep.
- Delusions, hallucinations and some of the negative symptoms of schizophrenia.



(Barlow and Durand ,2005)

- *Dopamine:* Dopamine is the pleasure neurotransmitter.
- Drugs such as cocaine, ecstasy and alcohol stimulate the release of Dopamine, causing a feeling of happiness and stimulation.
- In the brain, it actually controls movement, and can help with the regulation of information flow.

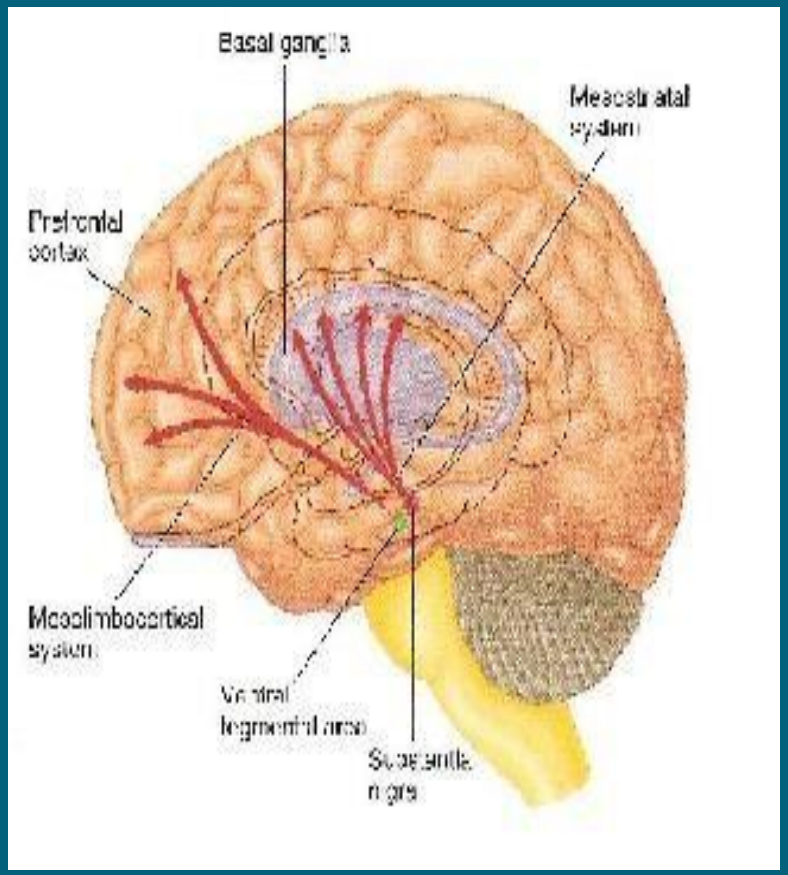
- **Dopamine (DA)**

Almost a million nerve cells in the brain contain dopamine. Role in ;

- complex movement
-cognition
- motor control
- emotional

responses such as euphoria or pleasure.

Newer antipsychotic medication focus on particular dopaminergic pathways in the brain. Lessening EPSE's.



(Barlow and Durand ,2005)

- People with Parkinson's disease have a lack of Dopamine in the brain interior, causing motor problems.
- This neurotransmitter is important in Clinical Psychology, as Schizophrenics suffer a lack of Dopamine in the frontal lobe.
- This clouds their thinking and causes their distinct symptoms.

Amino Acids

- **Glutamate**
  - found in all cells
  - controls opening of ion channels
  - blocking glutamate produces psychotic symptoms
  - Over exposure to glutamate causes cell death
- **GABA**(Gamma-aminobutyric acid)
  - Only found in CNS
  - Inhibitory neurotransmitter
  - controls excitatory neurotransmitters
  - Implicated in anxiety disorders

References

- Boyd (2002). *Psychiatric Nursing , contemporary practice* .Lippincott, USA
- Rosenweig, Breedlove and Leiman (2002) *Biological Psychology: an introduction to cognitive, behavioural and clinical neuroscience 3rd Edition.*Sineur Associates , Inc USA.
- Stuart and Laraia (2005) *Prinicples and Practice of Psychiatric Nursing.* Mosby, USA.
- Barlow and Durand (2005). *Abnormal Psychology, and intergrated approach.*Thompson/Wadsworth, Australia.
- Leonard BE (1997). *Fundamentals in Psychopharmacology*. 2nd ed. Chichester: Wiley & Sons.
- Purves DE, Augustine GJ, Fitzpatrick D, et al. (eds). *Neuroscience*. Sunderland, MA: Sinauer Associates, Inc; 1997.
- Lundbeck Institute, www.brainexplorer.com
- Blakemore & Frith (2005). *The Learning Brain*. Blackwell Publishing
- Begley (2005). The blood brain Barrier. *Gauchers News* May 2005c