

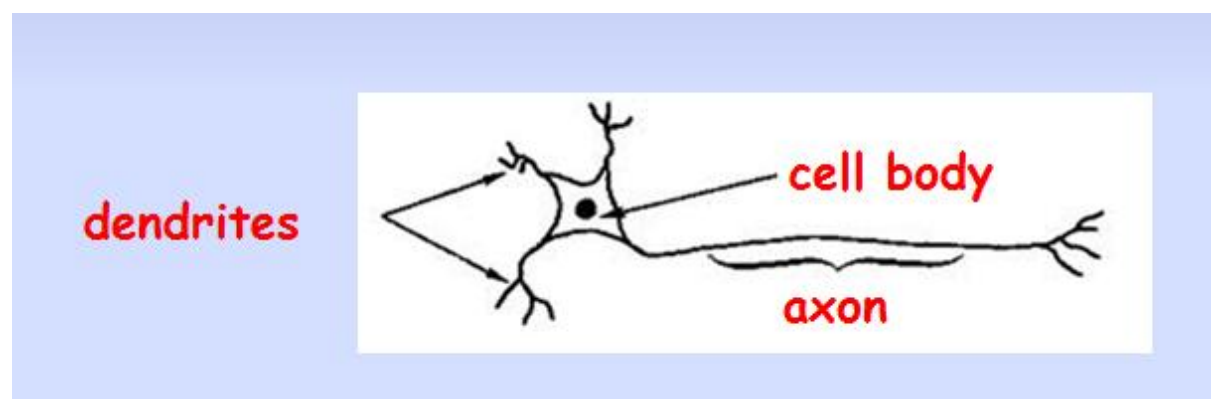
The cells of the nervous system

Neurons

- The nervous system is made up of a system of nerve cells, known as neurons, which transmit electrical signals called nerve impulses.
- Glial cells support and maintain these neurons.

Structure of neurons

- All neurons have the same basic structure, they are composed of three key structures:
 - dendrites
 - a cell body
 - axons



- Nerve impulses always travel in the same direction:

dendrites → cell body → axon.

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- **Cell body** - The cell body contains a nucleus and cytoplasm.
 - The nucleus codes for neurotransmitter. The nucleus also codes for the enzyme which makes or breaks down the neurotransmitter. The nucleus codes for receptors on the post synaptic neuron
 - The cytoplasm contains organelles such as mitochondria to provide energy for impulses and ribosomes which synthesise proteins (e.g. enzymes) for the synthesis of neurotransmitters.
- **Dendrites** – these fibres receive nerve impulses and carry them towards the cell body
- **Axon** – this fibre carries nerve impulses away from the cell body.
- A neuron in a newly-born child has fewer dendrites and synaptic knobs
- The axons of neurons are surrounded in a layer of fatty material known as the myelin sheath.
- The **myelin sheath** greatly increases the speed of transmission of a nerve impulse.
- Myelination (the extent to which an axon is covered in myelin) is not complete at birth.
- As a child ages, myelination increases and so does nervous control. *Some diseases, such as Polio, Tay-Sachs and Multiple Sclerosis (MS) can damage the myelin sheath and result in loss of muscular co-ordination.*
- Since there are fewer dendrites and less myelin sheath, the responses of a two year old child are slower than those of an adult.
- The impulses travel at a slower rate
- Fewer impulses reach the synaptic cleft
- Fewer connections are made to other nerve cells

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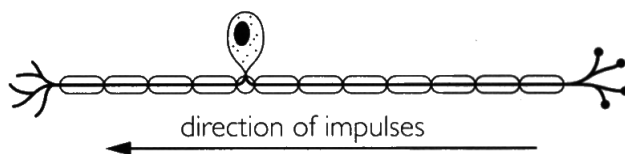
- Less neurotransmitters released into the synaptic cleft

Types of neurons

- There are three main types of neuron:
 - sensory neuron
 - inter neuron
 - motor neuron
- Each of these neurons has adapted to suit their function.

Sensory neuron

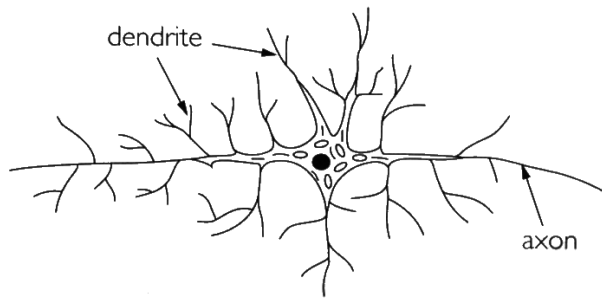
- Has dendrites in contact with sense organs.
- These dendrites merge to form a myelinated fibre which carries impulses to the cell body.
- Has a short axon
- Forms connections with neurons in the CNS



Inter neuron

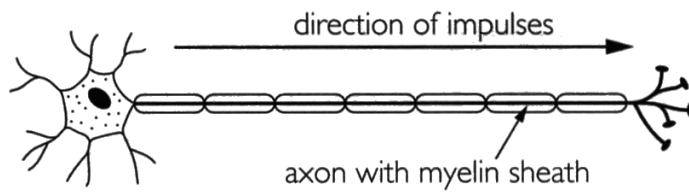
- Connects sensory neurons to motor neurons.
- Has many dendrites which form many complex, connections.

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Unit 3 Notes
The cells of the nervous system and neurotransmitters



Motor neuron

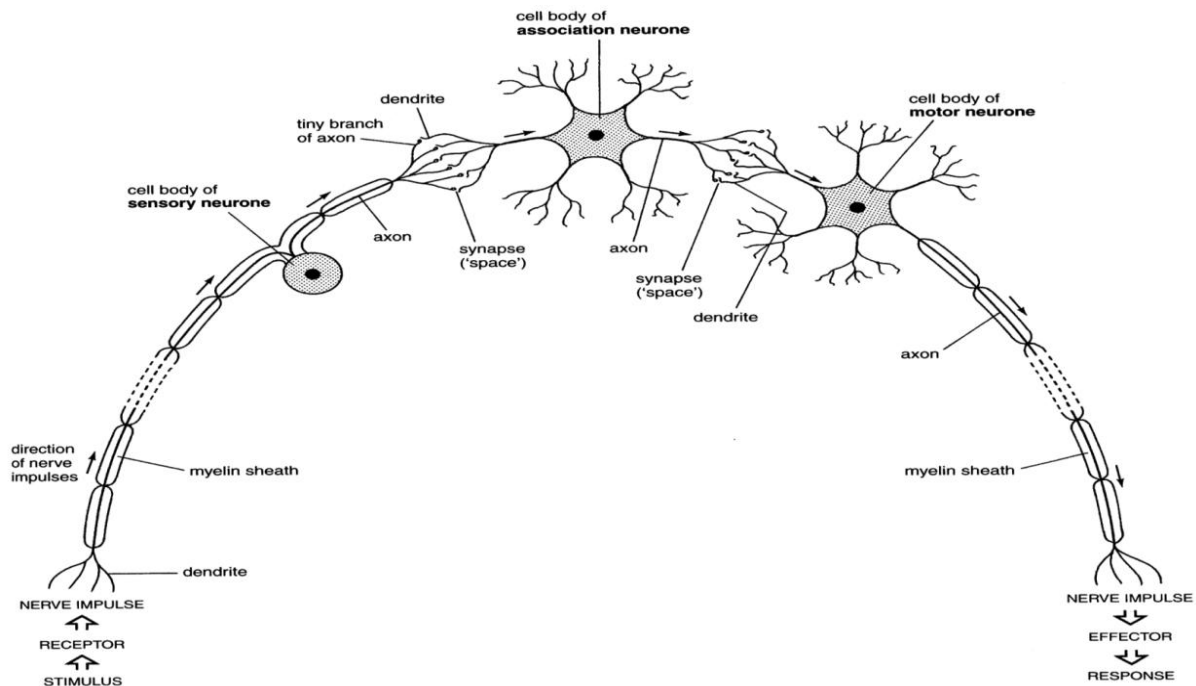
- Has short dendrites which connect to neurons in the CNS
- Has a long myelinated axon
- Axon carries nerve impulses to muscle connections.



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Glial cells

- Glial cells have a number of key functions:
 - physically support neurons
 - produce the myelin sheath
 - control the chemical composition of the fluid surrounding the neuron and so maintain a homeostatic environment.
 - remove debris by phagocytosis

Neurotransmitters at synapses

Synapse

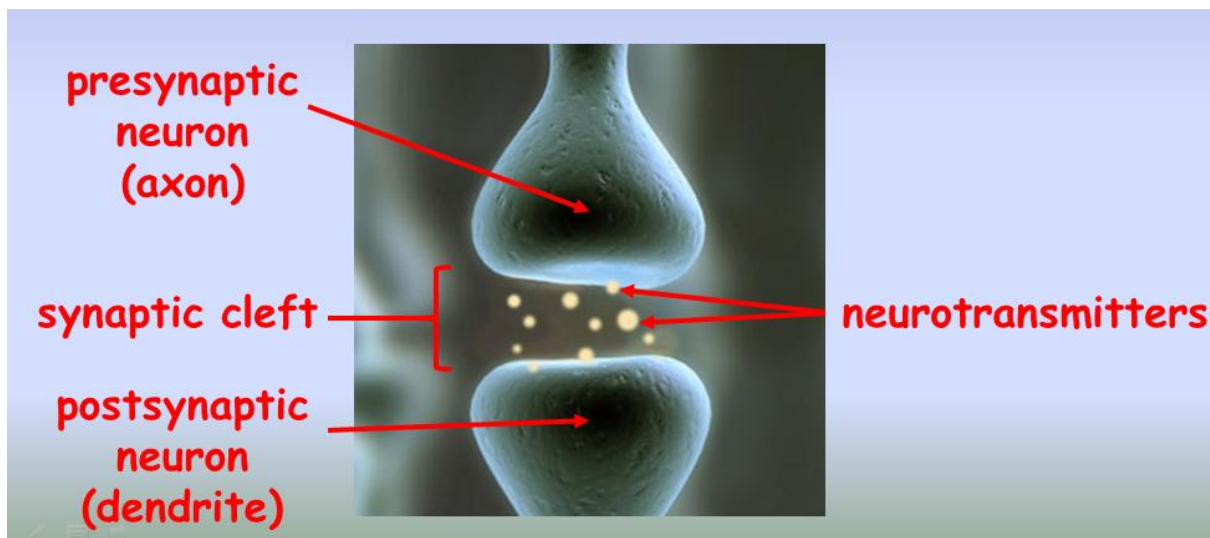
- The tiny area between the ending of the an axon of one neuron and the dendrite of another is known as a synapse.

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- The plasma membranes of each neuron are in very close contact and are separated by a narrow space called a synaptic cleft.
- Messages are passed across synaptic clefts by chemicals called neurotransmitters.
- Neurotransmitters can also relay messages from nerve to muscle as well as nerve to nerve
- Two examples are acetylcholine and norepinephrine (also known as noradrenaline).
- The neuron before the synaptic cleft is known as the presynaptic neuron.
- The neuron after the synaptic cleft is known as the postsynaptic neuron.



Action of neurotransmitters

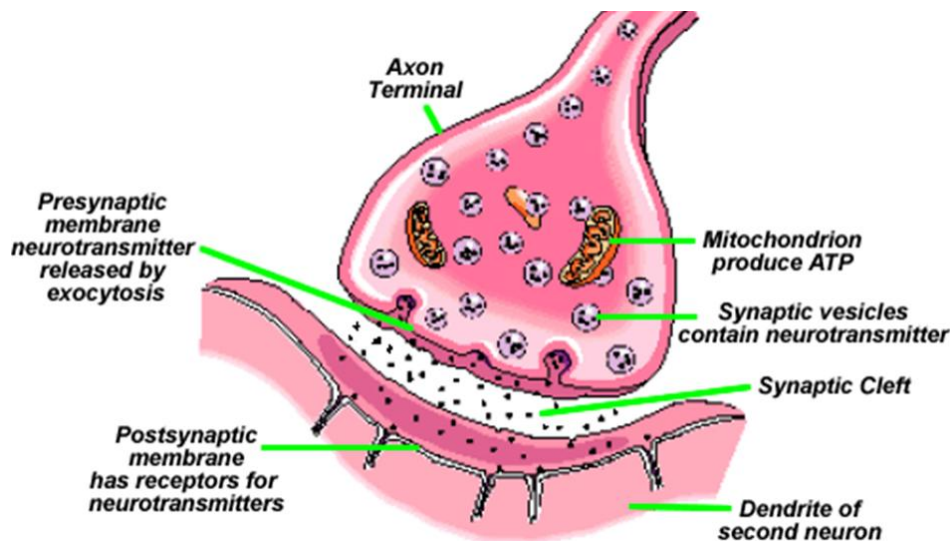
- The presynaptic knob contains many mitochondria to provide ATP for synthesis of neurotransmitters.
- When a nerve impulse passes through a neuron and reaches the end of the axon (known as the axon terminal), many vesicles containing neurotransmitters are stimulated.

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- These vesicles move to and fuse with the membrane at surface of the axon terminal. The neurotransmitters within the vesicles are then released (by **exocytosis**) into the synaptic cleft.
- The neurotransmitter then diffuses across the cleft and binds to receptor molecules on the dendrites of the next neuron; this transmits the impulse to the next neuron.



- Neurotransmitters must be rapidly removed as soon as the impulse has been transmitted for the following reasons:
 - to prevent continuous stimulation of the postsynaptic neuron
 - so that the membrane is sensitive to the next stimulus
 - otherwise, the neurotransmitter would continue to have an effect
 - this allows a neurone to send many separate impulses allowing a variety in the rate of impulse transmission.
- Neurotransmitters can be removed from the synaptic cleft by:
 - enzyme degradation - this occurs with acetylcholine, the products of which are absorbed and used to synthesise new neurotransmitters

or

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- re-uptake - this occurs with norepinephrine, which is reabsorbed by presynaptic membrane.
- The continual synthesis and removal of neurotransmitters requires a very large amount of energy.
- Neurones contain a large number of mitochondria to provide ATP.
- *This is why the brain is so easily damaged by oxygen deprivation.*

Excitatory & inhibitory signals

- The receptor cells found on the postsynaptic neuron will determine whether the signal is:
 - excitatory (causes an increase in action e.g. cause muscles to contract) or
 - inhibitory (cause a decrease in action e.g. slow heart rate)

Weak stimuli

- A nerve impulse will only be transmitted across a synaptic cleft if it causes the release of a sufficient number of neurotransmitter molecules; this is known as the threshold.
- Weak stimuli are known as sub-threshold stimuli and are too weak to cause the transmission of a nerve impulse.
- When the stimulus is weak, the synapse acts as a gap which the impulse cannot cross and the stimulus is 'filtered out' due to insufficient secretion of neurotransmitters.

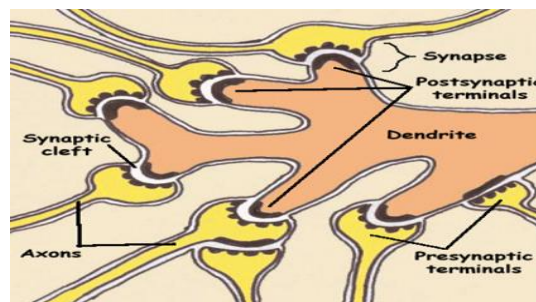
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Summation

- A single weak stimulus will not trigger the release of enough neurotransmitters to cause transmission of a nerve impulse.
- However, a series of weak stimuli from many neurons can bring about an impulse.
- The cumulative effect of a series of weak stimuli which triggers an impulse is known as summation.
- If a weak stimulus passed along one axon this would not trigger enough neurotransmitters to be released to reach the threshold.
- When many axons release their neurotransmitter at the same time or in rapid succession, this releases enough chemical to fire a response.



New born child

- Since there are fewer dendrites and less myelin in a new born child, fewer, slower impulses reach the synaptic cleft
- The threshold is less likely to be reached and less neurotransmitters released into the synaptic cleft
- There will be fewer connections to other nerve cells.

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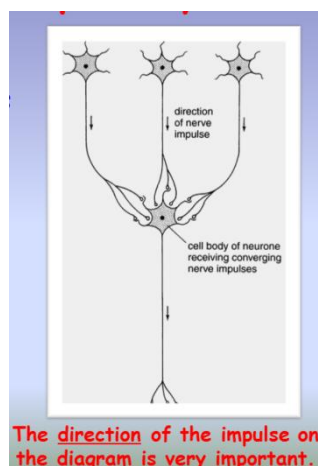
Neural Pathways

Complex neural pathways

- Neurons are connected to others in many different ways in the CNS.
- This allows many complex interactions to occur between neurons and so allows the nervous system to carry out many complex functions.
- There are three main neural pathways:
 - converging
 - diverging
 - reverberating

1. Converging neural pathways

- Converging neural pathways have many neurons coming together and feeding impulses to **one** neuron.
- This allows for signals to be brought together for a combined or concentrated effect (e.g. summation) at one neuron.
- *An example of this can be found with the convergence of the neurons from rod cells in the retina of the eye.*



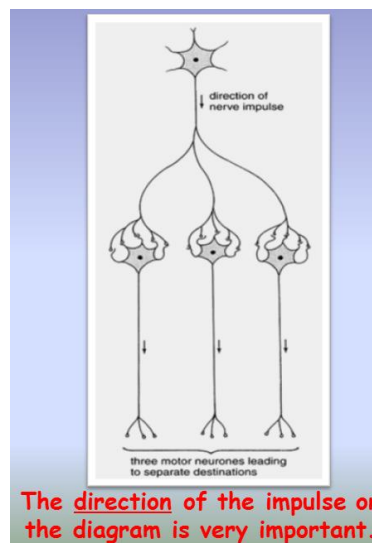
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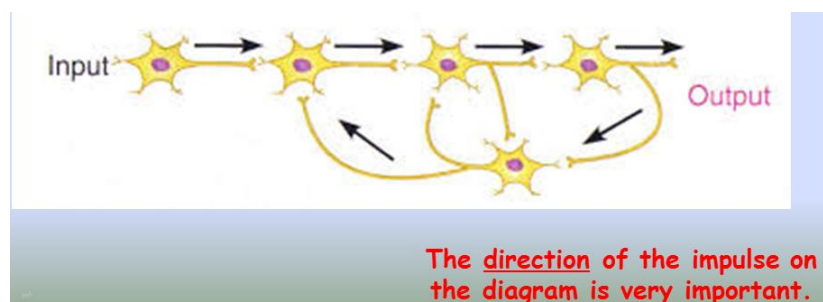
2. Diverging neural pathways

- Diverging neural pathways have one neuron branching out and feeding impulses to **many** neurons.
- This allows for signals from a single source to be sent to several destinations, at the same time and allows us to co-ordinate control (e.g. when threading a needle).



3. Reverberating neural pathways

- Reverberating neural pathways possess neurons later in the pathway which form connections with neurons earlier in the pathway.
- This allows for nerve impulses to be recycled and repeatedly stimulate the circuit, these impulses will only stop when they are no longer required.



Plasticity of response

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- The ability of brain cells to become altered and form new neural pathways as a result of new environmental experiences is known as plasticity of response.
- This allows new neural pathways to be formed during early development when learning many new skills.
- Major plasticity of response can occur after brain damage (e.g. stroke) and allows undamaged cells to form new neural pathways to take on the functions of the damaged area.
- Minor plasticity is used to suppress reflexes (e.g. blinking or prevent the body dropping a hot object) or suppress sensory responses (such as visual distractions).

Neurotransmitters, mood and behaviour

Endorphins

- Endorphins are neurotransmitters which act like natural painkillers by stimulating neurons which are involved in reducing the intensity of pain.
- Endorphin production increases in response to:
 - severe injury
 - prolonged and continuous exercise
 - physical & emotional stress
 - certain foods
 - (e.g. chocolate and chilli peppers)

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- Increased levels of endorphins can also bring about other responses within the body, such as:
 - euphoric feelings (intense happiness)
 - regulation (modulation) of appetite
 - release of sex hormones

Dopamine

- Dopamine is a neurotransmitter which induces the feeling of pleasure.
- Dopamine is also involved in reinforcing beneficial behaviour (such as satisfying hunger by eating) by activating the reward pathway.
- The reward pathway involves neurons which secrete or respond to dopamine.

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Neurotransmitter related disorders

- Below are some examples of neurotransmitter related disorders:

Disorder	Cause	Treatment
Alzheimer's disease	Loss of cells synthesising acetylcholine.	Cholinesterase inhibitors
Parkinson's disease	Loss of dopamine synthesising neurons.	Monamine oxidase inhibitors and the potential use of adult stem cells
Schizophrenia	Overactive dopamine system	The use of dopamine antagonists
General anxiety disorders	Imbalance in serotonin and norepinephrin	The use of GABA agonists and beta blockers
Depression	Low levels of serotonin	Norepinephrine re-uptake inhibitors and monoamine oxidase enzyme inhibitors

- Many drugs which treat neurotransmitter related disorders are similar to neurotransmitters.

Treatment Drugs

Agonists

- Agonists are chemicals that bind to and stimulate specific receptors on postsynaptic neurons.
- Agonists mimic the action of natural neurotransmitters and so normal cell responses occur (i.e. nerve impulse is transmitted).

Antagonists

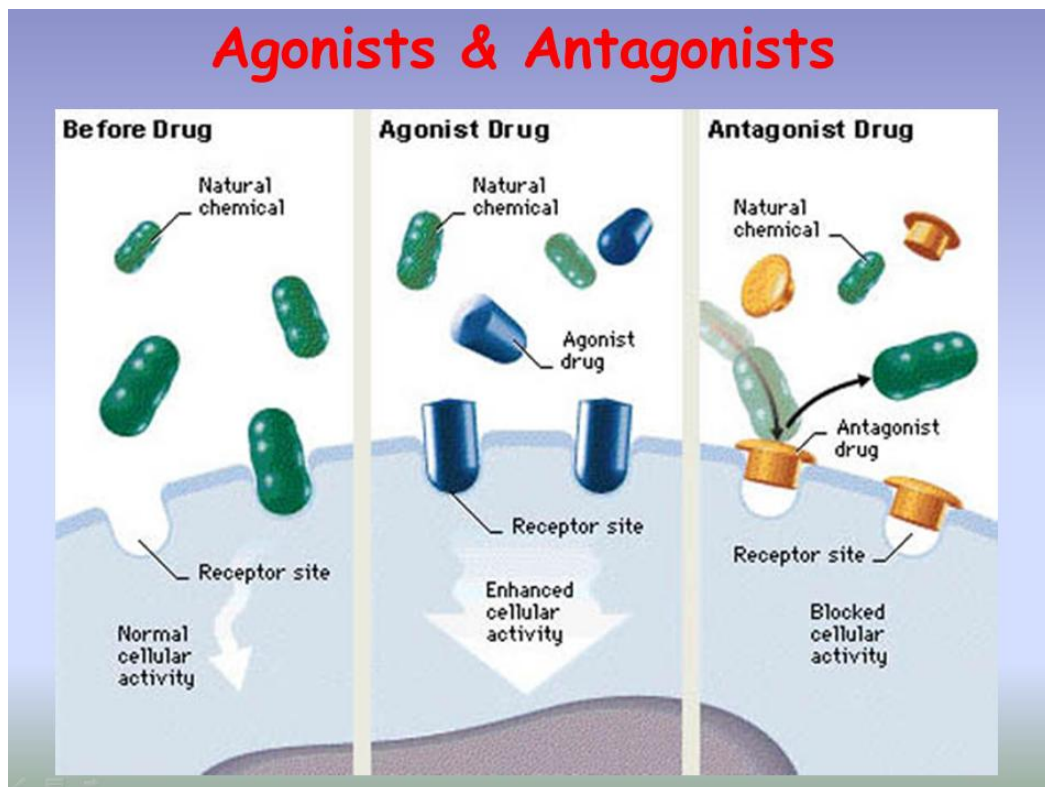
- Antagonists are chemicals that bind to and block specific receptors on postsynaptic neurons.
- Antagonists, by blocking the receptor sites, prevent the normal neurotransmitter from acting.

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- Antagonists can greatly reduce or even stop the normal transmission of nerve impulses.
- Other drugs, known as inhibitors, inhibit the enzymes which degrade neurotransmitters or inhibit re-uptake.
- Antagonistic drugs such as painkillers become less effective with repeated use since there is either an ;
 1. Increase in sensitivity of receptorsOR
 2. Increase in number of receptors



Mode of action of recreational drugs

Recreational drugs

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- Many recreational drugs can mimic the action of neurotransmitters and will affect the transmission of nerve impulses in the reward circuit of the brain.
- Recreational drugs can stimulate the release of neurotransmitters, acts as agonists or antagonists and inhibit their reuptake or enzyme degradation.
- Recreational drugs therefore alter a person's neurochemistry and so can lead to changes in:
 - mood
 - *e.g. happier/more confident/more aggressive*
 - cognition
 - *person becomes poorer at mental tasks such as problem solving and decision making*
 - perception
 - *misinterpretation of environmental stimuli e.g. colours, sounds, sense of time*
 - behaviour
 - *person is able to stay awake for longer and talk about themselves endlessly*

Drug addiction/tolerance

- Drug addiction is a chronic disease. The sufferer will compulsively seek out and use a drug regardless of the consequences.
- The initial use of the drug is often voluntary but the changes which occur after use soon override a person's control.

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- Drug tolerance occurs when a person's reaction to an addictive drug decreases in intensity although the concentration is the same. A large dose is then required to bring about the original effect.

Sensitisation

- Sensitisation is an increase in the number and sensitivity of neurotransmitter receptors.
- This occurs as a result of exposure to drugs which are antagonists, which block receptors; the body then responds by increasing the number of these receptors.
- Sensitisation leads to addiction.

Desensitisation

- Desensitisation is a decrease in the number and sensitivity of neurotransmitter receptors.
- This occurs as a result of exposure to drugs which are agonists, which stimulate receptors and cause feelings of euphoria.
- The body responds to this overstimulation by decreasing the number of these receptors and so a larger dose is required to bring about the original effect.
- Desensitisation leads to drug tolerance.

Summary of ways in which recreational drugs can affect the synapse

- 1) Stimulate or block neurotransmitter release.
- 2) Imitate neurotransmitter action (agonists).

Or

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Block neurotransmitter binding / receptor sites (antagonists).

3) Inhibit neurotransmitter uptake.

Or

Inhibit neurotransmitter degradation