HSTalks

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Introduction to the Nervous System

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Functions of the nervous system

The nervous system controls and coordinates functions throughout the body, and responds to internal and external stimuli

Specifically, the nervous system can:

- ✓ **Detect changes** within and around the body
- ✓ **Respond** to external changes
- ✓ **Receive and interpret** sensory information
- ✓ **Stimulate** muscles and glands

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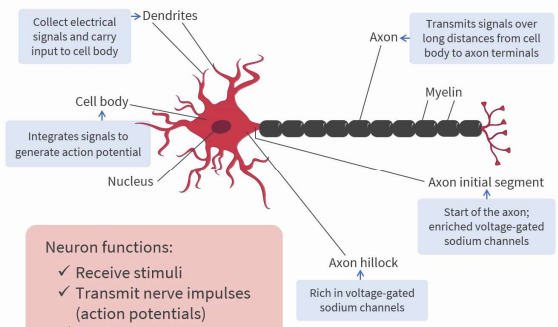
Basic building blocks of the nervous system



Neuron functions:

- ✓ Receive stimuli
- ✓ Transmit nerve impulses (action potentials)
- ✓ Activate muscles

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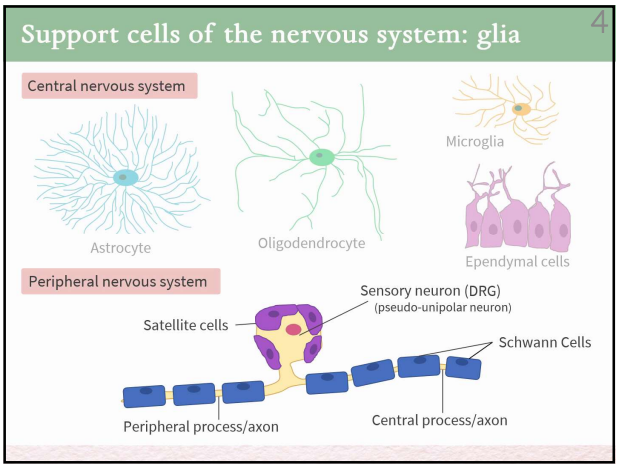

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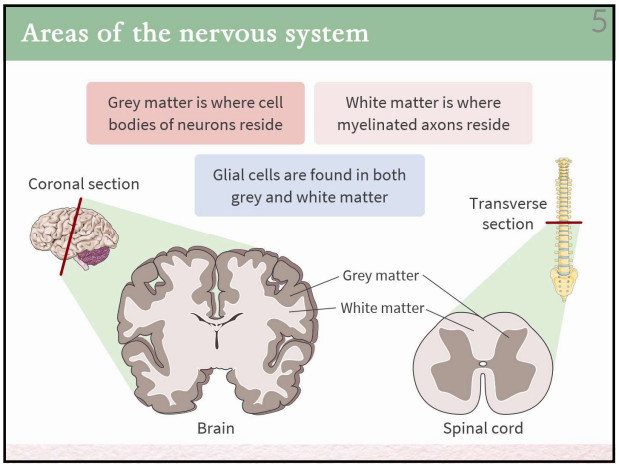

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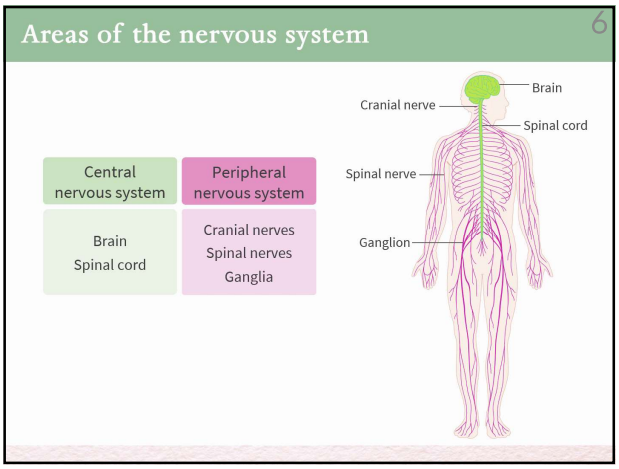

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Functional divisions of the nervous system

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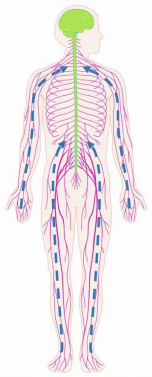
Sensory	Motor
Afferent: information going towards the CNS	
Responsible for acquiring and processing information from the environment	



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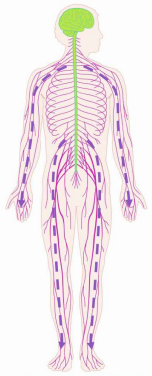
Functional divisions of the nervous system

Sensory	Motor
Afferent: information going towards the CNS	**Efferent:** information from CNS going to the effector organs
Responsible for acquiring and processing information from the environment	Responsible for generating movements and other behaviours



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Efferent division: somatic and autonomic

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Motor

Efferent: information from CNS going to the effector organs

Somatic (voluntary)	Autonomic (involuntary)
Motor axons connecting CNS to skeletal muscles	Motor axons that innervate cardiac and smooth muscle, glands (important for internal homeostasis)

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Efferent division: autonomic nervous system 9

Motor

Efferent: information from CNS going to the effector organs

Somatic (voluntary)	Autonomic (involuntary)
Motor axons connecting CNS to skeletal muscles	Motor axons that innervate cardiac and smooth muscle, glands (important for internal homeostasis)

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Efferent division: autonomic nervous system

Motor

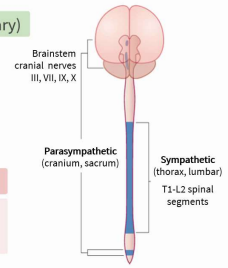
Autonomic (involuntary)

Sympathetic

'Fight or flight'
Thoracolumbar

Parasympathetic

'Rest and digest'
Craniosacral



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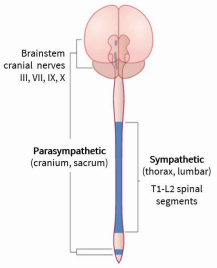
Autonomic control of internal organs 10

The autonomic nervous system controls the body's internal organs, and works together with the endocrine system

It innervates smooth muscles, cardiac muscle, and glands, controlling the circulation of blood, activity of the G.I. tract and body temperature

More specifically:

- ✓ Innervates smooth muscle, cardiac muscle and glands of internal organs
- ✓ Involuntary
- ✓ Two neuron chain
  - Preganglionic neurons (originate in the brain or spinal cord)
  - Postganglionic neurons (originate in the ganglia outside the CNS)



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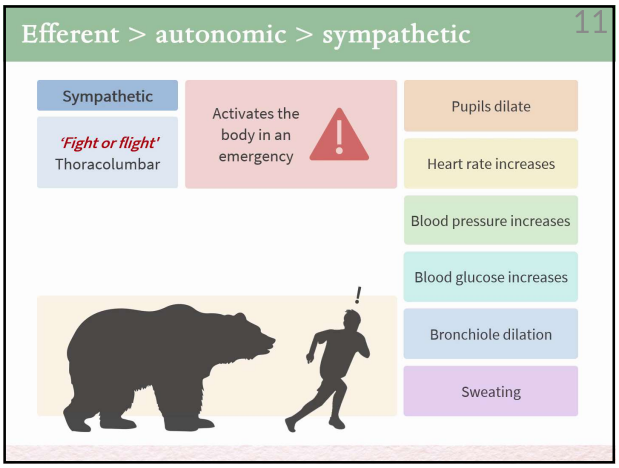

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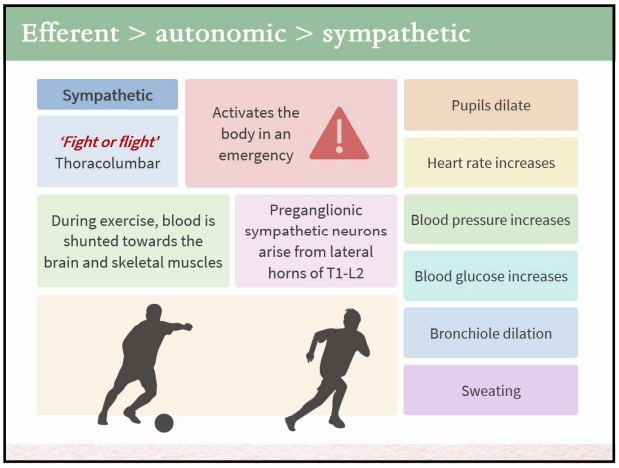

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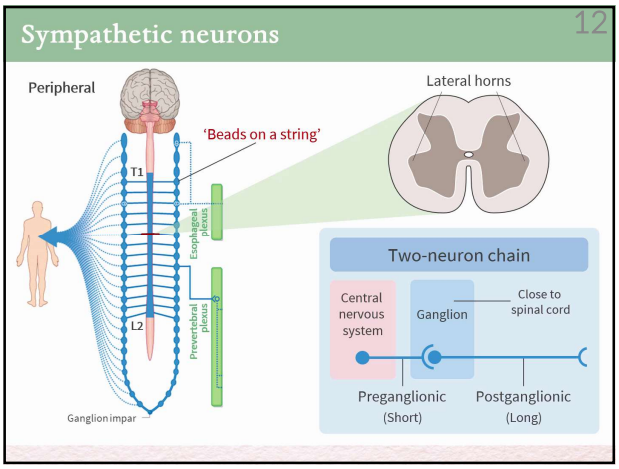

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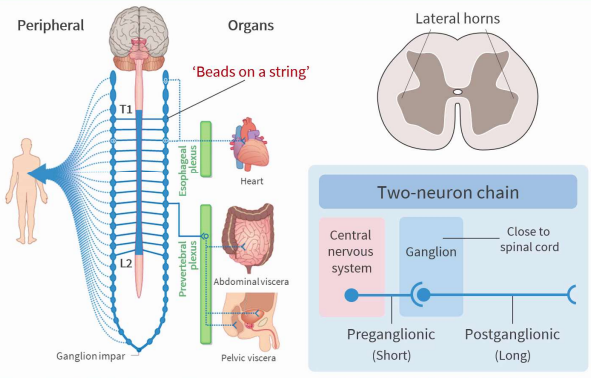
Sympathetic neurons



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Efferent > autonomic > parasympathetic

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Parasympathetic

'Rest and digest'

Craniosacral

Conserves body energy and maintains basal homeostatic levels

Preganglionic parasympathetic neurons arise from brainstem and from S2-S4

Pupils constrict

Glands secrete

Digestive tract mobility increases

Increased smooth muscle activity

Elimination of faeces

Elimination of urine

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Parasympathetic neurons

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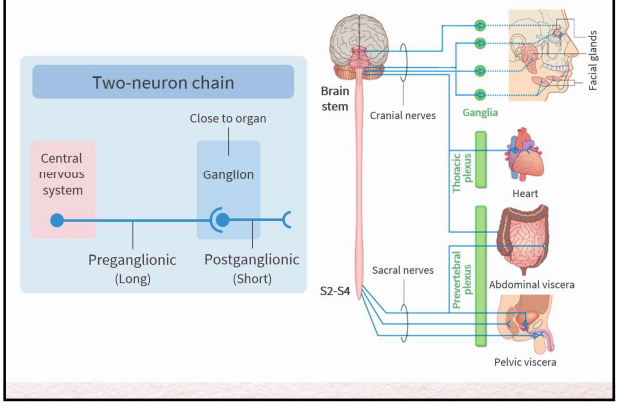

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Antagonistic autonomic reflex pathways

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Sympathetic	Parasympathetic
Increases arterial blood pressure, heart rate and force of contraction	Decrease in arterial blood pressure and heart rate
Inhibition of pancreatic enzyme secretion	Stimulation of pancreatic enzyme secretion
Inhibition of pancreatic insulin secretion	Stimulation of pancreatic insulin secretion
Decreased gut motility and secretion	Increased gut motility and secretion
Dilation of pupil in eye	Constriction of pupil in eye
Ejaculation in men	Penile erection in men; increased blood flow to external genitalia in women

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Signal propagation

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How does a single neuron propagate a signal to induce a response, such as those that occur in the autonomic nervous system?

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What makes a neuron an excitable cell?

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Excitability

The ability of a cell to respond to electrical/chemical stimuli by producing an **action potential**

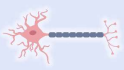
Action potential

A brief change in a cell's **electrical potential** across its membrane

This involves **movement of ions** across the cell membrane in response to stimulation, causing the negatively charged cell to become positively charged

Excitable cells

Neurons



Muscles fibres

Na^+ Sodium

K^+ Potassium

Resting membrane potential of a neuron: **-70mV**

What is the ionic basis for this negative resting membrane potential?

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Distribution of ions at rest

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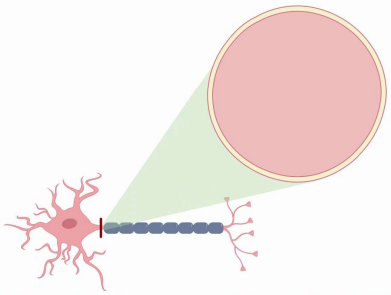

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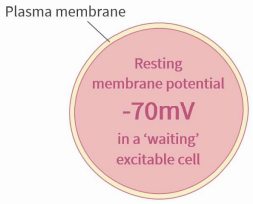
Distribution of ions at rest



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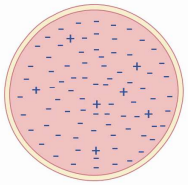
Distribution of ions at rest

Intracellular
Negatively charged



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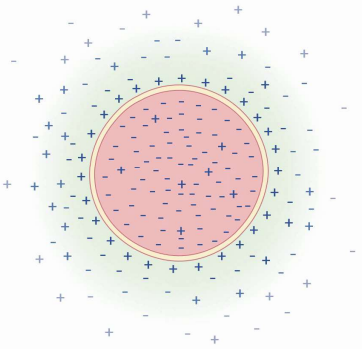
Distribution of ions at rest

Intracellular
Negatively charged

Extracellular
Positively charged



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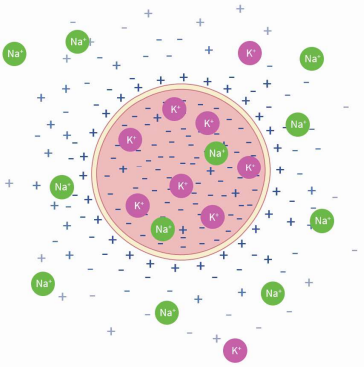
Distribution of ions at rest

Intracellular
Negatively charged
High K^+
Negatively charged proteins
Organic phosphates

Extracellular
Positively charged
High Na^+
High Cl^+

Plasma membrane
50-100 times greater permeable to K^+ than to Na^+



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Maintaining resting membrane potential

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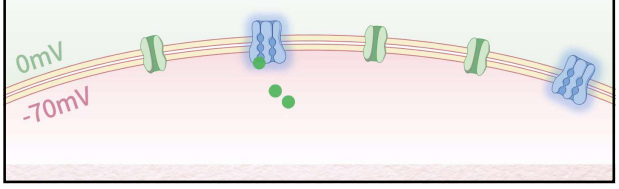
Resting membrane potential is maintained by ion channels and pumps in the plasma membrane

Na^+/K^+ channels are passive

Na^+/K^+ pumps are active

Three sodium ions are pumped out for every two potassium ions that are pumped in



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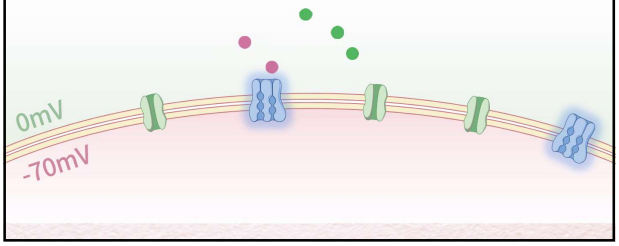

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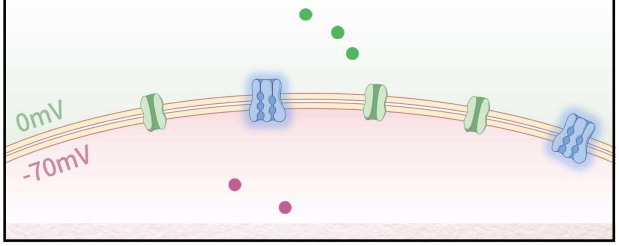

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Ionic basis of the action potential

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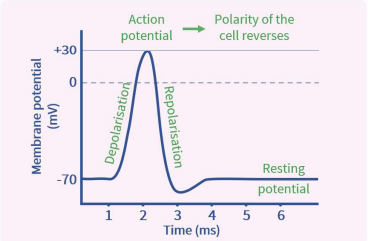
Excitable cells respond to electrical/chemical stimuli by producing an action potential

The action potential spike is due to a transient increase in intracellular Na^+ following a stimulus

During an action potential, an influx of sodium into causes membrane depolarisation



This occurs after voltage-gated Na^+ channels are opened

Na^+ mainly responsible for action potentials

K^+ mainly responsible for resting membrane potential

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Action potential ions

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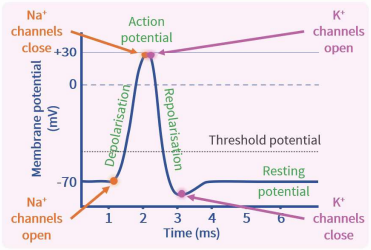
Stimulus causes Na+ cations to override negative charges inside the cell, leading to depolarisation

Threshold potential must be reached during depolarisation in order for an action potential to occur

Once the threshold is reached, Na^+ channels open and an action potential cannot be stopped **(All or none principle)**



K^+ channels respond once Na^+ channels close, and K^+ rushes out – this causes a repolarisation of the membrane and resting potential is restored

Depolarisation
+
Repolarisation
=
Action potential

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Refractory periods

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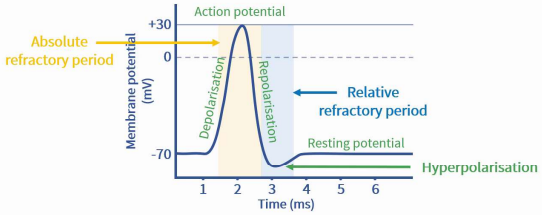

During depolarisation and repolarisation, the cell is within an **absolute refractory period**

No additional action potentials can be generated

Once the membrane is repolarised, it enters a short **relative refractory period** of hyperpolarisation before returning to resting membrane potential

An additional action potential can be generated with enough stimulus

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Synaptic transmission

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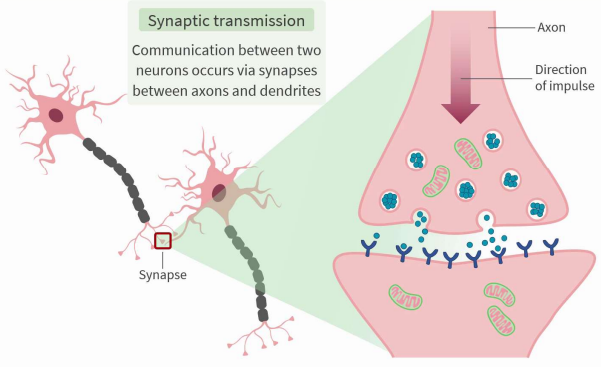
Synaptic transmission

Communication between two neurons occurs via synapses between axons and dendrites



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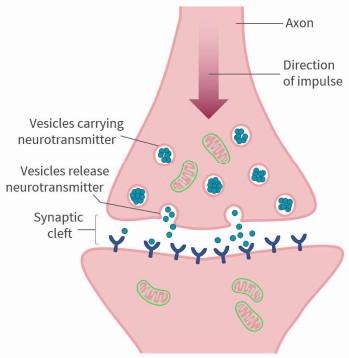
Synaptic transmission

1
The neurotransmitter is synthesised and stored in vesicles

When an action potential reaches the axon terminal, the cell is ready to pass it along to the next neuron

2
When an action potential arrives at the terminal, the neurotransmitter must be quickly and efficiently released into the synaptic cleft



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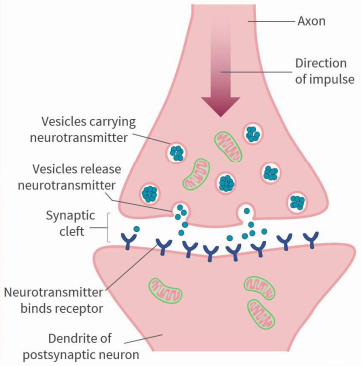
Synaptic transmission

3
The neurotransmitter is recognised by postsynaptic receptors, which pass along the signal and initiate another action potential, or in some cases, *block* other signals sent to the postsynaptic neuron

4
The neurotransmitter is then inactivated and removed from the receptors - this avoids constant stimulation of the postsynaptic cell, and frees up receptor sites for the arrival of further impulses



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Synaptic mitochondria

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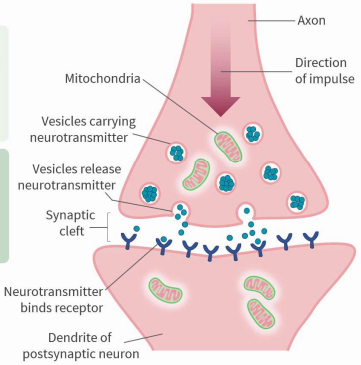
The transfer and uptake of the neurotransmitter is a process which requires energy

Mitochondria are therefore available to provide the necessary energy for transmission



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Myelination and saltatory conduction

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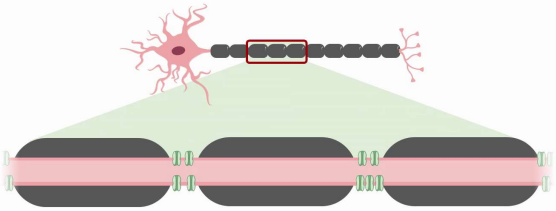

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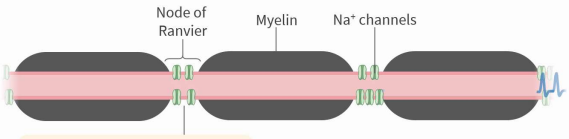
Myelination and saltatory conduction

A fatty cover, produced by oligodendrocytes (CNS) and Schwann cells (PNS), that wraps around the axon



The unmyelinated segments of axon between Schwann cells, are rich in Na^+ channels

The action potential **is amplified** due to the high density of Na^+ ions

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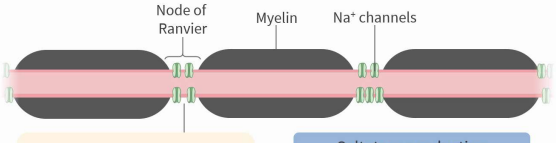
Myelination and saltatory conduction

A fatty cover, produced by oligodendrocytes (CNS) and Schwann cells (PNS), that wraps around the axon

Myelination is **not** a requirement of neurons



The unmyelinated segments of axon between Schwann cells, are rich in Na^+ channels

The action potential **is amplified** due to the high density of Na^+ ions

Saltatory conduction

The Na^+ inrush causes enough depolarisation to allow the action potential to jump from node to node, allowing rapid propagation of the nerve impulse

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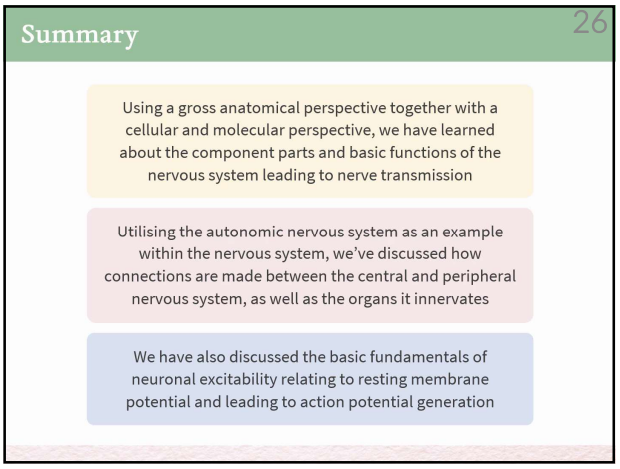

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