NERVOUS SYSTEM

Content Statements:

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C2.2.2	Generation of the resting potential by pumping to establish and maintain concentration gradients of sodium and potassium ions
C2.2.3	Nerve impulses as action potentials that are propagated along nerve fibres
C2.2.4	Variation in the speed of nerve impulses
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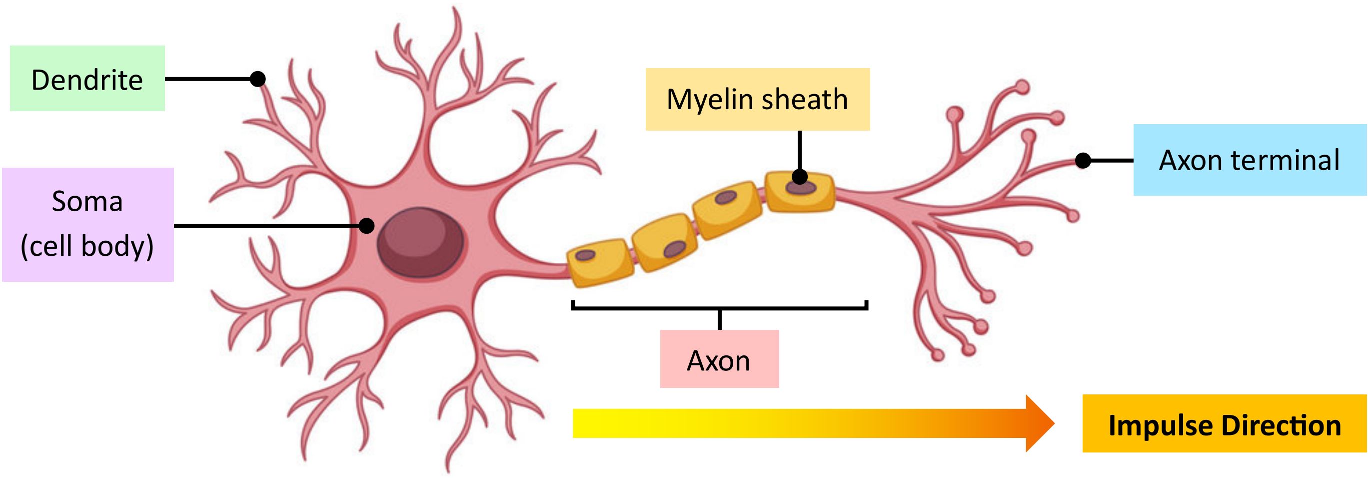
NEURONS

Neurons are specialised cells that function to transmit electrochemical impulses within the nervous system. While neurons may differ according to role (sensory, relay or motor), most share three basic components:

- **Dendrites** – Branched fibres that convert chemical signals from neurotransmitters into electrical signals
- **Axon** – A long fibre sending the electrical signal to terminal regions for communication with other cells
- **Soma** – A cell body containing the nucleus and organelles, where essential metabolic processes occur

In some neurons, the axon may be surrounded by an insulating layer known as a **myelin sheath**. The myelin sheath improves the conduction speed of electrical impulses along the axon, but require additional space and energy. The myelin sheath is produced by specific cells (called Schwann cells) that surround the axon.

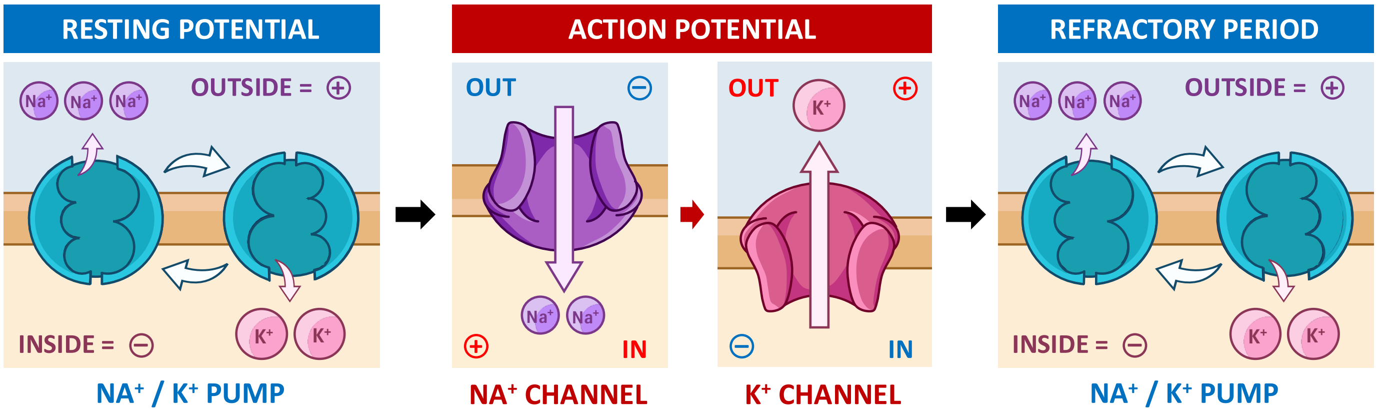


MEMBRANE POTENTIALS

Neurons generate and conduct electrical signals by pumping positively charged ions (Na^+ and K^+) across their membrane. The unequal distribution of these ions on the different sides of the membrane creates a charge difference called a membrane potential. The difference in charge that exists across the membrane when the neuron is *not firing* is called the **resting potential**. In a typical resting potential, the inside of the neuron is more negative than the outside (approximately –70 mV). When a nerve impulse is generated, the ionic distribution is changed and the inside becomes more positive than the outside (roughly +30 mV). The difference in charge that exists across a membrane when the neuron *is firing* is called the **action potential**.

NERVE IMPULSES

Nerve impulses are electrical signals created by a change in membrane potential. When a neuron is at rest, **sodium-potassium pumps** exchange ions to establish a resting potential. Three sodium ions are pumped out of a neuron in exchange for two potassium ions. This is an active process that requires ATP and results in a charge difference of –70 mV on the inside of the neuron. In response to a signal (either from a sensory receptor or a neurotransmitter), ion channels open to create an action potential. **Sodium channels** open, resulting in an influx of sodium ions that causes the membrane potential to become positive (+30 mV) – this is called *depolarisation*. Then **potassium channels** open, resulting in an efflux of potassium ions that restore a negative membrane potential – this is called *repolarisation*. The ion channels that occupy the length of the axon are **voltage-gated**, meaning an action potential at one point of the axon will trigger an action potential in the next segment of the axon. The action potential therefore spreads along the length of the axon as a unidirectional 'wave'. Before a neuron can fire again, the original ion distribution must be re-established by the sodium-potassium pumps. This brief period of inactivity is called the **refractory period**.



CONDUCTION SPEEDS

Conduction speeds along nerve fibres are not constant – larger organisms tend to have slower conduction speeds because there are more synaptic gaps that create delays in the speed of transmission. Animals have two mechanisms by which conduction speeds can be increased and the transmission efficiency improved:

- Axons with **wide diameters** have better conduction speeds (they encounter less longitudinal resistance)
- Axons that are insulated with a fatty layer called the **myelin sheath** have significantly faster conduction

Giant axons in squid have faster conduction than smaller fibres, but are slower than most myelinated fibres.

SYNAPTIC TRANSFER

Synapses are the physical gaps that separate neurons from other cells. Electrical impulses cannot cross synapses and so the impulse must be converted into a chemical signal. When an action potential reaches the axon terminal, depolarisation will trigger the opening of voltage-gated calcium channels. The influx of calcium ions causes vesicles containing **neurotransmitters** to fuse with the plasma membrane, releasing the chemicals into the synaptic cleft via exocytosis. The neurotransmitters diffuse across the synapse and bind to receptors on the post-synaptic membranes. This causes the opening of ligand-gated ion channels and the generation of an excitatory or inhibitory post-synaptic potential. The neurotransmitters are degraded or recycled by reuptake pumps. **Acetylcholine** is a neurotransmitter found in neuromuscular junctions.