Edexcel International A Level (IAL) Biology

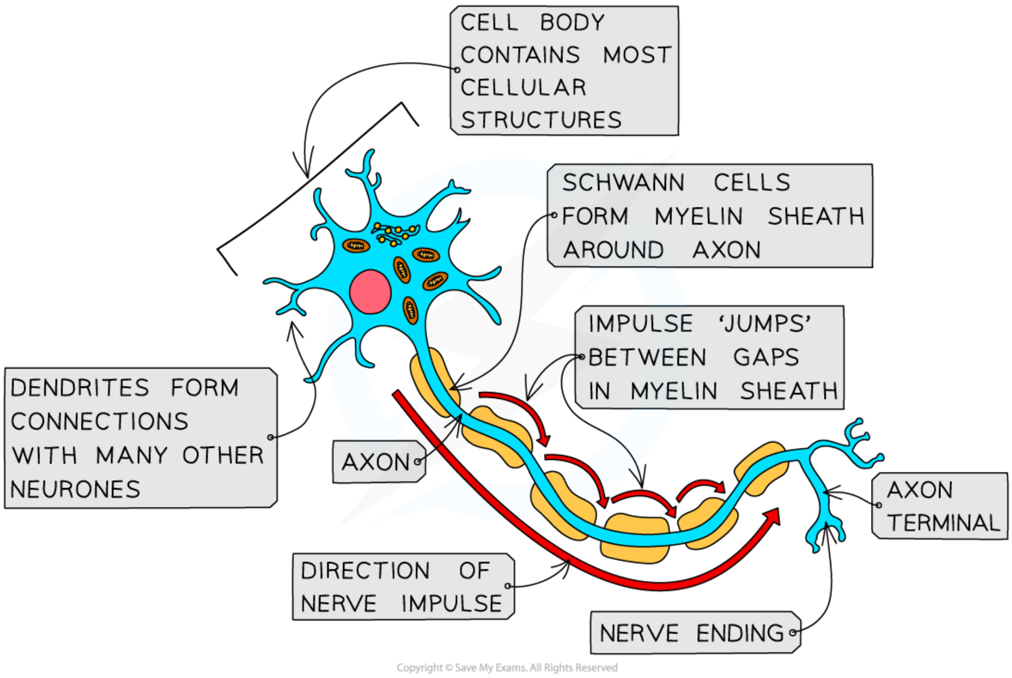
Your notes

The Nervous System

Contents

Neurones: Types & Functions

- **Neurones** are specialised cells of the nervous system which carry **electrical impulses** around the body
- A bundle of neurones is known as a **nerve**
- There are different types of neurones, but the following features are found in all types
  - A **long fibre** known as an **axon**
  - A **cell body** that contains the **nucleus** and other cellular structures
  - The end of the axon, known as the **axon terminal,** has many nerve endings
    - The nerve endings at the axon terminals allow neurones to **connect** to and **receive impulses from** other **neurones**, forming a **network** for easy **communication**
- Some neurones are **myelinated**, meaning that their axon is **insulated** by a fatty layer known as the **myelin sheath**
  - The myelin sheath is made up of specialised cells known as **Schwann cells** which wrap themselves around the axon
  - There are **uninsulated gaps** between the Schwann cells known as the **nodes of Ranvier**
  - Electrical impulses in myelinated cells do not travel down the whole axon, but jump from one **node** to the next, speeding up impulse transmission
- In **non-myelinated neurones** the axon is not insulated by Schwann cells
  - The impulse travels more slowly as it moves through the entire length of the axon



Neurones have a long axon, a cell body, and an axon terminal, and some neurones are myelinated

- There are **three main types** of neurones
  - **Sensory neurones** carry impulses from **receptors** to the brain and spinal cord in the **CNS**
  - **Relay neurones** are found entirely within the CNS and **connect sensory** and **motor** neurones
  - **Motor neurones** carry impulses from the **CNS** to **effector** muscles or glands
- Each type of neurone has a **slightly different structure**
  - **Motor neurones**
    - A large **cell body at one end** that lies within the spinal cord or brain
    - Many highly-branched **dendrites** extending from the cell body, providing many connections with the axon terminals of other neurones
  - **Relay neurones**
    - Short neurones with axons and highly branched dendrites
  - **Sensory neurones**
    - A **cell body** that branches off in the **middle** of the axon and has **no dendrites**
    - The axon terminal is attached to a **receptor cell**
    - The section of neurone that links the axon terminal with the cell body is known as a **axon**

- The section of neurone that connects the cell body with the CNS is the **dendron**

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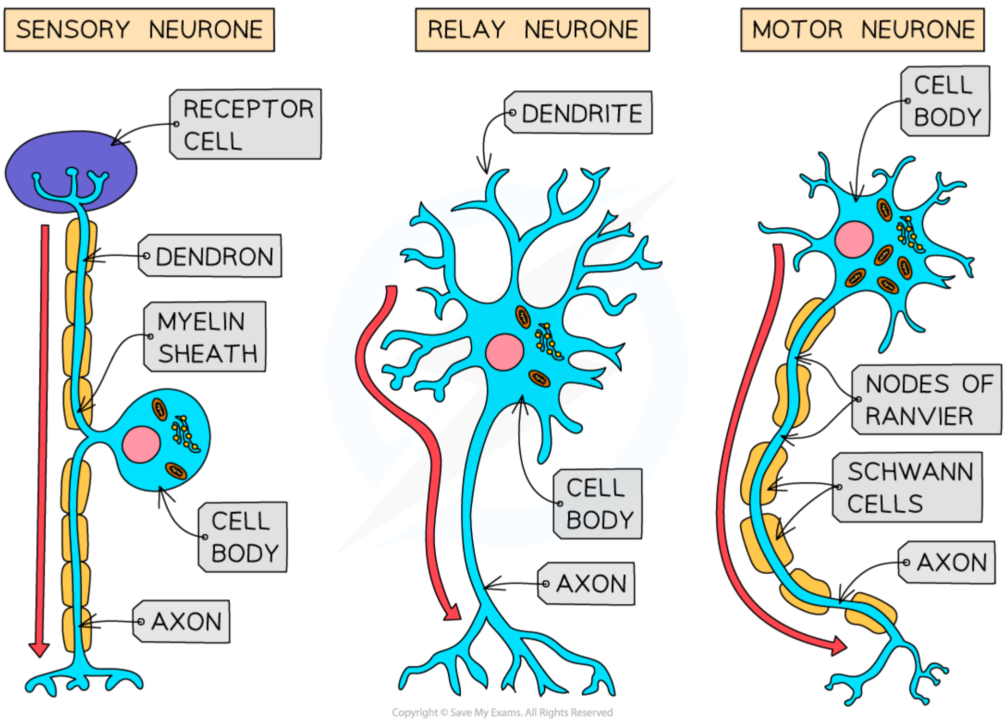


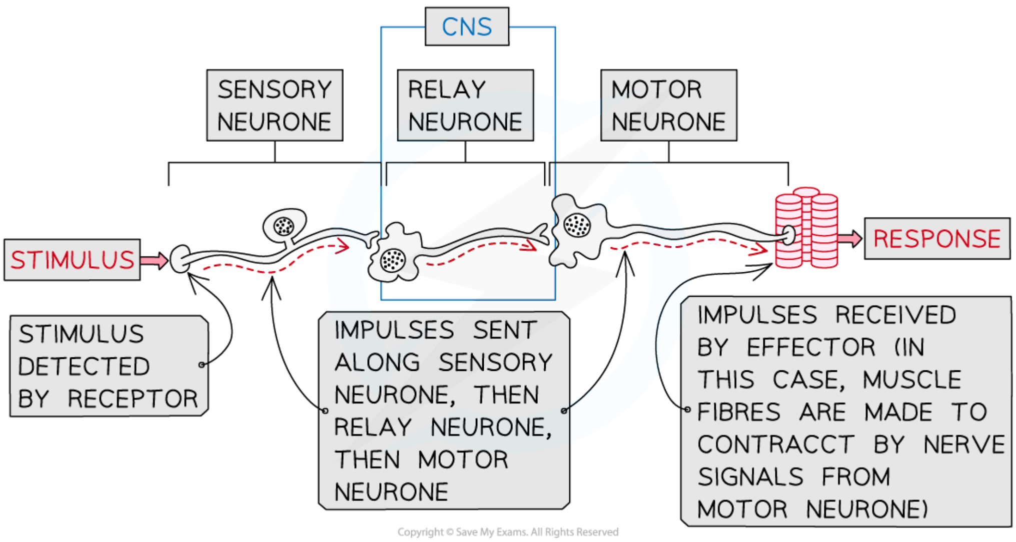
Different types of neurone differ in both structure and function

Your notes

How a Response is Generated by Effectors

- The nervous system enables the body to **detect changes in the environment** and brings about **appropriate responses** to ensure its safety
    - **Receptor cells** detect changes in the environment, or **stimuli**
    - Nerve impulses travel from the receptor cells along **sensory neurones** to the **central nervous system**, or CNS
    - The **CNS** acts as a **coordinating centre** for the impulses that arrive from the receptors, determining which part of the body needs to respond and sending out a new set of impulses along **motor neurones**
    - **Motor neurones send impulses** to the **effectors** to bring about a **response**
        - Effectors may be muscles or glands
- Nerve impulses pass through the nervous system along the following pathway

stimulus → receptor → sensory neurone → CNS → motor neurone → effector



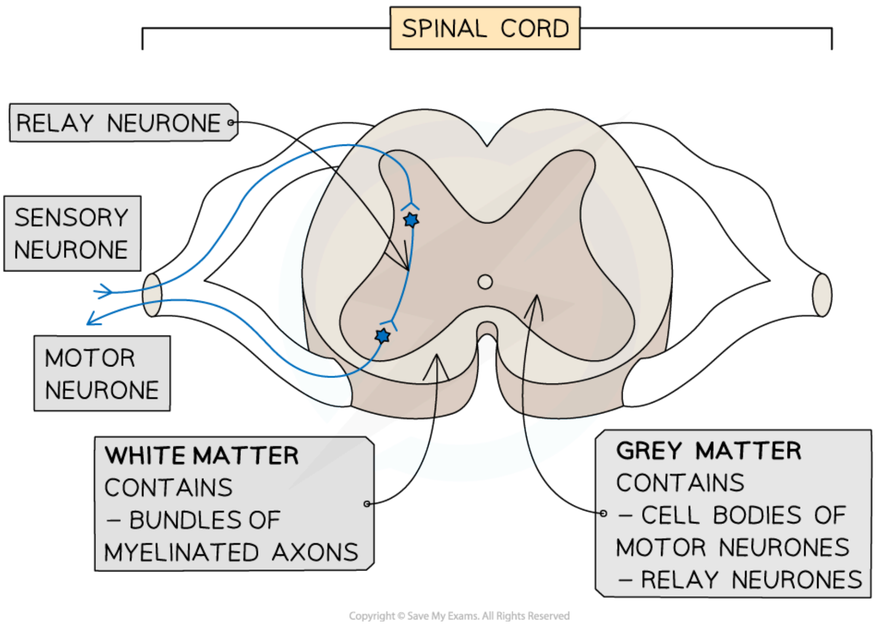
Receptors detect stimuli and impulses are sent through to the nervous system to bring about a response in the effector

The Reflex Arc

- The **central nervous system** (**CNS**) consists of the **brain** and **spinal cord**
  - The brain **processes information** about external and internal stimuli and **co-ordinates the body's responses**
  - The spinal cord **connects the brain** to the rest of the nervous system as well as **coordinating some reflex responses**
- **Reflex responses** are actions of the body that occur **without conscious thought**
  - Reflexes are **automatic** and **rapid, minimising damage** to the body and therefore **aiding survival**
  - Awareness of a reflex response occurs **after it has been carried out**; this is because the information takes longer to reach the conscious parts of the brain
- Examples of reflexes include blinking, coughing, and the pupil and knee reflexes
  - Blinking prevents the outer surface of the eye from drying out as well as protecting it from foreign objects
  - Coughing prevents food from entering the airways and removes mucus from the airways during infection or an allergic reaction
  - The pupil reflex prevents damage to the eye from bright light
  - The knee reflex aids balance when standing upright
- A **reflex arc** is a **pathway** along which impulses are transmitted from a receptor to an effector **without involving conscious regions of the brain**
  - A reflex arc therefore brings about a reflex response
  - **Sensory neurones, relay neurones and motor neurones** work together in a reflex arc

Spinal reflexes

- The pathway of a spinal reflex involves **relay neurones** located in the **spinal cord**
  - The spinal cord is made up of types of tissue known as **grey matter** and **white matter**
    - Grey matter contains the **cell bodies** of motor neurones along with **relay neurones**
    - White matter contains **long myelinated axons** that carry information through the spinal cord



The spinal cord contains both grey matter and white matter

- Pulling a foot away from a sharp object is an example of a spinal reflex
  - The stimulus of a sharp pin is detected by a **receptor cell** in the skin of the foot
    - The skin has receptors for pressure, touch, and pain
  - A **sensory neurone** sends electrical impulses to the CNS
  - An electrical impulse is passed to a **relay neurone** in the **spinal cord**
  - A relay neurone **synapses** with a motor neurone
    - A synapse is the junction between neurones; nerve impulses cross synapses by diffusion of a chemical called a neurotransmitter
  - A **motor** neurone carries an impulse to an **effector** muscle in the leg
  - When stimulated by the motor neurone the muscle will contract and pull the foot up and away from the sharp object; this is the **reflex response**
- The reflex arc for a spinal reflex is as follows

stimulus → receptor → sensory neurone → relay neurone in spinal cord → motor neurone → effector → response

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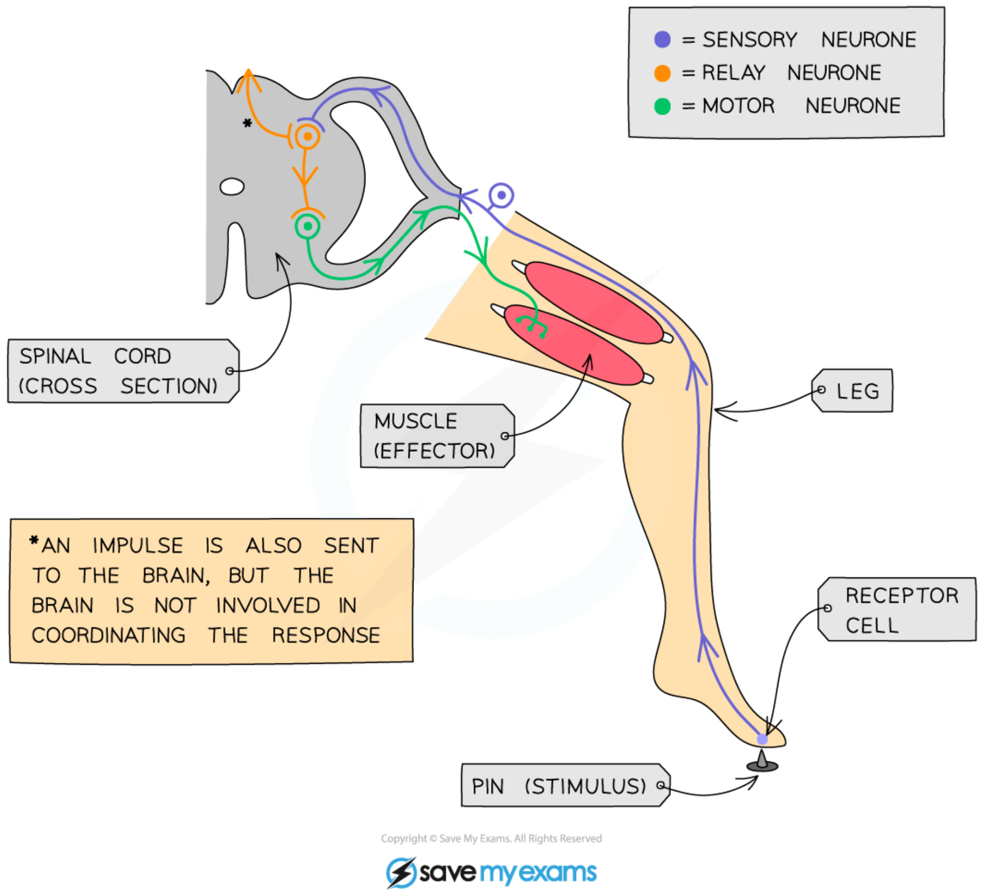

Spinal reflexes involve relay neurones in the spinal cord

Cranial reflexes

- The pathway of a cranial reflex involves relay neurones located in the **brain**
- The pupil reflex is an example of a cranial reflex
  - Changing pupil diameter enables the eye to **control the amount of light** hitting the retina
  - The diameter of the pupil in the eye is determined by two sets of muscles
    - The **circular muscles** contract to **constrict** the pupil
    - The **radial muscles** contract to **dilate** the pupil
  - The two sets of muscles work **antagonistically**, meaning that when one set of muscles contracts the other relaxes, and vice versa
- When bright light falls on the eye, the following events occur
  - The light level is detected by photoreceptors in the retina
  - A **sensory** neurone sends electrical impulses to the CNS
  - An electrical impulse is passed to a **relay neurone** in the **brain**

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- A relay neurone **synapses** with a motor neurone
- A **motor** neurone carries an impulse to the **effector** muscle; in this case the **circular muscle in the iris**
- When stimulated by the motor neurone the muscle will contract and **constrict** the pupil; this is the **reflex response**

- When in dim light the same process occurs, but the motor neurone stimulates the **radial muscles in the iris**, causing them to contract and **dilate** the pupil
- The reflex arc for a cranial reflex is as follows

stimulus → receptor → sensory neurone → relay neurone in brain → motor neurone → effector → response

Your notes

The Nerve Impulse

- **Neurones** transmit **electrical impulses** which travel along the neurone **cell surface membrane** from one end of a neurone to the other
  - Note that an impulse is **not** an electrical current that flows along neurones as if they were wires
  - Instead, an impulse is a **momentary reversal in the electrical potential difference** across the **neurone cell surface membrane**
    - The electrical potential difference across a membrane can also be described as the **voltage** across a membrane, the **difference in charge** across a membrane, or the **membrane potential**
- The different states of membrane potential across a neurone cell surface membrane during transmission of a nerve impulse include
  - **Resting potential**
  - **Action potential**

Resting potential

- In a **resting axon,** i.e. one that is **not transmitting impulses**, the **inside** of the axon always has a **negative electrical potential** compared to outside the axon
  - The **difference in charge** between the inside and outside of the neurone is due to **different numbers of ions** on each side of the neurone cell surface membrane
  - When there is a difference in charge across a membrane, we say that the membrane is **polarised**
- This **potential difference,** or **difference in charge,** across the membrane when there are no impulses is usually about **-70 mV** (millivolts) i.e. the inside of the axon has an electrical potential about 70 mV **lower** than the outside
  - -70 mV is the **resting potential** of the neurone
- Two factors contribute to establishing and maintaining resting potential
  - The active transport of sodium ions and potassium ions
  - A difference in membrane permeability to sodium and potassium ions

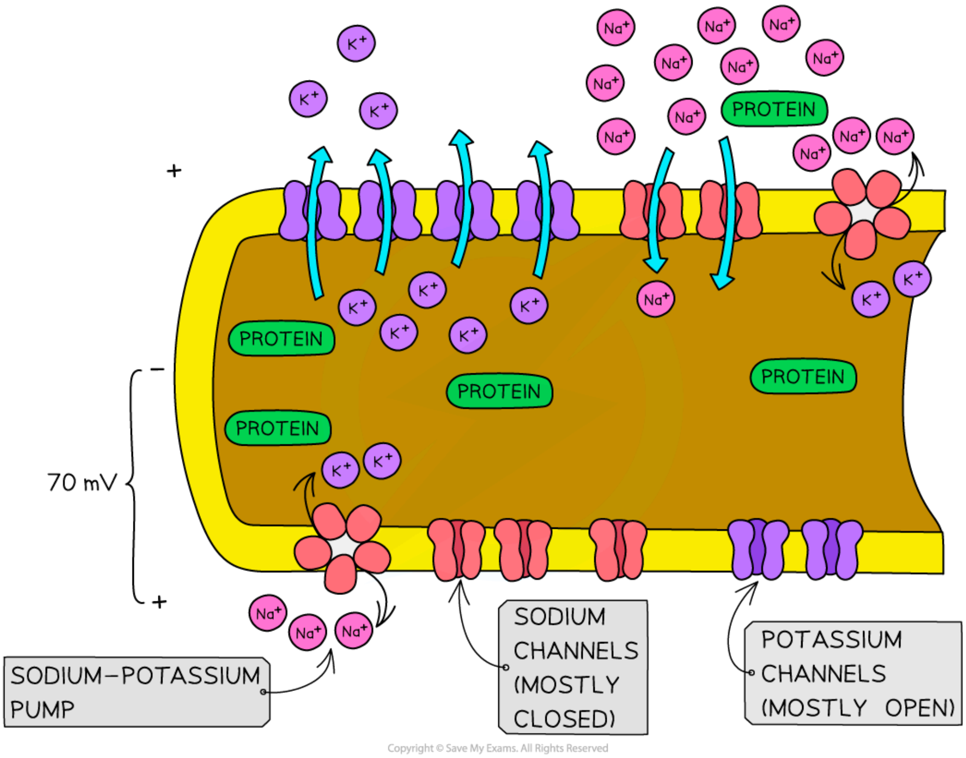
The active transport of sodium ions and potassium ions

- Carrier proteins called **sodium-potassium pumps** are present in the cell surface membranes of neurones
- These pumps use **ATP** to actively transport **sodium ions** (Na^+) **out** of the axon and **potassium ions** (K^+) **into** the axon

- The two types of ions are pumped at an unequal rate; for every **3 sodium ions that are pumped out** of the axon, only **2 potassium ions are pumped in**
- This creates a concentration gradient across the membrane for both sodium ions and potassium ions

Difference in membrane permeability to sodium ions and potassium ions

- Because of the concentration gradient generated by the sodium-potassium pumps, both sodium and potassium ions will **diffuse back across the membrane**
  - The neurone cell surface membrane has **sodium ion channels** and **potassium ion channels** that allow sodium and potassium ions to move across the membrane by facilitated diffusion
- The neurone membrane is **less permeable** to sodium ions than potassium ions, so potassium ions inside the neurone can diffuse **out** at a **faster rate** than **sodium ions** can diffuse **back in**
- This results in **more positive ions** on the **outside** of the neurone than on the inside, generating a **negative charge inside** the neurone in relation to the outside
- The result of this is that the neurone has a **resting membrane potential** of around **-70 millivolts (mV)**



Sodium-potassium pumps in the membrane of a resting neurone generate a concentration gradient for both sodium ions and potassium ions. This process, together with the facilitated diffusion of potassium ions back out of the cell, generates a negative resting potential across the membrane.

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Action potential

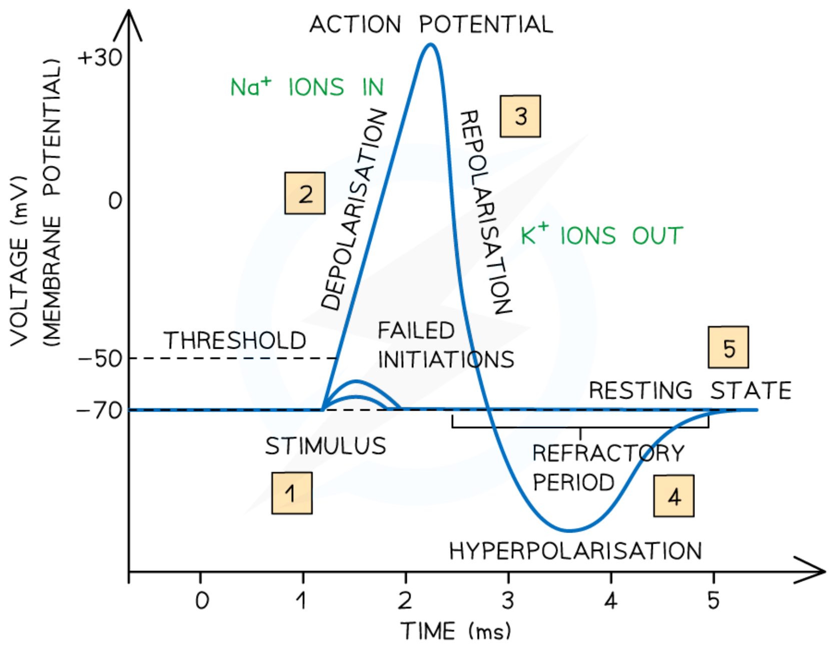
- Once resting potential is reached the neurone membrane is said to be **polarised**
- To initiate a nerve impulse in a neurone the membrane needs to be **depolarised**
  - Depolarisation is the **reversal of the electrical potential difference** across the membrane
- The depolarisation of the membrane occurs when an **action potential** is generated
  - Action potentials lead to the reversal of resting potential from around **-70 mV** to around **+30 mV**
- Action potentials involve the **rapid movement** of **sodium ions** and **potassium ions** across the **membrane** of the **axon**
- An action potential is the **potential electrical difference** produced across the axon membrane when a neurone is **stimulated** e.g. when an environmental stimulus is detected by a receptor cell

Generating an action potential

- Some of the ion channels in the membrane of a neurone are **voltage gated**, meaning that they open and close in response to changes in the **electrical potential** across the membrane
  - Voltage gated ion channels are **closed** when the membrane is at rest, but they are involved in the generation and transmission of action potentials
  - Note that not all of the channels in a neurone membrane are voltage gated e.g. some types of potassium ion channels are open when a neurone is at rest to enable potassium ions to diffuse out of the axon and generate a resting potential
- When a neurone is stimulated the following steps occur
  - A small number of **sodium ion channels** in the axon membrane **open**
  - **Sodium ions** begin to move **into the axon** down their **concentration gradient**
    - During resting potential there is a greater concentration of sodium ions outside the axon than inside due to the action of sodium-potassium pumps
  - This **reduces** the **potential difference** across the axon membrane as the **inside** of the axon becomes **less negative**
  - If the potential difference reaches around **-55 mV,** known as the **threshold potential**, **more sodium ion channels** open, leading to a further influx of sodium ions
    - This second set of sodium ion channels are voltage gated channels
    - Note that an **action potential** is only **initiated** if the **threshold potential** is reached
  - Once the charge has been reversed from -70 mV to around +30 mV the membrane is said to be **depolarised** and **an action potential** has been **generated**

Repolarisation

- About 1 millisecond after an action potential is generated all the **voltage gated sodium channels** in this section of membrane **close**
- **Voltage gated potassium channels** in this section of axon membrane now **open**, allowing the diffusion of potassium ions **out of the axon** down their concentration gradient
  - Remember that the sodium-potassium pumps have not stopped working during the action potential; hence the potassium ion gradient is still present
- This movement of potassium ions causes the inside of the axon to become negatively charged again, a process known as **repolarisation**
  - There is a short period during which the membrane potential is more negative than resting potential; this is known as **hyperpolarisation**
  - The period during which the membrane is hyperpolarised is known as the **refractory period**
    - The membrane is unresponsive to stimulation during the refractory period, so a new action potential cannot be generated at this time
    - This makes the action potentials **discrete** events and means the impulse can **only travel in one direction**
    - This is essential for the successful and efficient transmission of nerve impulses along neurones
- The voltage gated potassium channels then **close,** and the **sodium-potassium pumps** work to restore **resting potential**
  - Only once resting potential is restored can the membrane be stimulated again



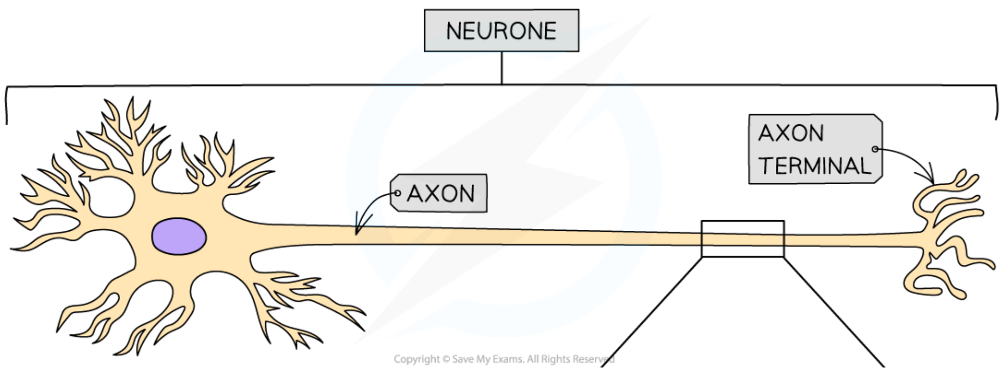
Your notes

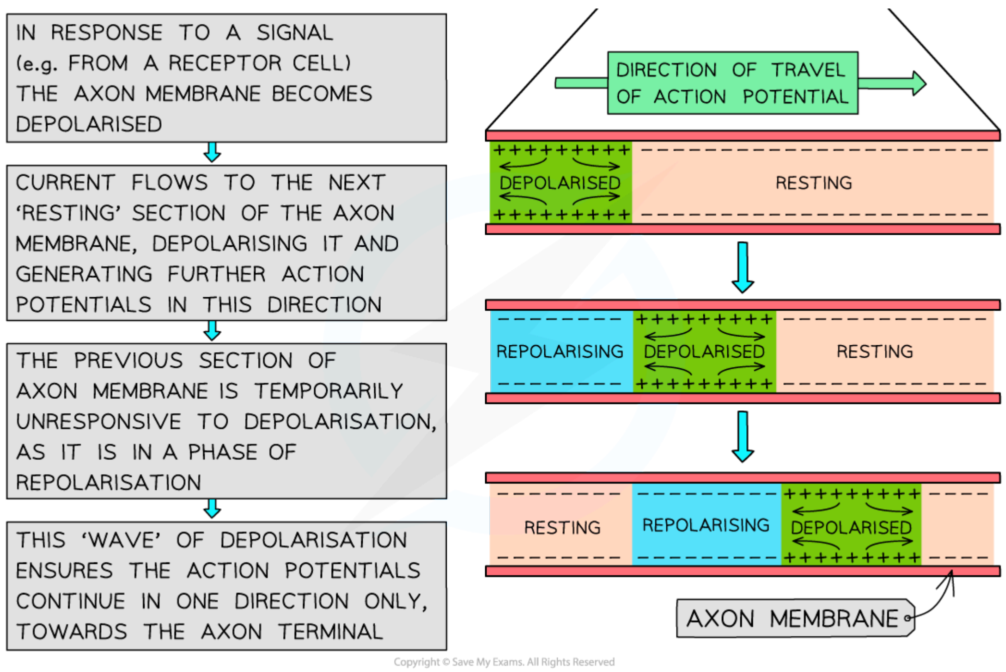
The depolarisation and repolarisation of an action potential can be clearly seen in a graph of membrane potential against time

Your notes

Transmission of an action potential

- Once an action potential has been generated it can be **propagated**, or transmitted, along the length of the axon
  - The depolarisation of the membrane at the site of the first action potential causes **sodium ions** to **diffuse along the cytoplasm** into the next section of the axon, **depolarising** the membrane in this new section, and causing voltage gated sodium channels to open
  - This triggers **another action potential** in this section of the axon membrane
  - This process then repeats along the length of the axon
    - Note that any sodium ions that diffuse backwards along the membrane are unable to initiate a new action potential due to the **hyperpolarised** nature of the membrane in the moments following an action potential
- The action potential is said to move along the axon in a **wave of depolarisation**
- In the body, this allows action potentials to begin at one end of an axon and then pass along the entire length of the axon membrane





Nerve impulses can be transmitted along axons by the diffusion of sodium ions

The all-or-nothing principle

- Action potentials are either generated or not generated depending on whether the **threshold potential** is reached; there is **no such thing as a small or large action potential**
  - If a stimulus is **weak** only a few sodium ion channels will open and the membrane won't be sufficiently depolarised to reach the **threshold potential;** an action potential will not be generated
  - If a stimulus is **strong enough** to raise the membrane potential above the **threshold potential,** then an action potential will be generated
- This is the **all-or-nothing principle**
  - An impulse is **only transmitted** if the **initial stimulus is sufficient** to increase the membrane potential above a **threshold potential**
- Stimulus size can be detected by the brain because as the **intensity of a stimulus increases**, the **frequency** of action potentials transmitted along the neurone **increases**
  - This means that a small stimulus may only lead to one action potential, while a large stimulus may lead to several action potentials in a row

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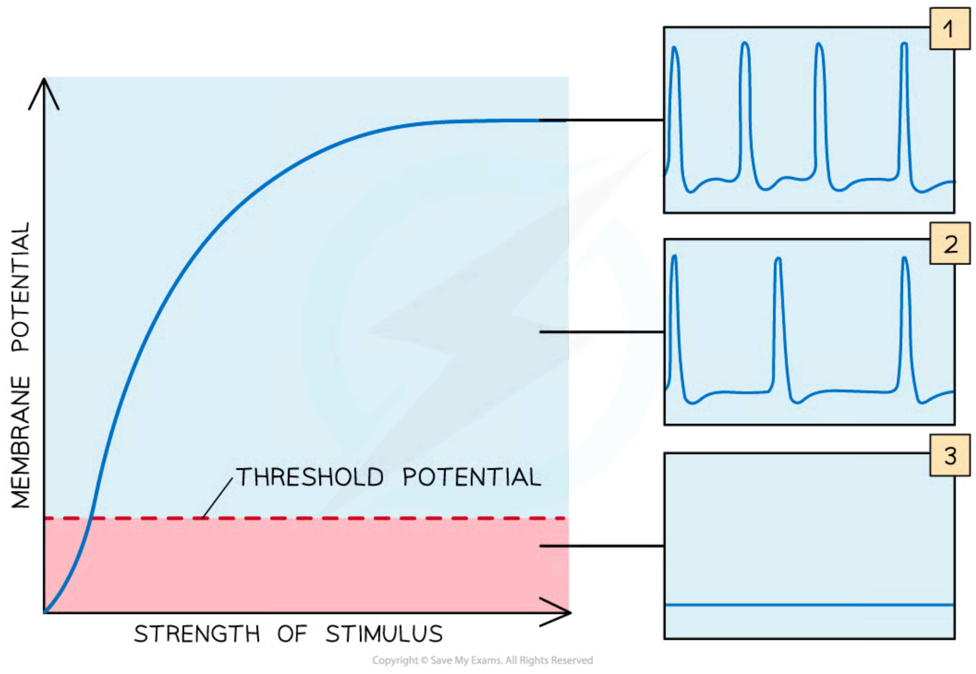


As the strength of a stimulus increases, the frequency at which action potentials are generated also increases

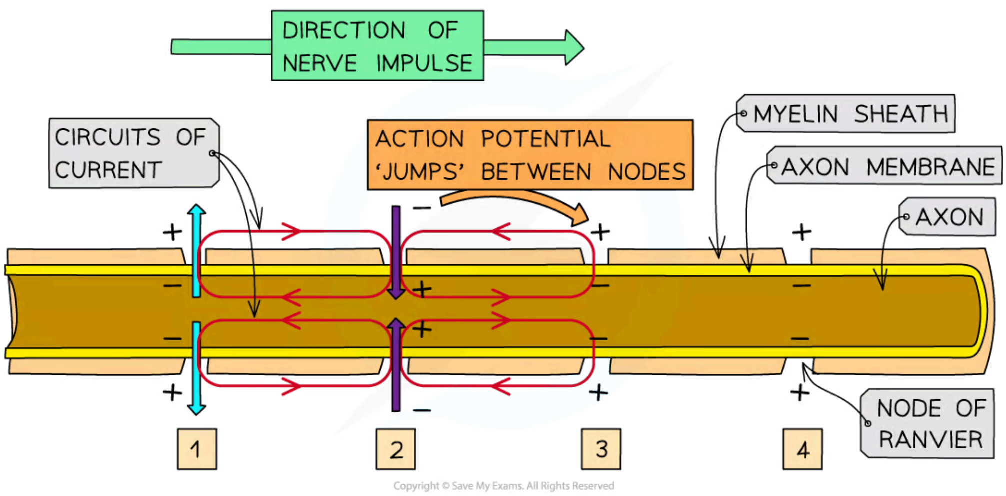
Preventing impulse transmission

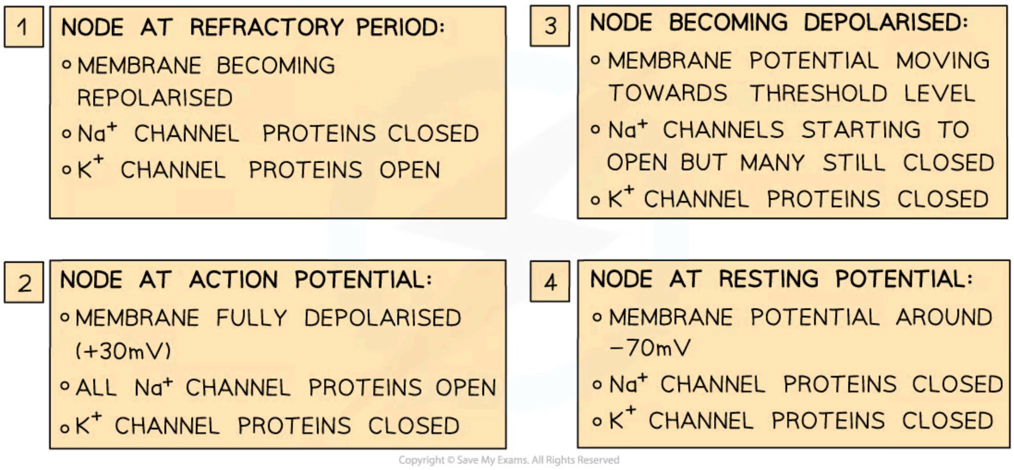
- The transmission of nerve impulses is essential to survival as it allows the body to **detect and respond to stimuli**
- On occasion, however, it is useful to be able to prevent the transmission of impulses e.g. in painkillers and anaesthetics
- Our understanding of the way that action potentials are transmitted means that it is possible to design medications that **prevent impulse transmission**
    - Such drugs may **bind to sodium ion channels**, preventing them from opening and therefore **preventing an influx of sodium ions** when an axon is stimulated
    - Preventing sodium ion influx **prevents membrane depolarisation** and an **action potential cannot be generated**

Your notes

Myelination & Saltatory Conduction

- In **unmyelinated** neurones the speed of conduction is relatively **slow** because depolarisation must occur along the whole membrane of the axon
- By insulating the axon membrane myelin **increases the speed at which action potentials can travel** along the neurone
  - In sections of the axon that are surrounded by a myelin sheath **depolarisation cannot occur** as the myelin sheath **stops** the diffusion of sodium and potassium ions
  - Action potentials can only occur at the **nodes of Ranvier**
    - Nodes of Ranvier are the gaps between the Schwann cells that make up the myelin sheath
  - Sodium ions diffuse along the axon within the Schwann cells and the membrane at the nodes of Ranvier depolarises when the sodium ions arrive
    - The diffusion of sodium ions in this way is known as **local currents**, or **local circuits**
  - The action potential therefore appears to **'jump' from one node to the next;** this is known as **saltatory conduction**
- Saltatory conduction allows the impulse to travel **much faster** than in an unmyelinated axon of the same diameter





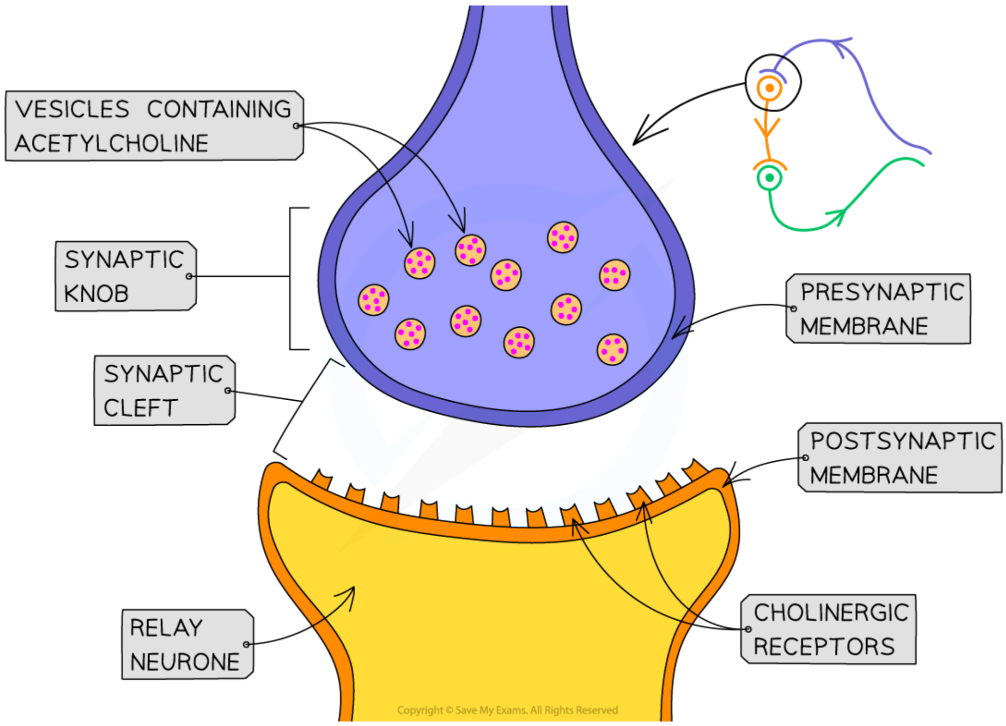
Action potentials are transmitted along myelinated axons by saltatory conduction

Your notes

Your notes

Synapses & Neurotransmitters

- Structures known as **synapses** are found at the **junctions between cells in the nervous system** e.g.
  - In the sense organs there are synapses between **sensory receptor cells** and **sensory neurones**
  - In muscles there are synapses between **motor neurones** and **muscle fibres**
- The structure of a synapse includes the following features
  - A gap between the neurones known as the **synaptic cleft**
  - The neurone before the synapse is known as the **presynaptic neurone** and has a rounded end known as the **synaptic knob**
  - The neurone after the synapse is known as the **postsynaptic neurone**
  - Nerve impulses are passed across the synaptic cleft by the **diffusion of chemicals** known as **neurotransmitters** e.g. acetylcholine
    - Neurotransmitters are contained within vesicles in the synaptic knob



Synapses are the junctions between neurones e.g. between a sensory neurone and a relay neurone

Synaptic transmission

- Electrical impulses cannot ‘jump’ across the synaptic cleft
- When an action potential arrives at the end of the axon of the **presynaptic neurone** the **membrane** becomes depolarised, causing **voltage gated calcium ion channels** to open
- **Calcium ions** diffuse into the synaptic knob via **calcium ion channels** in the membrane
- The calcium ions cause vesicles in the synaptic knob to move towards the presynaptic membrane where they fuse with it and **release chemical messengers** called **neurotransmitters** into the synaptic cleft by exocytosis
    - A common neurotransmitter is **acetylcholine**, or **ACh**
- The neurotransmitters **diffuse** across the **synaptic cleft** and **bind with receptor molecules** on the **postsynaptic membrane**; this causes associated **sodium ion channels** on the postsynaptic membrane to open, allowing **sodium ions** to diffuse into the postsynaptic cell
- If enough neurotransmitter molecules bind with receptors on the postsynaptic membrane, then an **action potential** is generated, which then travels down the **axon** of the **postsynaptic neurone**
    - Whether or not an action potential is generated depends on whether or not **threshold potential** is reached, which in turn depends on the **number of action potentials arriving at the presynaptic knob**
        - Many action potentials will cause more neurotransmitter to be released by exocytosis
        - A large amount of neurotransmitter will cause many sodium ion channels to open
        - Many sodium ion channels opening will allow a large influx of sodium ions, increasing the likelihood of threshold being reached
- The neurotransmitters are then **broken down** to prevent continued stimulation of the postsynaptic neurone
    - The enzyme that breaks down acetylcholine is **acetylcholinesterase**

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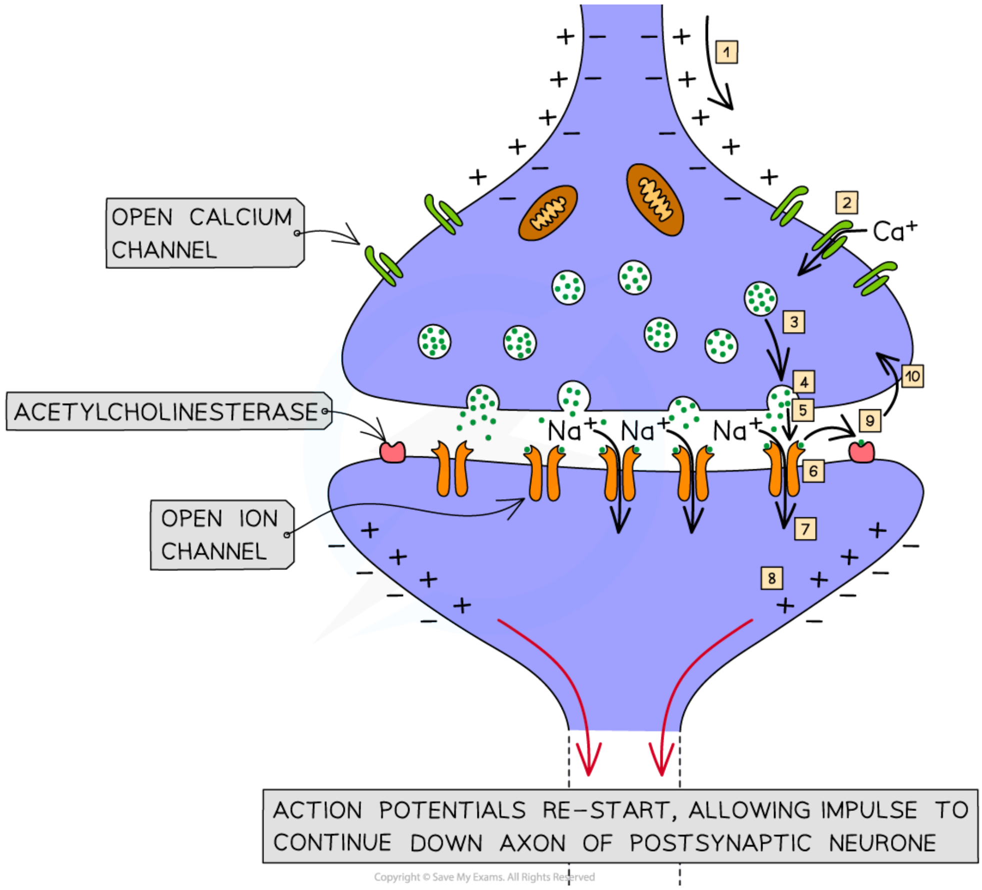

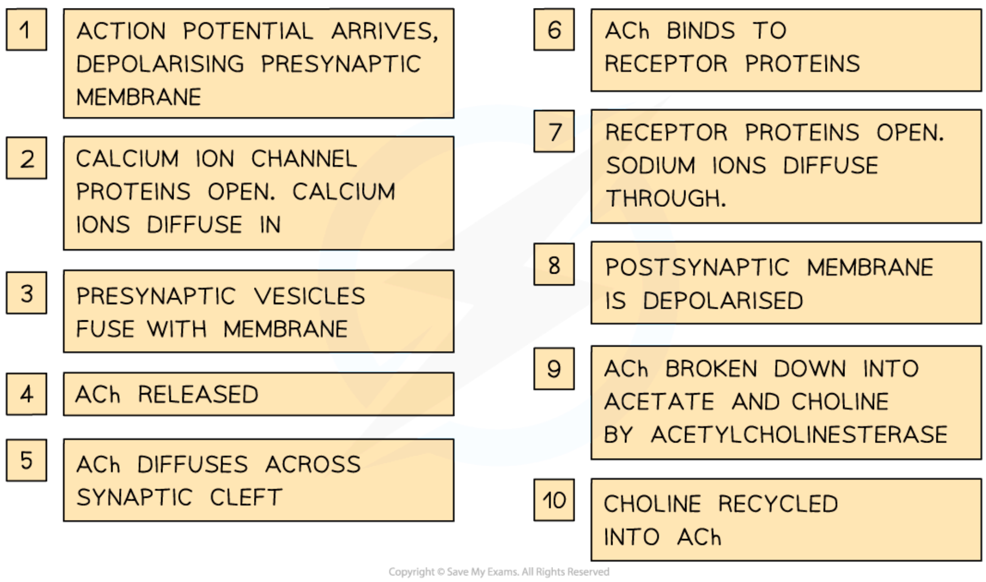

Impulses are transmitted across the synaptic cleft by the diffusion of neurotransmitters such as acetylcholine

Additional roles of synapses

- Synapses enable

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Your notes

- **Unidirectionality** of impulse transmission
  - Synapses ensure the **one-way transmission** of impulses
  - Impulses can only pass in **one direction** at synapses because **neurotransmitter is released on one side** and its **receptors are on the other;** chemical transmission cannot occur in the opposite direction
- **Divergence** of nerve impulses
  - One neurone can connect to **several other neurones** at a synapse, allowing nerve signals to be sent in several directions from a single presynaptic neurone
- **Amplification** of nerve signals by **summation**
  - When an impulse arrives at a synapse it **does not always** cause an impulse to be generated in the next neurone; a **single impulse** that arrives at a synaptic knob may be **insufficient** to generate an action potential in the post-synaptic neurone
    - Only a small amount of acetylcholine may release into the synaptic cleft
    - A small number of sodium ion channels are opened in the postsynaptic axon membrane
    - An insufficient number of sodium ions pass through the membrane
    - The threshold potential is not reached
  - The effect of multiple impulses can be added together to overcome this in a process known as **summation**
  - Summation can be achieved by
    - **Several presynaptic neurones** converging to meet a single postsynaptic neurone
      - This is known as **synaptic convergence**
    - **Many action potentials** arriving at a postsynaptic knob in quick succession

The Pupil Reflex

- The connections between neurones at synapses enable the sequence of events that leads to a change in the diameter of the pupil in the eye; this is known as the **pupil reflex**
  - Changing pupil diameter enables the eye to **control the amount of light hitting the retina,** avoiding damage that could be caused by bright light
- The diameter of the pupil in the eye is determined by two sets of muscles
  - The **circular muscles** contract to **constrict** the pupil
  - The **radial muscles** contract to **dilate** the pupil
- The two sets of muscles work **antagonistically**, meaning that when one set of muscles contracts the other relaxes, and vice versa

- In **bright light** the following events occur

bright light → light receptors in eyes → sensory neurone → CNS → motor neurone → circular muscles in iris

- Contraction of the circular muscles in the iris of the eye causes the pupil to **constrict**
  - This limits the amount of light entering the eye and **prevents damage to the retina**
- In **low light** the following events occur

low light → light receptors in eyes → sensory neurone → CNS → motor neurone → radial muscles in iris

- Contraction of the radial muscles in the iris of the eye causes the pupil to **dilate**
  - This **maximises the amount of light entering the eye**, improving vision

BRIGHT LIGHT

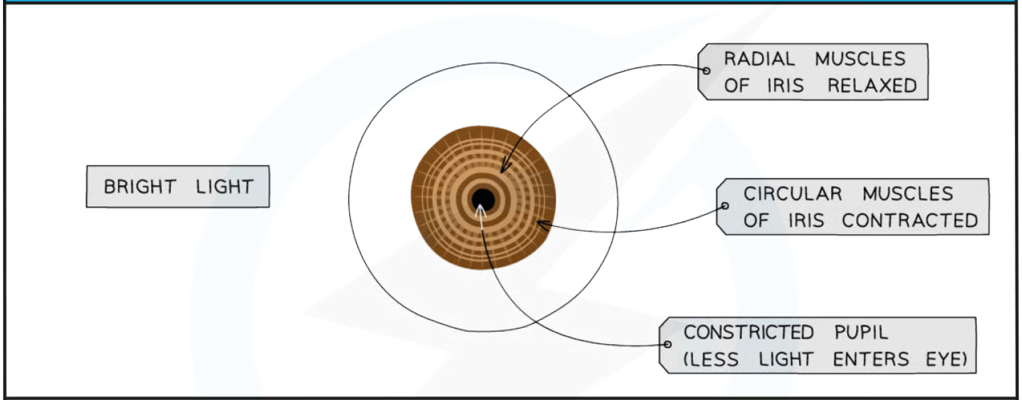

DIAGRAM SHOWING THE EYE IN A BRIGHT ENVIRONMENT
- PHOTORECEPTORS DETECT CHANGE IN ENVIRONMENT (BRIGHT)
- RADIAL MUSCLES RELAX
- CIRCULAR MUSCLES CONTRACT
- PUPIL CONSTRICTS (DIAMETER OF PUPIL NARROWS)
- LESS LIGHT ENTERS THE EYE

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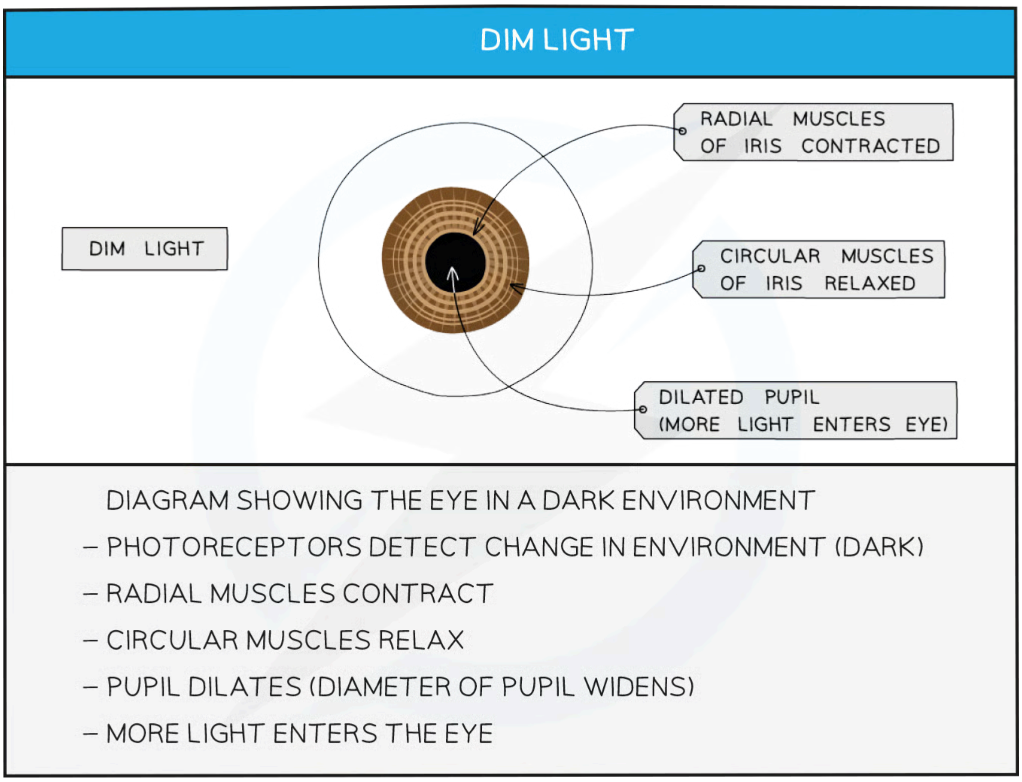
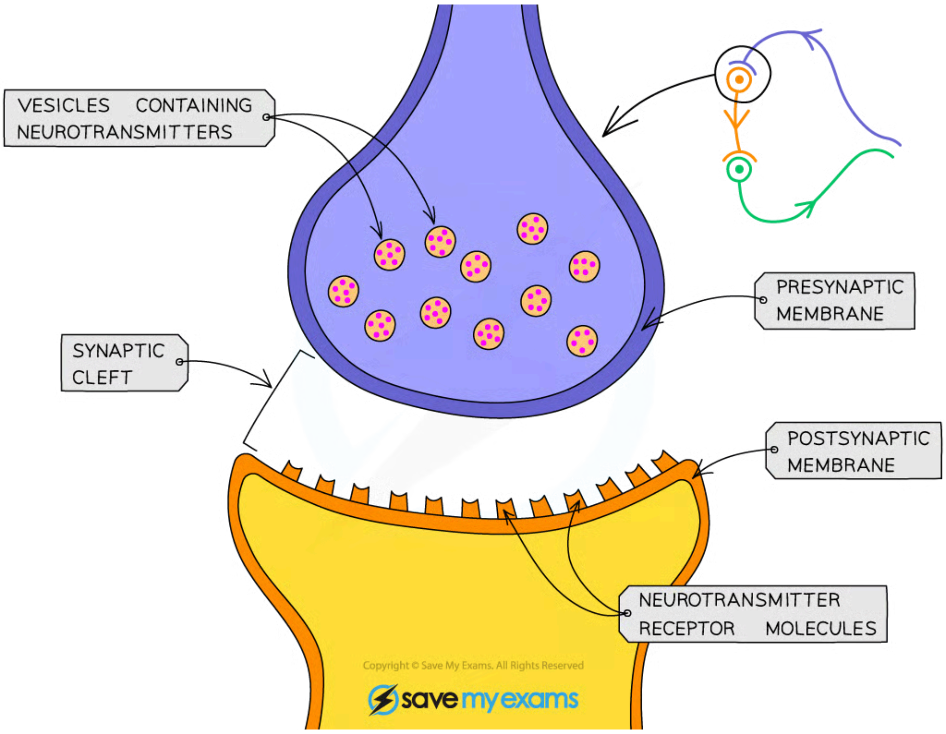


The pupil reflex allows unconscious control of the amount of light entering the eye; this prevents damage to the retina by bright light

Your notes

The Effects of Drugs on Nervous Transmission

- The chemicals in **drugs** can have a major impact on the **functioning of the brain and nervous system**
- Many drugs impact the nervous system by altering the events that occur at **synapses**
- Drugs can **increase transmission** of impulses at a synapse by
  - Causing more neurotransmitter to be **produced** in the synaptic knob
  - Causing more neurotransmitter to be **released** at the presynaptic membrane
  - Imitating the effect of a neurotransmitter by **binding to and activating receptors** on the postsynaptic membrane
  - **Preventing the breakdown** of neurotransmitters by enzymes
  - **Preventing the reuptake** of neurotransmitters by the presynaptic cell
- Drugs can **decrease transmission** of impulses at a synapse by
  - **Preventing production** of neurotransmitter in the presynaptic knob
  - **Preventing the release** of neurotransmitter at the presynaptic membrane
  - Enabling neurotransmitter to gradually leak out of the presynaptic knob so there is little left when an action potential arrives
    - The neurotransmitter that leaks out of the cell is **destroyed by enzymes**
  - Binding to receptors on the postsynaptic membrane and so **preventing neurotransmitters from binding**



Drugs can influence the transmission of nerve impulses at synapses

Nicotine

- Nicotine is the addictive chemical found in **tobacco**
- Nicotine affects synapses in more than one way
  - It **mimics acetylcholine**
    - Nicotine binds to a type of acetylcholine receptor on the postsynaptic neurone known as a **nicotinic receptor**
    - The binding of nicotine to nicotinic receptors **initiates an action potential** in the postsynaptic neurone
    - After stimulation by nicotine these receptors **become unresponsive** to other stimulation
      - While it is normal for receptors to be briefly unresponsive to further stimulation after being activated, nicotine causes a **prolonged period of unresponsiveness**
  - It **stimulates release of dopamine**
    - Dopamine is released from the **pleasure centres** in the brain in response to nicotine
    - The release of dopamine is thought to **reinforce rewarding behaviours,** in this case smoking, increasing the likelihood that we will carry out that behaviour again

Your notes

- Nicotine **increases heart rate and blood pressure**, as well as **increasing the likelihood that an individual will continue smoking**; this further impacts the circulatory system as well as increasing the risk of other health problems such as lung cancer

Your notes

Lidocaine

- Lidocaine is often used as a **local anaesthetic** for **numbing small areas** of the body
  - E.g. it is used by dentists before dental procedures such as tooth extraction
- It can also be used to **regulate the heart beat** in people suffering from irregular heart rhythms
- Lidocaine works by **blocking voltage gated sodium channels**
  - This **prevents a large influx of sodium ions** in the postsynaptic neurone, therefore **preventing an action potential** from being generated

Cobra venom

- Cobra venom, also known as α-cobratoxin, is a type of **venom** produced by some species of cobra
  - Receiving a snake bite from a cobra can be fatal
  - α = alpha
- α-cobratoxin **binds to acetylcholine receptors** on the postsynaptic membrane, preventing an influx of sodium ions and therefore the generation of an action potential
- When this occurs at the synapses between motor neurones and muscle fibres, known as **neuromuscular junctions**, this can lead to **muscle paralysis**
  - Eventual paralysis of the **muscles that control breathing** leads to death
- Small quantities of α-cobratoxin can be used as a **muscle relaxant** during asthma attacks

L-dopa

- L-dopa is a drug used to treat the symptoms of **Parkinson's disease**
- It has a very **similar structure to dopamine;** a neurotransmitter present at lower levels than usual in the brains of those who suffer from Parkinson's disease
- L-dopa is transported from the blood into the brain, where it is **converted into dopamine** in a reaction catalysed by the **enzyme** dopa-decarboxylase
- The effect is to **increase levels of dopamine in the brain**
  - Note, dopamine cannot be given directly to those who have Parkinson's disease as it cannot cross the barrier between the blood and the brain
- Increased levels of dopamine mean that **more nerve impulses are transmitted** in parts of the brain that control movement, giving sufferers better control over their movement and lessening the symptoms of Parkinson's disease

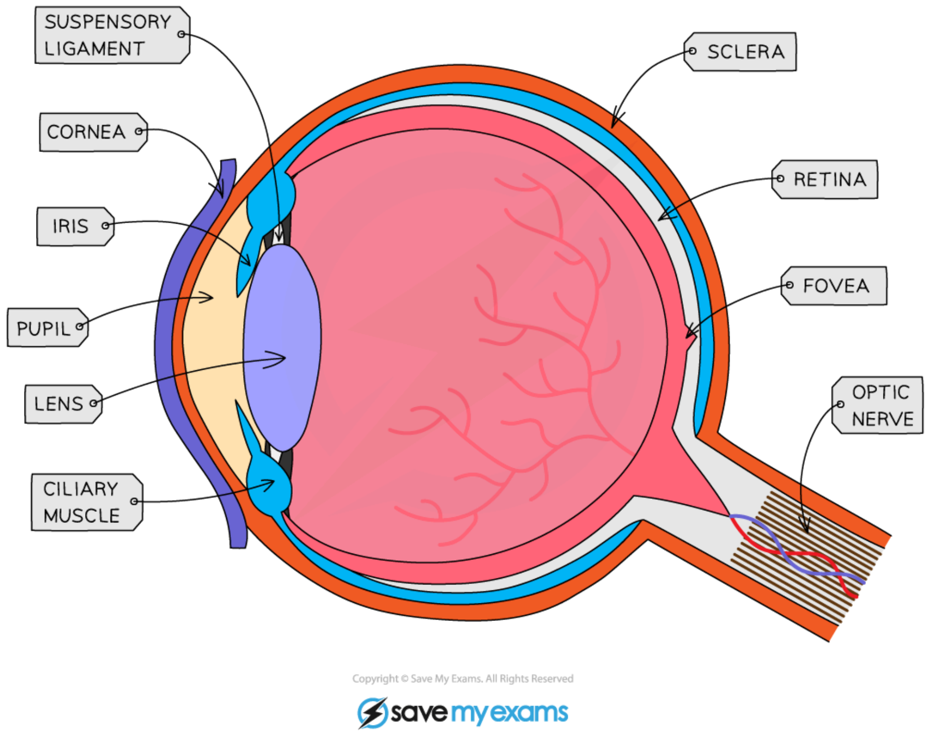
MDMA

- MDMA is a **recreational drug** that is also known as ecstasy
  - Its use and sale are criminal offences in most parts of the world
- MDMA effects multiple neurotransmitters, most notably **serotonin**
  - MDMA **inhibits the reuptake** of serotonin into the presynaptic neurone by **binding to the specific proteins that enable serotonin reuptake**, located on the presynaptic membrane; this increases the amount of serotonin present in the brain
    - Serotonin is usually reabsorbed into the **presynaptic neurone to be recycled** for future action potentials
  - MDMA also triggers the **release of further serotonin** from presynaptic neurones, further adding to the increase
- Serotonin can affect people in many ways including their **mood**, anxiety and sleep
- When an individual takes MDMA they may feel **extreme euphoria** and enhanced touch and bodily sensations

Your notes

Detection of Stimuli

- The eye is a **sense organ** containing receptors sensitive to light intensity and wavelength
    - **Receptors** are specialised cells that can generate an electrical impulse in a sensory neurone when stimulated by a particular stimulus e.g. light receptors are stimulated when light falls on them
- Light enters the eye through the **pupil** and is focused onto a region of the **retina** called the **fovea**
    - The amount of light that enters the eye is controlled by the muscles of the **iris**
    - Light is focused using the **lens**, the shape of which is controlled by **ciliary muscles** attached to the lens by **suspensory ligaments**
        - The muscles change the shape of the lens to allow it to focus light reflected from objects at different distances from the eye
    - The fovea contains many **light receptors,** or **photoreceptors**
- The retina contains two types of photoreceptors
    - **Rod cells**
        - Primarily located around the **outer retina**
        - Sensitive to **light intensity** so can detect the presence and brightness of light
        - Images generated using information from only rod cells is **black and white**
    - **Cone cells**
        - Mostly found grouped together in the **fovea**
        - Sensitive to **different wavelengths** of visible light so detect colour
            - Cone cells can be **red-sensitive, green-sensitive**, or **blue-sensitive**
            - The number of red-, green-, and blue-sensitive cone cells stimulated will **determine the colours seen**
        - Images generated using information from cone cells will be in **colour**
- Action potentials generated in the photoreceptor are transmitted to the brain via the **optic nerve**
    - The optic nerve leaves the back of the eye from a region known as the **blind spot**
        - The blind spot contains no photoreceptors

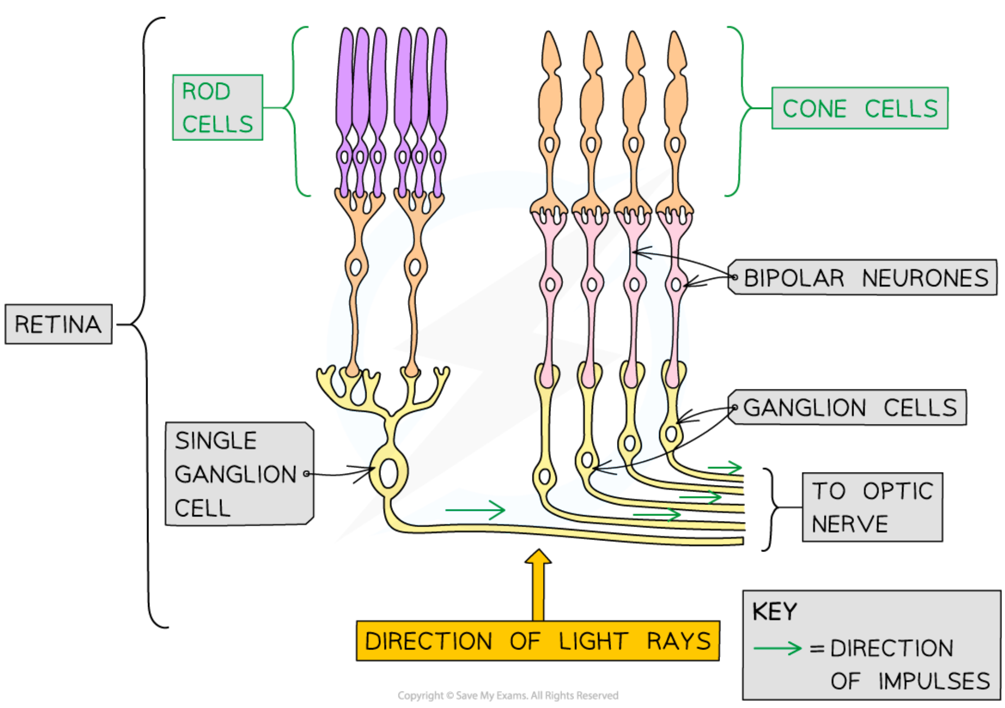


The eye focuses light on the retina, which contains many light receptors

Photoreceptors generate nerve impulses

- Photoreceptors in the eye generate action potentials when **stimulated** by **bright enough light** (rods), or by **light of a particular wavelength** (cones)
- **Light-sensitive pigments** inside the photoreceptors are **bleached** when light falls on them e.g.
  - Rod cells contain a light-sensitive pigment called **rhodopsin**
  - When light hits rhodopsin it **breaks apart** into constituent parts **retinal** and **opsin**
  - The breaking apart of rhodopsin is known as **bleaching**
- The bleaching of light-sensitive pigments causes a **chemical change** in the photoreceptor that results in the generation of a **nerve impulse**
- Nerve impulses travel along a **bipolar neurone** to the optic nerve, which carries information to the brain

Your notes



Information passes from rod and cone cells to the optic nerve via bipolar neurones. Note that you do not need to know about ganglion cells here

The action of rod cells

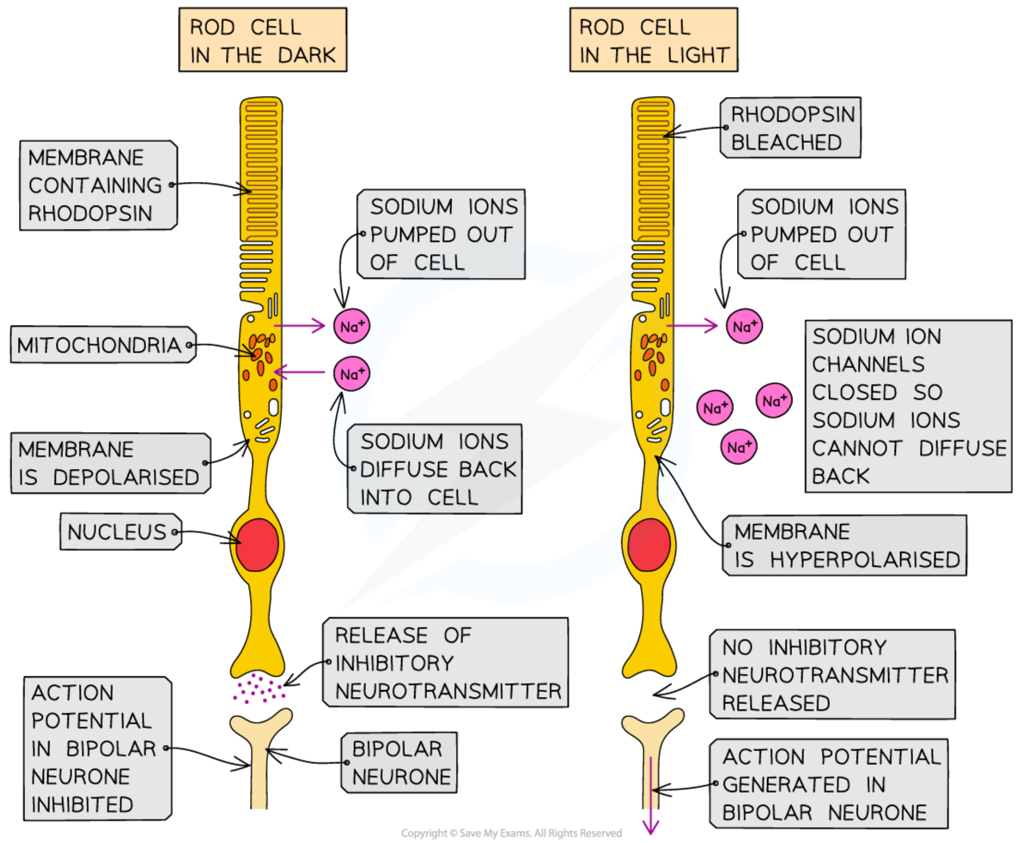
- The way in which rod cells pass information to the optic nerve is a bit back-to-front in comparison to the action of other nerve cells; rather than initiating an action potential when they are **depolarised**, rod cells initiate action potentials in neighbouring bipolar neurones when they are **hyperpolarised**
- In the **dark** the following occurs inside rod cells
  - **Sodium ions** are actively pumped out of rod cells, generating a **concentration gradient**
    - Sodium ions (Na^+) are **positively charged** ions, also known as **cations**
  - Sodium ions **diffuse** back down this concentration gradient into the rod cell via **sodium channels**
    - Sodium channels are also known as **cation channels** because they allow the movement of positively charged ions
  - At this stage there is little difference in charge between the outside and inside of the rod cell, and the cell is said to be **depolarised**
    - In reality the inside of the rod cell is **slightly negative** in comparison to the outside
  - The depolarised rod cell **releases neurotransmitters** which diffuse across a synapse to a **bipolar neurone**

Your notes

Your notes

    - Rather than initiating an action potential in the bipolar neurone **this neurotransmitter inhibits the generation of an action potential**, preventing a nerve impulse from being sent to the optic nerve
        - This neurotransmitter is said to be an **inhibitory neurotransmitter**
- In the **light** the following occurs inside rod cells
    - Light **bleaches rhodopsin**, causing it to break apart into retinal and opsin
    - When light is absorbed the **cis** retinal (+ opsin) is converted to **trans** retinal (+ opsin)
    - The bleaching of rhodopsin causes the sodium ion channels in the cell surface membrane of the rod cell to **close**, **preventing sodium ions from diffusing** back into the rod cell
        - The active transport of sodium ions out of the cell is still taking place, so sodium ions are removed from the cell but not able to return
    - The lack of positively charged ions entering the rod cell causes its interior to become **more negative** until it reaches a **hyperpolarised state**
        - A membrane that is hyperpolarised has a **more negative** potential difference across it than the resting -70 mV
    - The hyperpolarised rod cell **stops releasing an inhibitory neurotransmitter**, so the generation of an action potential in the neighbouring bipolar neurone is **no longer inhibited**
    - An **action potential** is generated in the bipolar neurone attached to the rod cell and **an impulse is sent to the optic nerve**

Your notes



Rod cell membranes are depolarised in the dark and hyperpolarised in the light

Habituation

- Animals must **respond to changes** in their **external** and **internal** environments in order to survive
  - Changes in the environment, or **stimuli** (singular **stimulus**) are detected by specialised **receptor cells**
  - Receptor cells send **signals** via either the **nervous system** or the **hormonal system** to the body's co-ordination centres in the **brain** or **spinal cord**
  - Signals are then sent on to the parts of the body which respond, known as the **effectors**
- The process of detecting and responding to stimuli **requires energy**, so it is important that animals don't **waste energy responding to non-threatening stimuli**
  - Animals need to conserve energy for essential processes that increase their survival chances
- If a stimulus is **repeated many times** with **no negative outcome** then an animal will learn **not to respond to it**; this process is known as **habituation**
  - An animal that doesn't respond to a stimulus is said to be **habituated** to that stimulus
- Examples of habituation include
  - Humans no longer noticing a new smell or sound after a period of exposure
  - Wild animals losing their fear of humans after regular non-harmful contact
  - Animals learning not to be alarmed by the presence of non-predatory species
- If a stimulus to which an animal has become habituated **changes,** then the nervous system will respond to it again
  - E.g. a constant low-level sound that suddenly becomes louder

The process of habituation

- Animals **become habituated** due to **changes in the transmission of nerve impulses** from one neurone to the next
  - Nerve impulses are transmitted across synapses by the diffusion of **chemical neurotransmitters**
  - Neurotransmitters are released at the presynaptic membrane in response to an **influx of calcium ions**
- When habituation has taken place **fewer calcium ions** move into the presynaptic neurone on arrival of a nerve impulse
- As a result, **less neurotransmitter** is released and **an action potential is less likely** to be generated in the postsynaptic neurone

- Fewer molecules of neurotransmitter bind to receptors on the postsynaptic membrane
- Fewer sodium ion channels open
- Fewer sodium ions move into the axon and the charge inside the axon remains negative
- Threshold potential is not reached

- The nerve impulse therefore **does not reach the effector** organ and the animal **does not respond** to the stimulus

Investigating habituation

- Habituation to a stimulus can be studied by **measuring the changes in an animal's response to a non-harmful stimulus** e.g.
    - Snails often respond to a stimulus by **withdrawing into their shell**, waiting to **emerge again** until the harmful stimulus is likely to be gone
    - As snails become habituated to a stimulus the **time taken for them to re-emerge** from their shells after a stimulus **gets shorter**

Apparatus

- Snail
- A soft object with which to provide a stimulus e.g. a damp cotton bud or a blade of grass
- Stopwatch

Method

1. Place a snail on a clean, flat surface and give it time to emerge from its shell
    - The **same surface** should be used throughout the experiment
    - Ensure that **humidity remains the same** throughout as snails will withdraw in a dry environment
2. Gently brush the snail's head with a damp cotton bud or blade of grass
    - It is expected that the snail will withdraw into its shell in response to the touch
3. Start the stopwatch and measure the time taken until the snail re-emerges from the shell and fully extends its eye-stalks again
4. Repeat steps 2 and 3 10-15 times, recording the time taken until full re-emergence each time
    - Ensure that the **same soft object** is used throughout and that the **location of the touch on the snail's body remains the same**
    - Waiting for full extension of the eye stalks ensures that the **same end-point** is used each time
5. Plot a graph of touch number against time taken for full re-emergence

Your notes

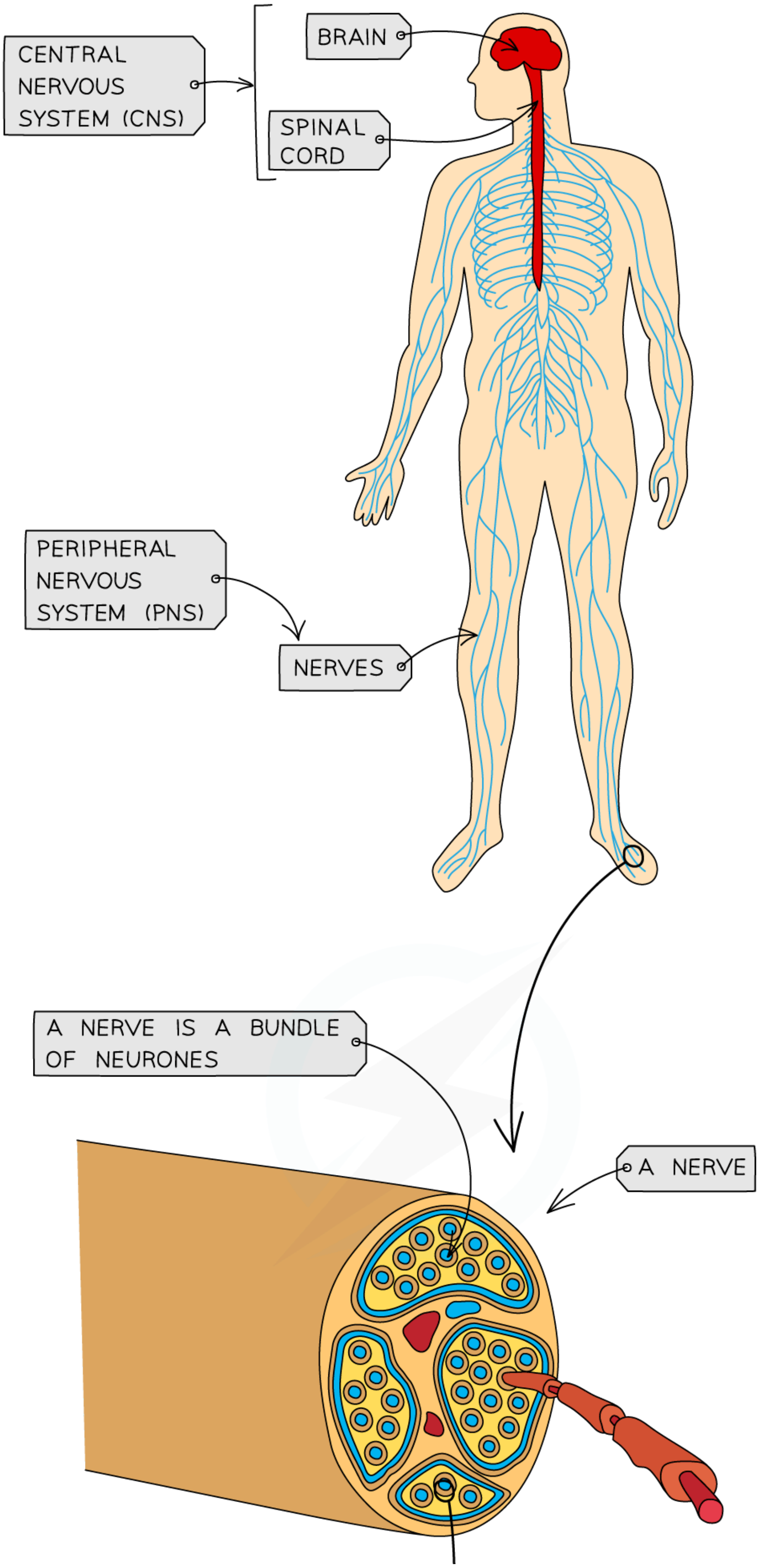
    - The graph would be expected to show a **gradual decrease in the time taken for full re-emergence** as the snail becomes habituated to the stimulus
- Note that snails are living organisms and so **welfare considerations** should be taken into account when using them for experimental purposes
    - Snails should be **returned to a suitable environment** that replicates their natural habitat at the end of the experiment
        - If snails were taken from a garden or the school grounds then they should be returned to the **exact location from which they were removed**
    - Any handling and transfer of snails should be carried out **gently and quickly**
    - Snails should not be exposed to **high temperatures** or an overly **dry environment**

Your notes

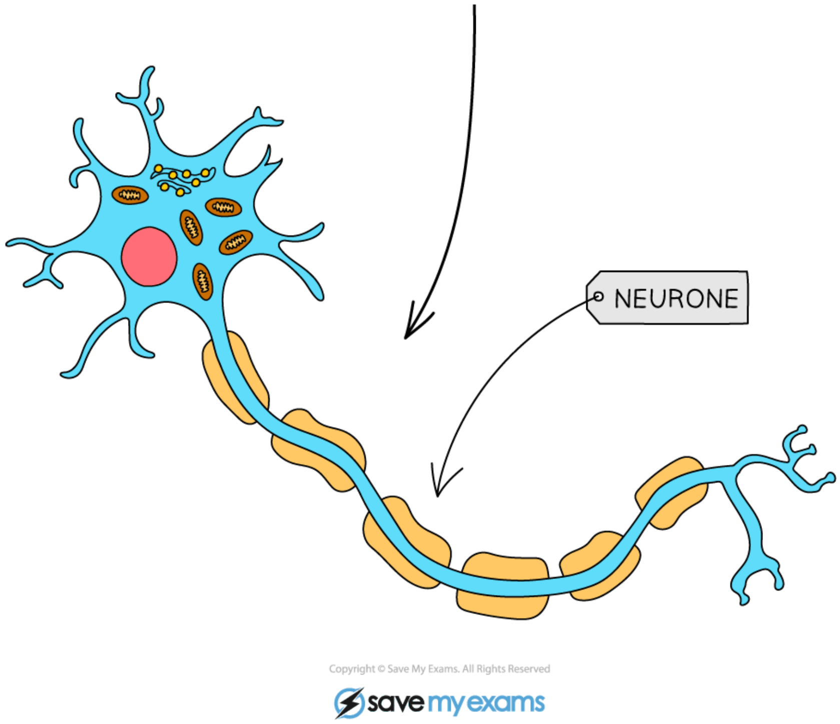
Central & Peripheral Nervous System

- The human nervous system consists of
  - **Central nervous system** (CNS) – the **brain** and **spinal cord**
  - **Peripheral nervous system** (PNS) – the parts of the nervous system that are not within the central nervous system and that extend to the rest of the body
- The nervous system allows detection of stimuli in the surroundings and the **coordination** of the body's **responses** to the stimuli
  - Stimuli are detected by cells called **receptor cells**
    - Receptor cells are gathered together in the **sense organs**, e.g.
      - Photoreceptors that are stimulated by light are found in the eye
      - Chemoreceptors that are stimulated by chemicals are found on the tongue
      - Pressure receptors that are stimulated by pressure are found on the skin and inside the blood vessels
  - The parts of the body that respond to stimuli are known as the **effectors**
    - Effectors can be muscles or glands
- Information is sent through the nervous system in the form of **electrical impulses** that pass along **nerve cells** known as **neurones**
  - A **bundle of neurones** is known as a **nerve**
  - There are different types of neurones including **sensory neurones, relay neurones**, and **motor neurones**
- The PNS connects the receptor cells in the sense organs with the CNS, and connects the CNS with effectors
  - The **CNS** acts as a **central coordinating centre** for the impulses that come in from, and are sent out to, any part of the body
- Nerve impulses pass through the nervous system along the following pathway

stimulus → **receptor** → **sensory neurone** → **CNS** → **motor neurone** → **effector**


CENTRAL NERVOUS SYSTEM (CNS)
BRAIN
SPINAL CORD
PERIPHERAL NERVOUS SYSTEM (PNS)
NERVES
A NERVE IS A BUNDLE OF NEURONES
A NERVE

Your notes



The nervous system consists of the central nervous system and the peripheral nervous system

Your notes