Cambridge (CIE) IGCSE Biology

Your notes

Coordination, Response & Homeostasis

Contents

Your notes

Structure & Role of the Mammalian Nervous System

- The **human nervous system** consists of the:
  - **central nervous system** (CNS) - the brain and the spinal cord
  - **peripheral nervous system** (PNS) - all of the nerves in the body
- It allows us to
  - Make sense of our surroundings and respond to them
  - **Coordinate** and **regulate body functions**
- Information is sent through the nervous system as **nerve impulses** - electrical signals that pass along nerve cells known as **neurones**
- A bundle of neurones is known as a **nerve**

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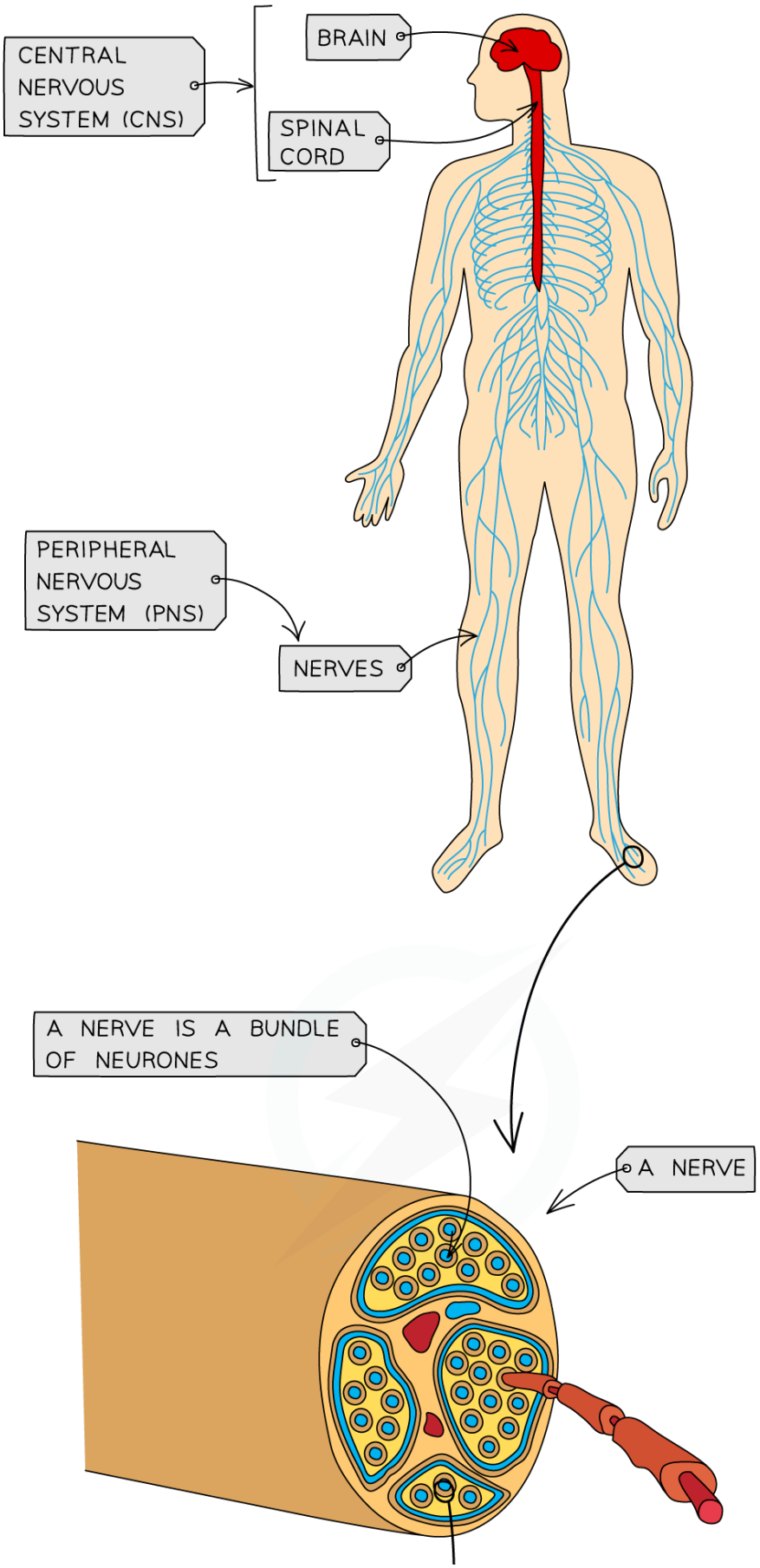

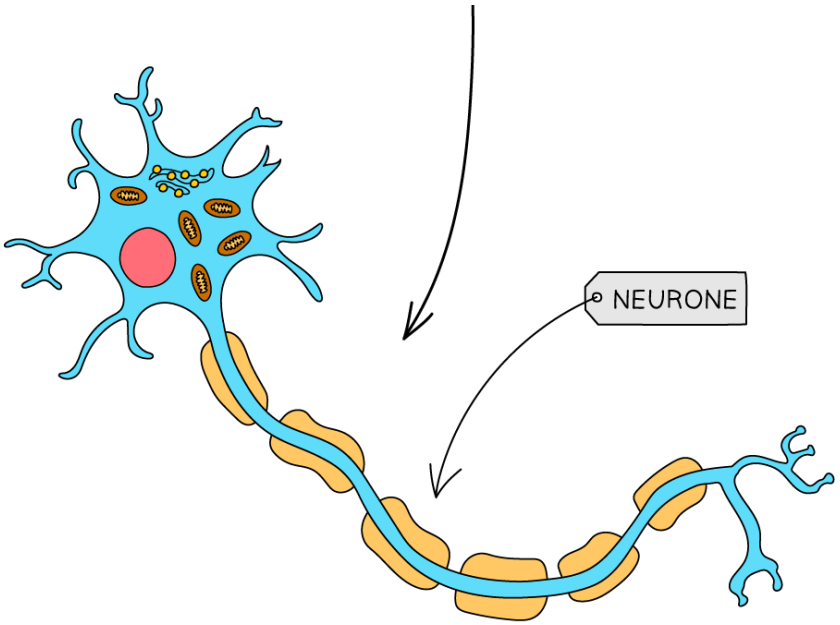

The human nervous system

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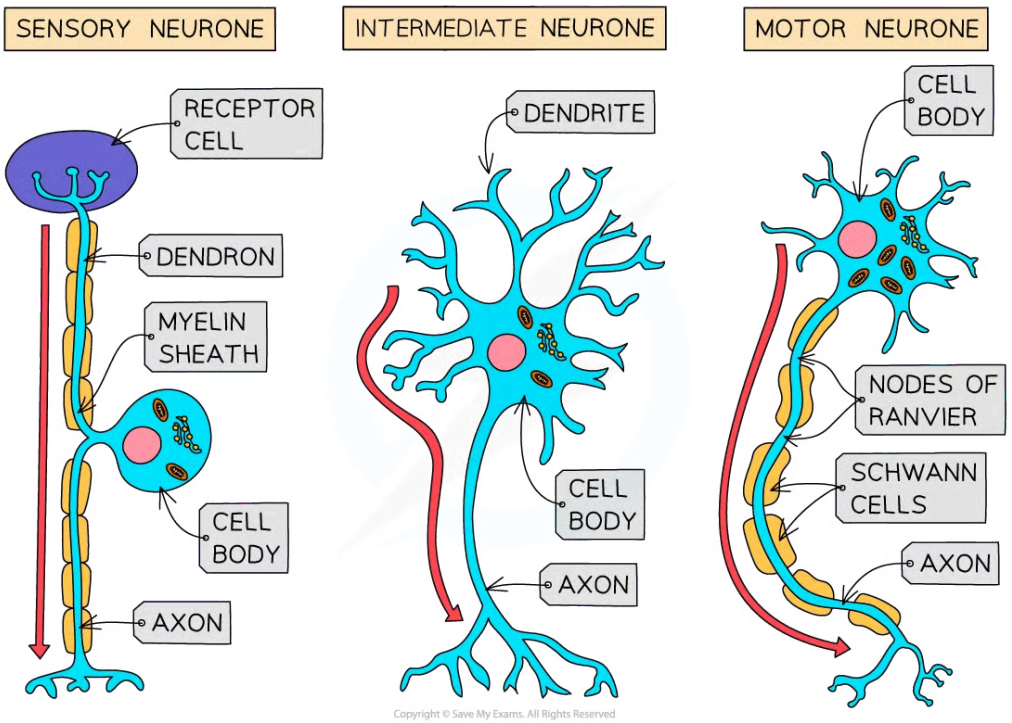
Neurone Diagrams

- There are three main types of neurone: **sensory, relay and motor**
  - **Sensory** neurones carry impulses **from sense organs to the CNS** (brain or spinal cord)
  - **Relay** neurones (also known as intermediate neurones) are found inside the CNS and **connect sensory and motor neurones**
  - **Motor** neurones carry impulses **from the CNS to effectors** (muscles or glands)
- Neurones have a long fibre (**axon**)
- This means that less time is wasted transferring the impulse from one cell to another
- The axon is insulated by a fatty sheath with small uninsulated sections along it (called nodes)
- This means that the electrical impulse does not travel down the whole axon, but **jumps from one node to the next**
- Their cell body contains many extensions called **dendrites**
- This means they can **connect to many other neurones** and receive impulses from them, forming a network for easy communication

Identifying the types of neurone:



The three types of neurone

- Sensory neurones are **long** and have a **cell body branching off the middle of the axon**
- Relay neurones are **short** and have a **small cell body at one end** with many dendrites branching off it
- Motor neurones are **long** and have a **large cell body at one end with long dendrites branching off it**

Examiner Tips and Tricks

A way to remember which neurone is which:

Sensory neurones connect a sense organ eg. eye, nose, tastebuds to the CNS

Motor neurones result in a response, which is often movement; think of a moving motorbike

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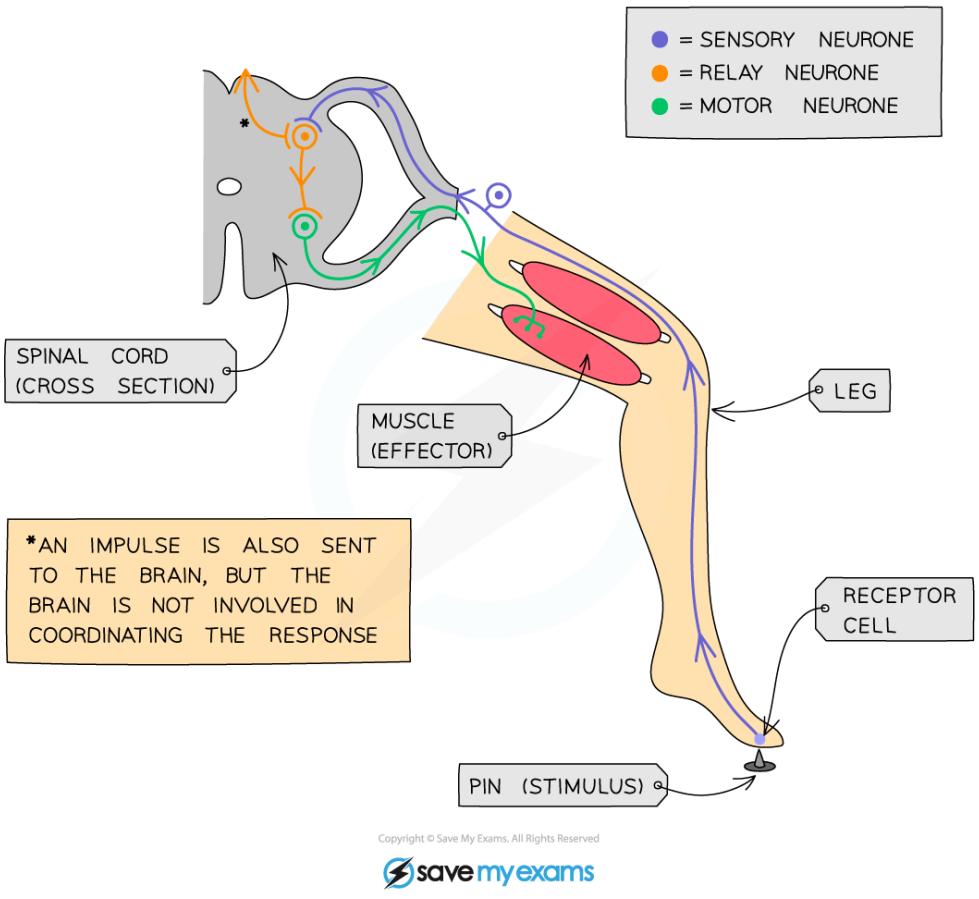
The Reflex Arc

Voluntary Responses

- A voluntary response is one where you make a **conscious decision** to carry out a particular action therefore it **starts with your brain**
  - An example is reaching out to pick up a cup of coffee
- An involuntary (or reflex) response does **not involve the brain as the coordinator** of the reaction and you are **not aware** you have completed it until **after** you have carried it out
- Involuntary actions are usually ones which are **essential to basic survival** and are **rapid**, whereas voluntary responses often **take longer** as we consider what the consequences might be before doing it

Reflex Responses

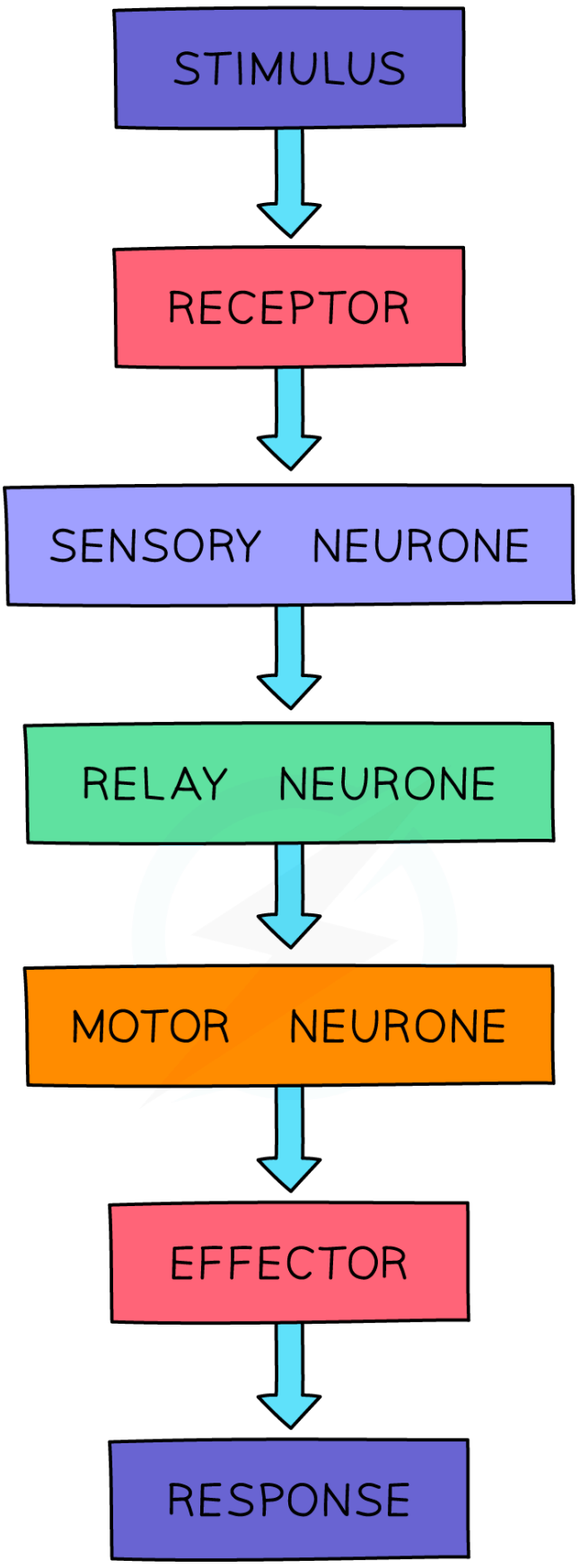
- An **involuntary** (or **reflex**) response **does not involve the brain** as the coordinator of the reaction and you are not aware you have completed it until after you have carried it out
- This is an **automatic and rapid response** to a stimulus such as touching something sharp or hot
- As it does not involve the brain, a reflex response is **quicker** than any other type of nervous response
- This helps to **minimise the damage to the body**



A reflex

1. The pin (the stimulus) is detected by a pain/pressure/touch receptor in the skin
2. Sensory neurone sends electrical impulses to the spinal cord (the coordinator)
3. Electrical impulse is passed on to relay neurone in the spinal cord
4. Relay neurone connects to motor neurone and passes the impulse on
5. Motor neurone carries impulse to a muscle in the leg (the effector)
6. The muscle will contract and pull the foot up and away from the sharp object (the response)

Your notes



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THE REFLEX PATHWAY

The reflex pathway

Synapses

- Where two neurons meet or join, they do so at a junction called a synapse
- Synapses allow junctions between neurones so are important in the nervous system being a connected network of neurones
- Nerve impulses can transmit across synapses and be directed along the appropriate route by them eg. to the correct part of the brain
    - Think about the analogy of railway points that guide the trains onto the appropriate tracks based on that train's destination.

Examiner Tips and Tricks

Reflex actions are:

1. Automatic
2. Fast
3. Protective

A common exam question is to be asked to draw arrows on the neurones in the reflex arc diagram to show **the direction of movement of the impulse**. Make sure you read questions carefully – not all questions have a line underneath them to write an answer, so they can be easy to miss!

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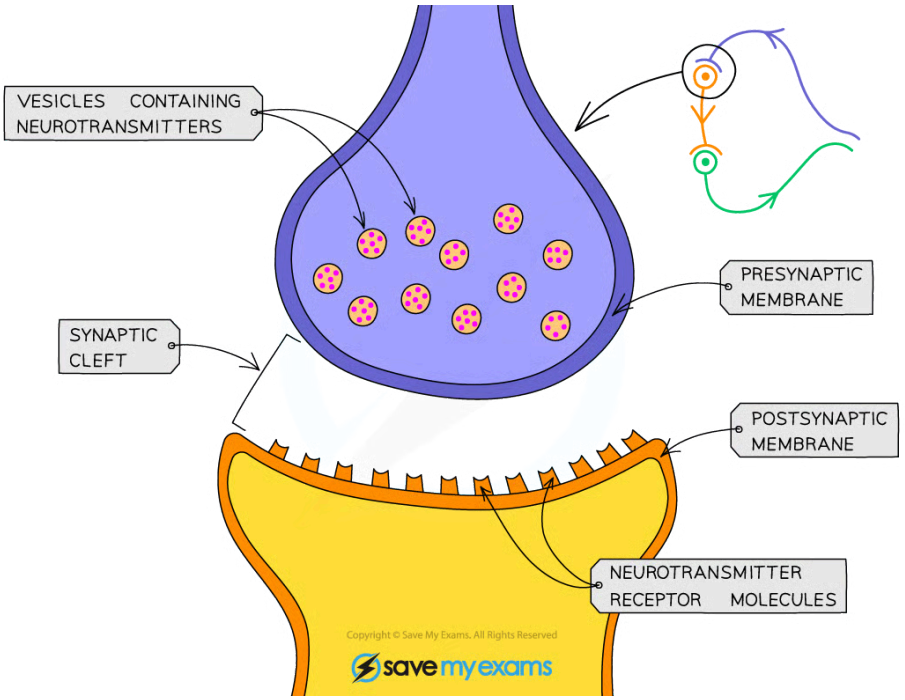
Structure of a Synapse: Extended

- The junction between two neurones is known as a **synapse**

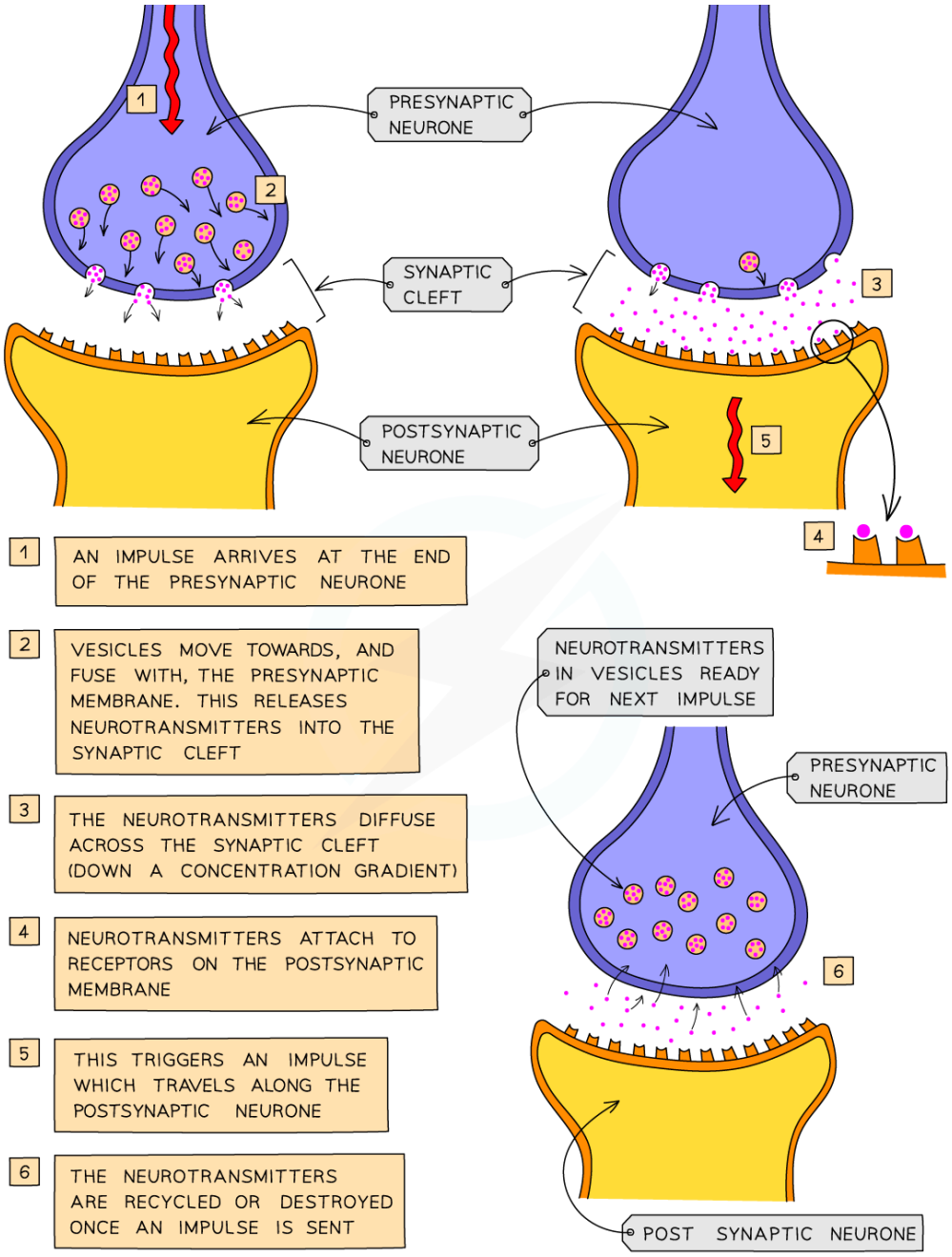


A synapse

Synapses & Neurotransmitters: Extended

- Neurones never touch each other
- The junctions (gaps) in between them are called **synapses**
- The electrical impulse travels along the first axon
- This triggers the nerve-ending of the presynaptic neurone to release **chemical** messengers called **neurotransmitters** from vesicles which fuse with the presynaptic membrane
- The neurotransmitters **diffuse** across the synaptic gap (or cleft) and **bind with receptor molecules** on the membrane of the second neurone (known as the **postsynaptic membrane**)
- This **stimulates** the second neurone to generate an electrical impulse that travels down the second axon

- The neurotransmitters are then **destroyed to prevent continued stimulation** of the second neurone which would cause repeated impulses to be sent
- Synapses ensure that impulses **only travel in one direction**, avoiding confusion within the nervous system if impulses were travelling in both directions
- As this is the only part of the nervous system where messages are **chemical** as opposed to electrical, it is the **only place where drugs can act to affect the nervous system** - eg. this is where heroin works



How an impulse is passed on at a synapse

Your notes

Examiner Tips and Tricks

For maximum marks you will need to be able to understand the structure and functioning of a synapse and **explain what happens at each step**.

Your notes

Your notes

Sense Organs as Receptors

- Receptors are groups of specialised cells
- They **detect a change in the environment and stimulate electrical impulses in response**
- Sense organs contain **groups of receptors** that respond to specific stimuli

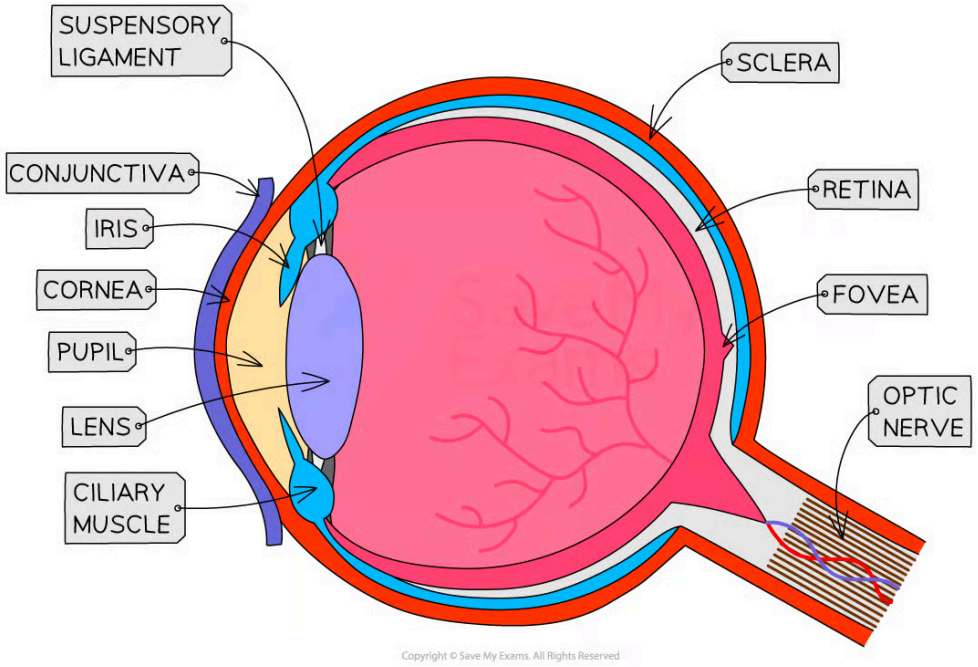
SENSE ORGAN	WHAT IT IS SENSITIVE TO	SENSE
SKIN	SENSITIVE TO PRESSURE, HEAT AND COLD (TEMPERATURE) AND PAIN.	TOUCH AND TEMPERATURE
TONGUE	SENSITIVE TO CHEMICALS IN FOOD AND DRINK	TASTE
NOSE	SENSITIVE TO CHEMICALS IN THE AIR	SMELL
EAR	SENSITIVE TO SOUND AND MOVEMENT	a) HEARING b) BALANCE
EYE	SENSITIVE TO LIGHT	SIGHT

- Once the receptor cell in the sense organ has been stimulated, it generates an **electrical impulse**
- This is passed on to a **sensory neurone** which carries the impulse to the **central nervous system**
- Here a response will be decided on and the impulse will be passed to a **motor neurone** (via a relay neurone)
- The motor neurone carries the impulse to the **effector** (muscle or gland)
- The effector **carries out the response**

Your notes

Structure & function of the eye

- The eye is a **sense organ** containing receptor cells that are sensitive to **light**
- The structure of the eye allows it to carry out its function; important structural features include the:
  - cornea
  - iris
  - lens
  - retina
  - optic nerve



The structures of the eye allow it to detect light and transmit nerve impulses to the brain

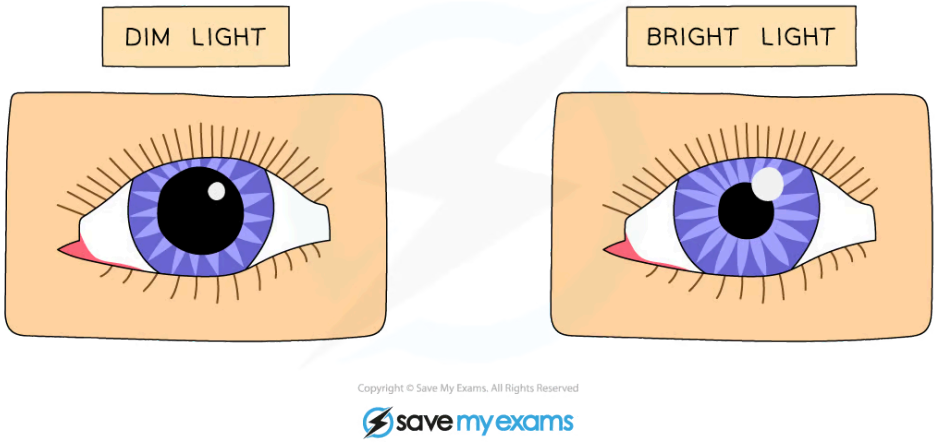
Structure	Function
Cornea	Transparent covering at the front of the eye that refracts (bends) light
Iris	Muscle that controls how much light enters the pupil
Lens	Transparent disc that changes shape to focus light onto the retina

Retina	Layer of light receptor cells that detect light intensity and colour
Optic nerve	Sensory neurone that carries electrical impulses from the eye to the brain
Fovea	The fovea is a region of the retina with the highest density of cones cells. Its function is to form sharp, coloured images

Your notes

The pupil reflex

- The pupil reflex is an example of a reflex action; its role is to control the light that enters the eye by altering the pupil diameter
  - In **dim light** the pupil **dilates** in order to allow as much light into the eye as possible
  - In **bright light** the pupil **constricts** in order to prevent too much light entering the eye and damaging the retina



The pupil reflex causes the pupil to dilate in dim light and constrict in bright light

Examiner Tips and Tricks

Note that features labelled on the eye structure diagram that are not listed in the table above are not part of the core content for this specification.

Students studying the extended course will also need to know about ciliary muscles, suspensory ligaments, the retina and the fovea.

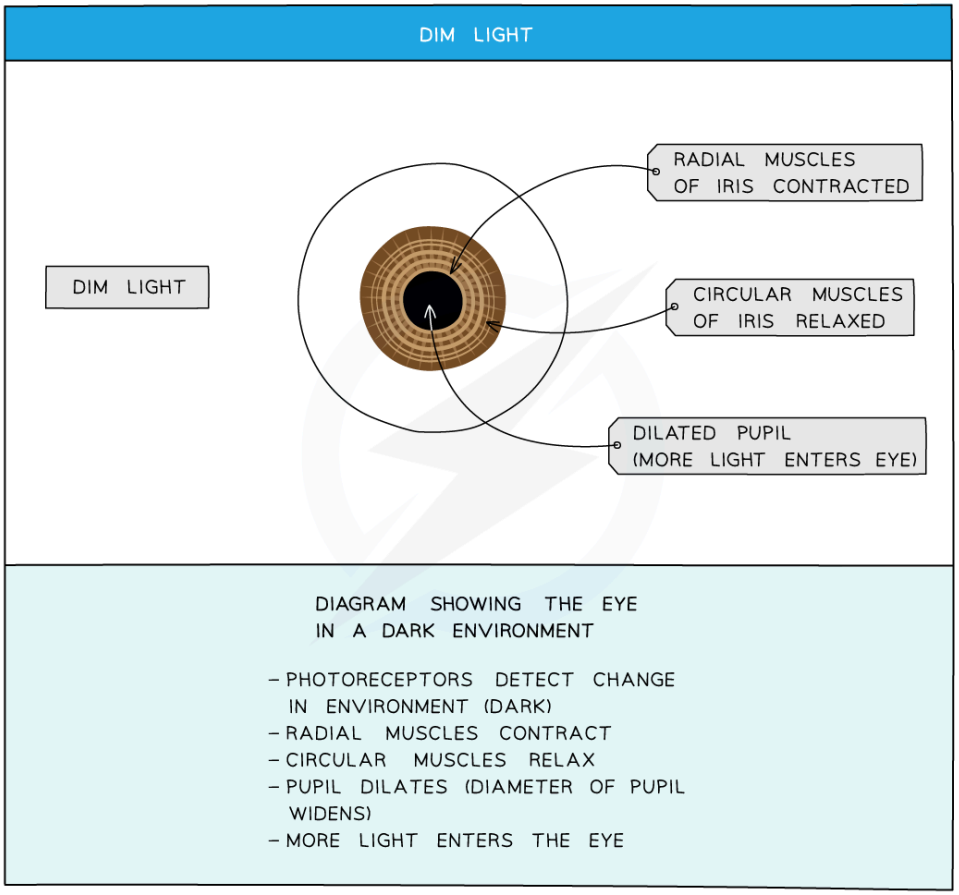
The pupil reflex: antagonistic muscle action: extended

- The pupil reflex occurs due to changes in the **iris muscles**
  - The iris muscles work together to regulate the amount of light entering the eye
- The iris contains **circular muscles** and **radial muscles**
  - The circular muscles form circles around the pupil
  - The radial muscles radiate outwards from the pupil
- The circular and radial muscles of the iris are **antagonistic**, meaning that they work against each other
  - When one set of muscles contracts the other relaxes, and vice versa

Your notes

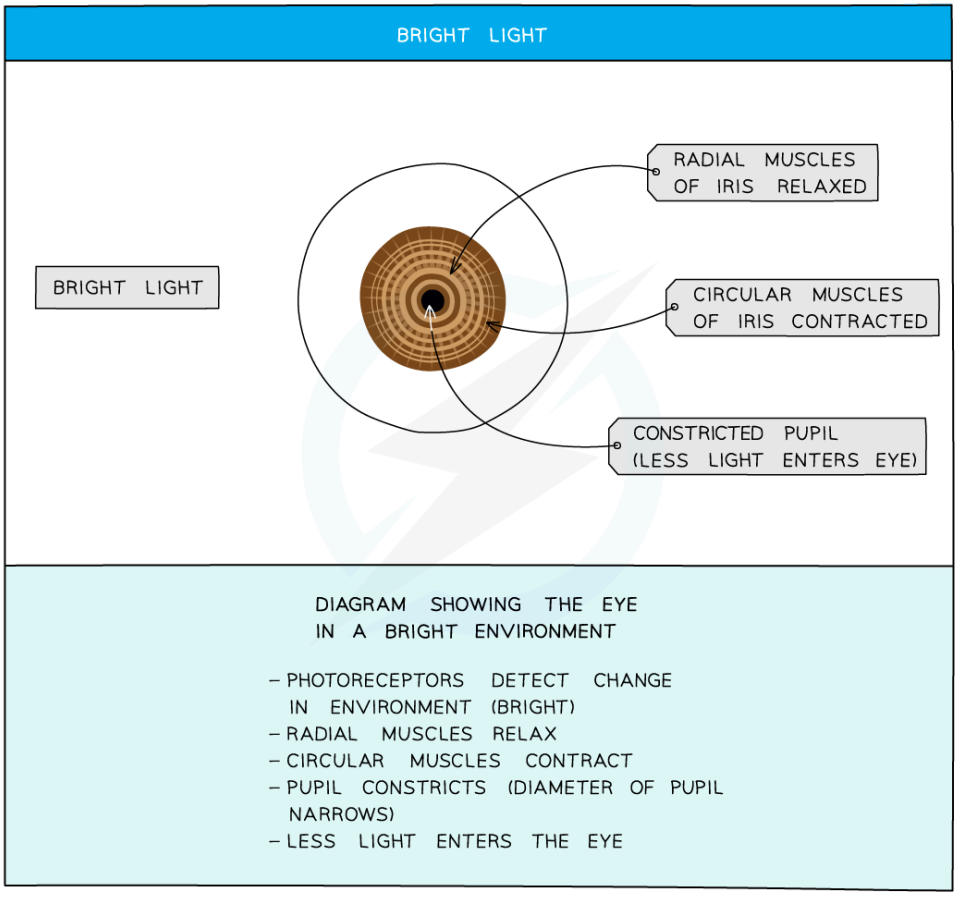
Iris muscles in dim light

- When light levels are low the pupil reflex acts to dilate the pupil and maximise the light entering the eye; this is achieved as follows:
  - light receptors in the eye detect low light levels
  - the **radial muscles contract** and the **circular muscles relax**
  - the pupil **dilates**



Iris muscles in bright light

- When light levels are high the pupil reflex acts to constrict the pupil to reduce light entering the eye and protect the retina; this occurs as follows:
  - light receptors in the eye detect bright light
  - the **radial muscles relax** and the **circular muscles contract**
  - the pupil **constricts**



Stimulus	Radial muscles	Circular muscles	Pupil	Light entering eye
Dim light	Contract	Relax	Dilated	More
Bright light	Relax	Contract	Constricted	Less

Accommodation in the eye: extended

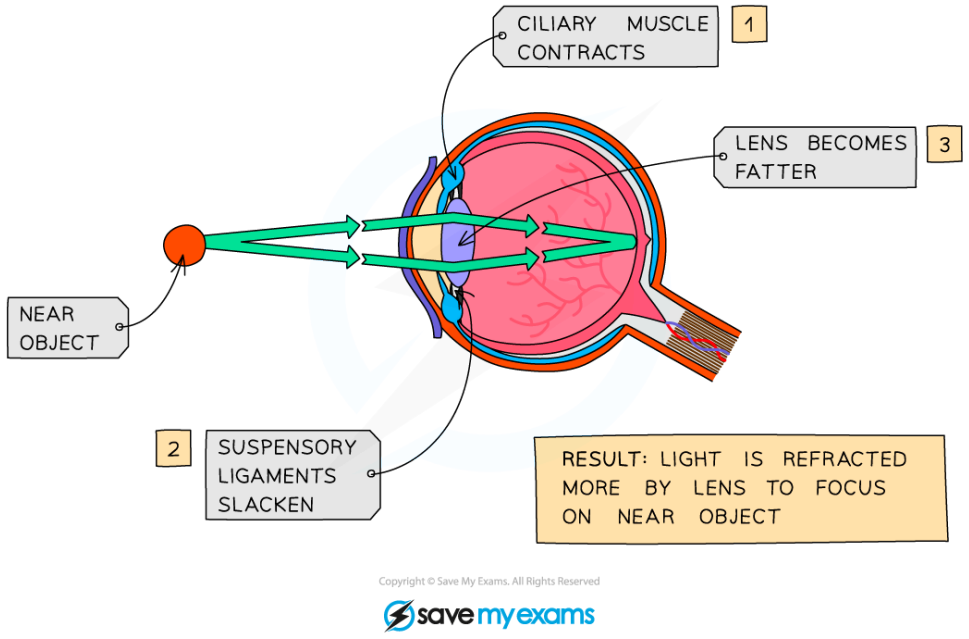
Your notes

- Accommodation is the term used to describe the way in which the eye **focuses on near or distant objects**
- During eye accommodation the **shape of the lens** is changed, altering the extent to which light is **refracted**; this change is brought about by:
  - contraction or relaxation of the **ciliary muscles**
  - adjustment of tension in the **suspensory ligaments**

Your notes

Eye accommodation and near objects

- When an object is close up:
  - the **ciliary muscles contract**
  - the **suspensory ligaments loosen**
  - the suspensory ligaments exert less pull on the lens, allowing the lens to become **more rounded**
  - light is refracted more

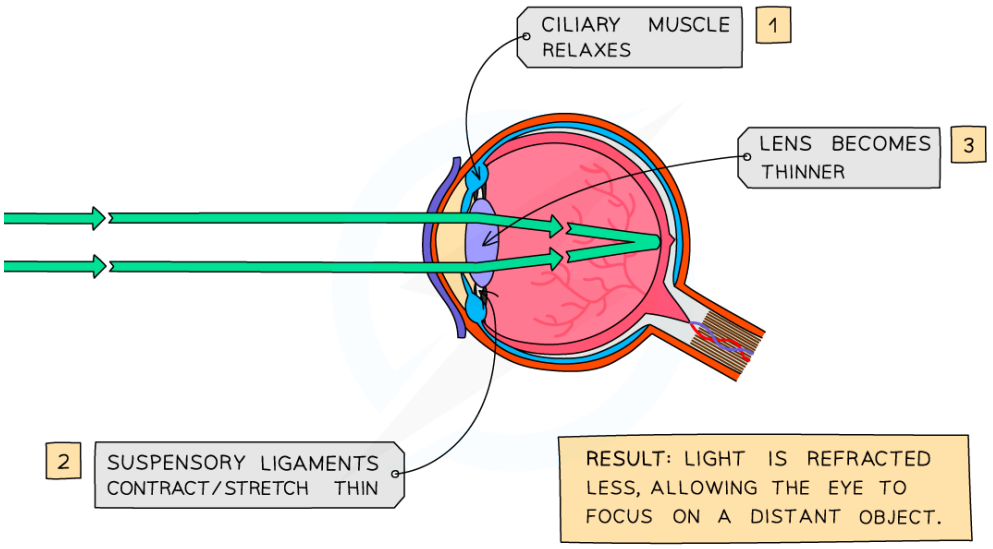


When viewing a near object accommodation of the eye involves contraction of the ciliary muscles and loosening of the suspensory ligaments

Eye accommodation and distant objects

- When an object is far away:
  - the **ciliary muscles relax**
  - the **suspensory ligaments tighten**
  - the suspensory ligaments pull on the lens, causing it to become **thinner**

- light is refracted less



When viewing a distant object accommodation of the eye involves relaxation of the ciliary muscles and tightening of the suspensory ligaments

Part of the eye	Near objects	Distant objects
Ciliary muscles	Contract	Relax
Suspensory ligaments	Loosen	Tighten
Lens	Fatter	Thinner
Light	Refracted more	Refracted less

Examiner Tips and Tricks

Eye accommodation is complex and it can be hard to recall the details. If you find that you are struggling to remember in an exam, the following might be helpful:

- Staring at your hand right in front of your eye will make your eyes feel tired after a few seconds; this is because the **ciliary muscles are contracted**
- Staring at an object far away feels relaxing and comfortable because the **ciliary muscles are relaxed**

Rod & cone cells: Extended

Your notes

- Rods and cones are the two types of **receptor cell** present in the retina of the eye
- Rod cells and cone cells have different roles in detecting light stimuli:
  - **Rods** can detect light at low levels, so play an important role in **night vision**
  - Three different types of **cones** can detect light at **three different wavelengths**, enabling **colour vision**
- Rods and cones are **not distributed evenly** across the retina:
  - Rod cells are found **all over the retina**, with the exception of the blind spot
  - Cone cells are **concentrated in the fovea**, the region of the eye onto which light is focused by the process of accommodation
    - The fovea enables the brain to form **sharp, coloured images** when light is effectively focused by the eye

Examiner Tips and Tricks

You are expected to be able to identify the fovea on diagrams of the eye, so check the eye structure image at the top of the page to see where the fovea is located.

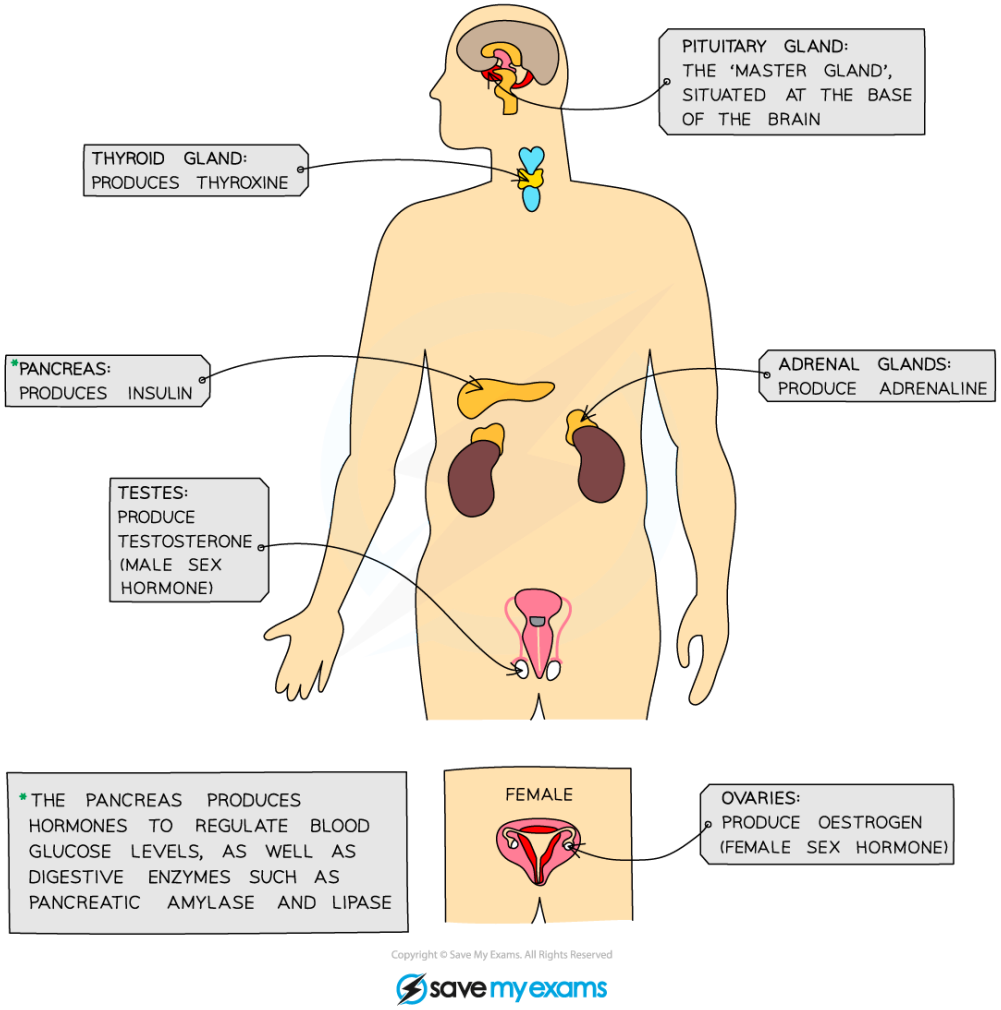
Your notes

Your notes

Hormones & Their Associated Glands

What is a Hormone?

- A **hormone** is a chemical substance produced by a **gland** and carried by the **blood**
- The hormone alters the activity of one or more specific target organs i.e. they are chemicals which transmit information from one part of the organism to another and bring about a change
- The glands that produce hormones in animals are known collectively as the **endocrine system**

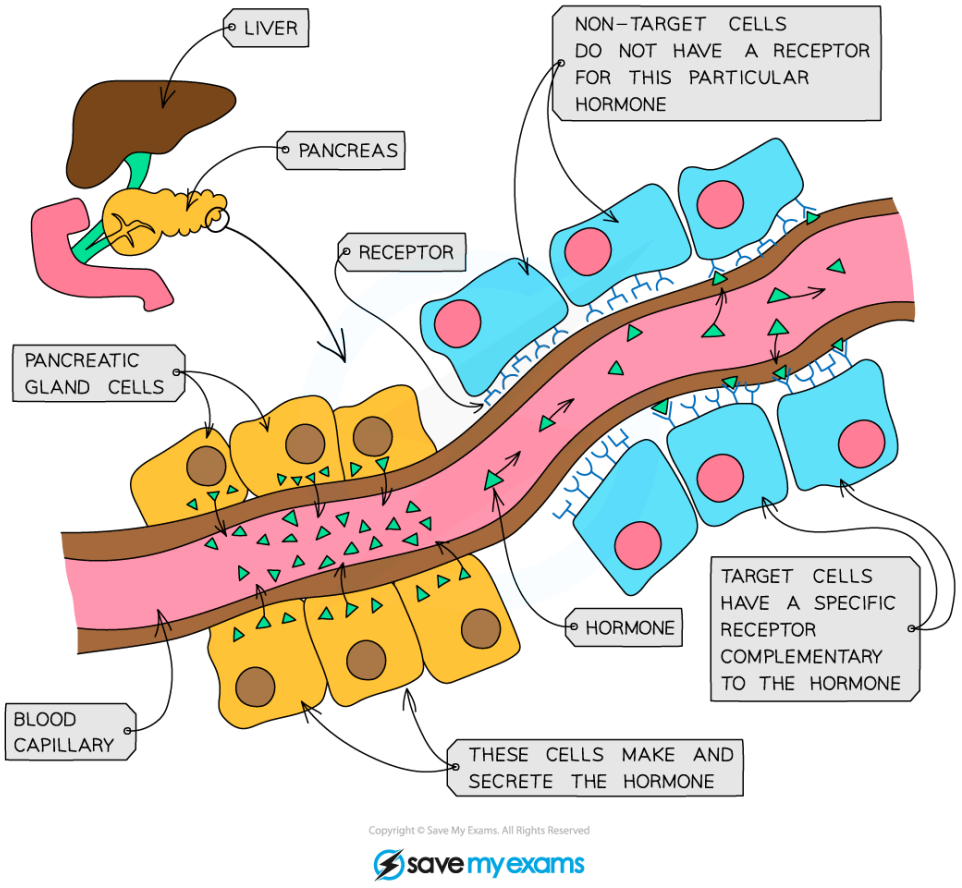


The major endocrine glands in the body

Transport around the body

- Endocrine glands have a **good blood supply** as when they make hormones they need to get them into the bloodstream (specifically the blood plasma) as soon as possible so they can travel around the body to the target organs to bring about the response
- Hormones only affect cells with target receptors that the hormone can bind to. These are either found on the cell membrane, or inside cells. Receptors have to be complementary to hormones for there to be an effect.
- The liver regulates levels of hormones in the blood; transforming or breaking down any that are in excess.

Your notes



How hormones work

Important hormones in the human body:

HORMONE	SOURCE	ROLE	EFFECT
ADRENALINE	ADRENAL GLAND	READIES THE BODY FOR A 'FIGHT OR FLIGHT' RESPONSE	INCREASES HEART AND BREATHING RATE, DILATES PUPILS
INSULIN	PANCREAS	LOWERS BLOOD GLUCOSE LEVELS	CAUSES EXCESS GLUCOSE IN THE BLOOD TO BE TAKEN UP BY THE MUSCLES AND LIVER AND CONVERTED INTO GLYCOGEN FOR STORAGE
TESTOSTERONE	TESTES	MAIN SEX HORMONE IN MALES	DEVELOPMENT OF SECONDARY SEXUAL CHARACTERISTICS IN MALES
OESTROGEN	OVARIES	MAIN SEX HORMONE IN FEMALES	DEVELOPMENT OF SECONDARY SEXUAL CHARACTERISTICS IN FEMALES AND CONTROLS MENSTRUAL CYCLE

Your notes

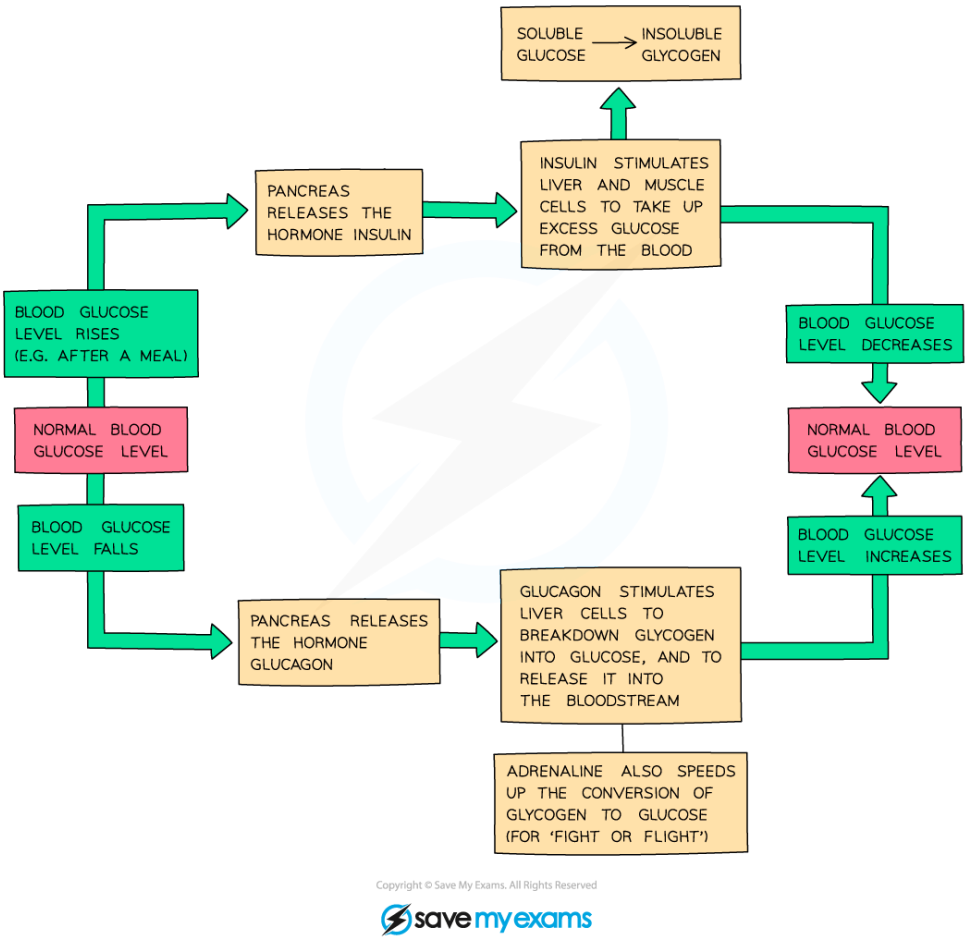
Comparison of Nervous & Hormonal Control

	NERVOUS SYSTEM	ENDOCRINE SYSTEM
MADE UP OF:	NERVES (NEURONES), BRAIN, SPINAL CORD	GLANDS
TYPE OF MESSAGE:	ELECTRICAL IMPULSE	CHEMICAL HORMONE
SPEED OF TRANSMISSION:	VERY FAST	SLOWER
LENGTH OF EFFECT:	SHORT – UNTIL NERVE IMPULSES STOP	LONGER – UNTIL HORMONE IS BROKEN DOWN

Glucagon: Extended

- Blood glucose levels are controlled by a negative feedback mechanism involving the production of two **hormones** - **insulin** and **glucagon**
- Both hormones which control blood glucose concentration are made in the **pancreas**

- **Insulin** is produced when **blood glucose rises** and **stimulates liver and muscle cells to convert excess glucose into glycogen to be stored**
- **Glucagon** is produced when **blood glucose falls** and **stimulates liver and muscle cells to convert stored glycogen into glucose to be released into the blood**



Negative feedback regulation of blood glucose levels

Examiner Tips and Tricks

The terms glucagon and glycogen are very often mixed up by students as they sound similar. Remember:

- Glucagon is the **hormone**
- Glycogen is the polysaccharide **glucose is stored as**

Learn the differences between the spellings and what each one does so you do not get confused in the exam!

The Hormone Adrenaline

Your notes

- Adrenaline is known as the '**fight or flight**' hormone as it is **produced in situations where the body may be in danger**
  - Flight = remove oneself rapidly from a dangerous situation eg. run away
  - Fight = if flight is not possible, resort to physical combat to overcome danger
- It causes a range of different things to happen in the body, all designed to prepare it for movement (ie fight or flight).
- These include:
- **Increasing blood glucose concentration** for **increased respiration in muscle cells**
- **Increasing pulse rate** and **breathing rate** so glucose and oxygen can be **delivered to muscle cells**, and carbon dioxide taken away, from muscles cells **more quickly**
- **Diverting blood flow towards muscles** and away from non-essential parts of the body such as the alimentary canal; again to ensure the reactants of respiration are as available as possible
- **Dilating pupils** to allow as much light as possible to reach the retina so **more information can be sent to the brain**

Examiner Tips and Tricks

It is worth learning this list of effects of adrenaline as it is a fairly common exam question and can be worth several easy marks.

More on Adrenaline: Extended

More on Adrenaline: Extended

- Additional effects of adrenaline include;
  - Increasing the concentration of glucose in the blood
    - This help deliver more important glucose to muscles for respiration
  - Increasing heart rate
    - This has the same effect, to ensure that all muscles are well prepared for high levels of activity in a flight or fight situation

Your notes

Your notes

Role of insulin in homeostasis

- Homeostasis is defined as:

the maintenance of a constant internal environment

- Homeostasis ensures that **internal conditions** within the body (such as temperature, blood pressure, water concentration, glucose concentration etc) are **kept within set limits** in order to ensure that reactions in body cells can function

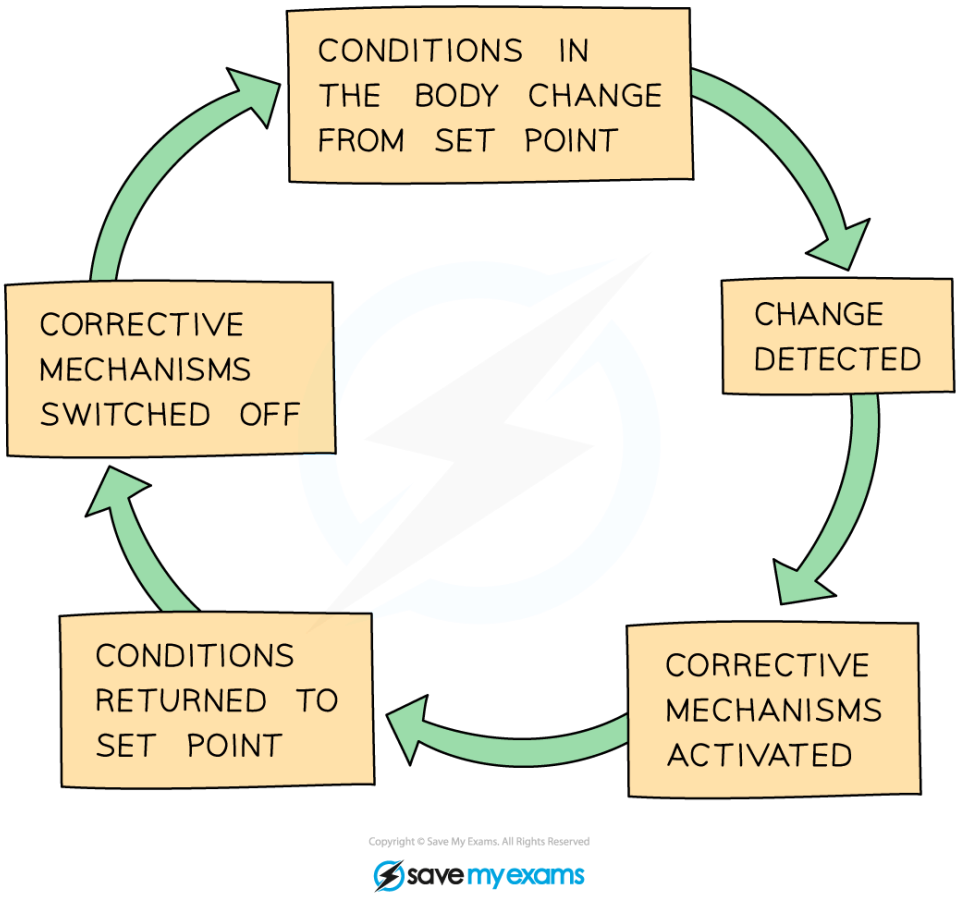
The role of insulin

- Insulin is secreted into the blood at times when blood glucose levels are **high**
- This is (most often) directly after a meal
- The kidneys can only cope with a certain level of glucose in the blood
  - If the level gets too high, glucose gets **excreted** and is **lost** in the urine
  - This is like running a car with a hole in the petrol tank; valuable fuel is being wasted
- To avoid this, insulin temporarily converts excess glucose into glycogen in the liver and muscles
  - Insulin **decreases blood glucose concentration**
- The glycogen is converted back to glucose several hours later when blood glucose levels have dipped due to respiration in all tissues

Your notes

The Concept of Negative Feedback: Extended

- Negative feedback occurs when conditions change from the ideal or **set point** and returns conditions to this set point
- It works in the following way:
  - if the level of something **rises**, control systems are switched on to **reduce it** again
  - if the level of something **falls**, control systems are switched on to **raise it** again
- Negative feedback mechanisms are usually a continuous cycle of bringing levels down and then bringing them back up so that overall, they stay within a **narrow range** of what is considered '**normal**'



The negative feedback cycle

Blood Glucose Control: Extended

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- Both hormones which control blood glucose concentration are made in the **pancreas**
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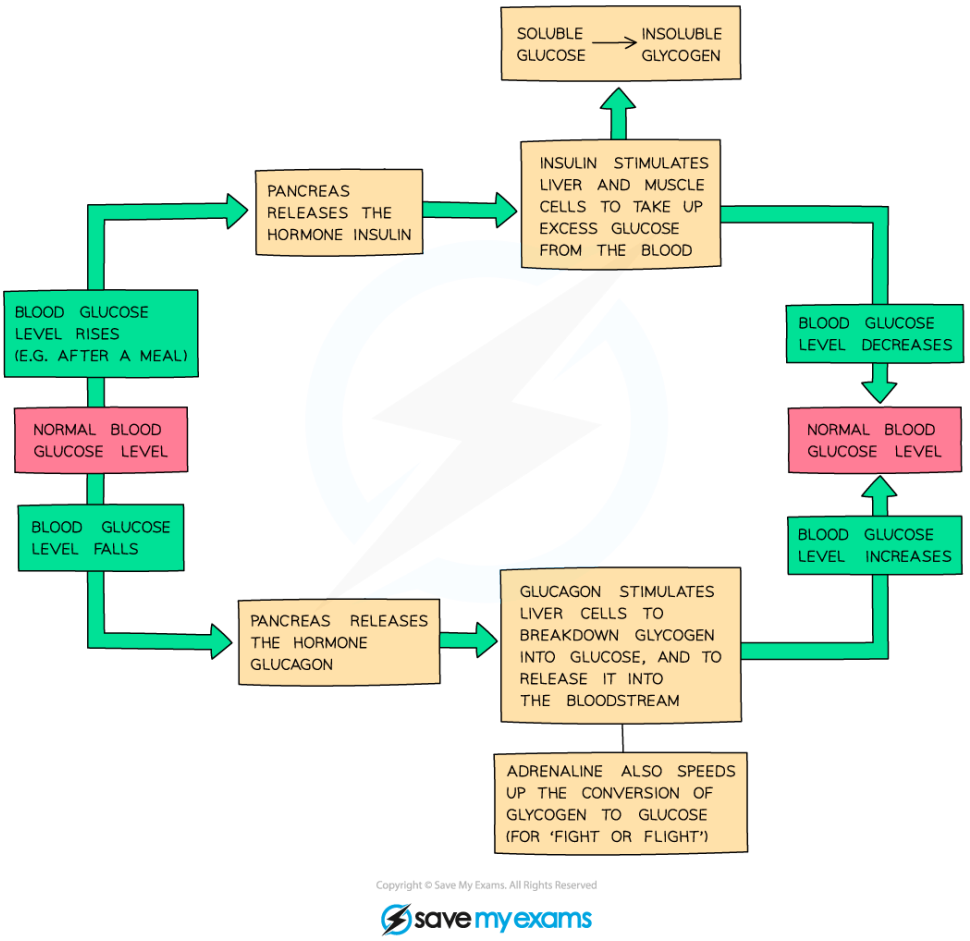
Your notes



Negative feedback regulation of blood glucose levels

Examiner Tips and Tricks

The terms glucagon and glycogen are very often mixed up by students as they sound similar. Remember:

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Your notes

Type 1 Diabetes: Extended

- **Type 1 diabetes** is a condition where the blood glucose levels are not able to be regulated as the **insulin-secreting cells in the pancreas are not able to produce insulin**
- This means that blood glucose levels are often **far too high**
- It can be treated by **injecting insulin**
- The extra insulin causes the liver to convert **glucose into glycogen**, which **reduces** the blood glucose level
- **Symptoms** of diabetes include extreme thirst, weakness or tiredness, blurred vision, weight loss and loss of consciousness in extreme cases
- People with Type 1 diabetes have to **monitor** their blood glucose levels throughout the day as their levels of **physical activity** and their **diet** affect the amount of insulin needed
- They can help to **control** their blood glucose level by being careful with their **diet** - eating foods that will not cause large increases in blood glucose level, and by **exercising**, which can lower blood glucose levels due to increased respiration in the muscles

Examiner Tips and Tricks

Type 2 diabetes is not in the specification, so you don't need to learn the details of it. This is the diabetes form that doctors are most concerned about because it is linked to obesity and lifestyle factors.

You only need to know the symptoms and treatment of Type 1

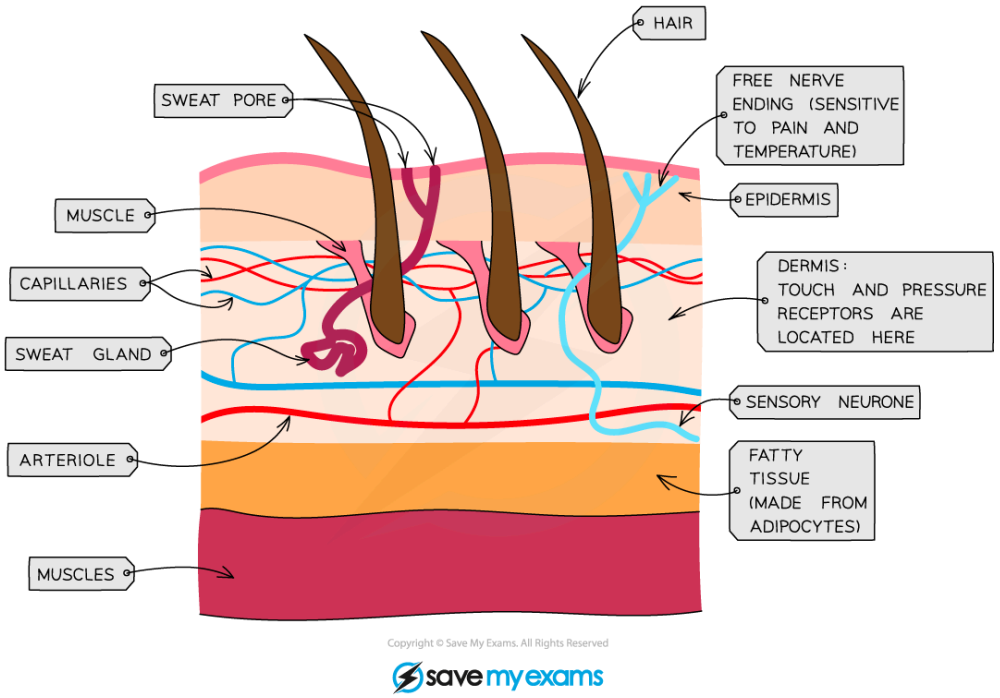
Your notes

The skin & homeostasis: extended

- Control of body temperature is a **homeostatic** mechanism
  - Homeostasis is **the maintenance of a constant internal environment**
  - This means that **internal conditions within the body** (such as temperature, blood pressure, water concentration and glucose concentration) need to be **kept within set limits** in order to ensure that reactions in body cells can function
- The human body maintains the temperature at which enzymes work best: around **37°C**
- If body temperature increases too far above this, **enzymes will denature** and become less effective at catalysing reactions

The skin and temperature regulation

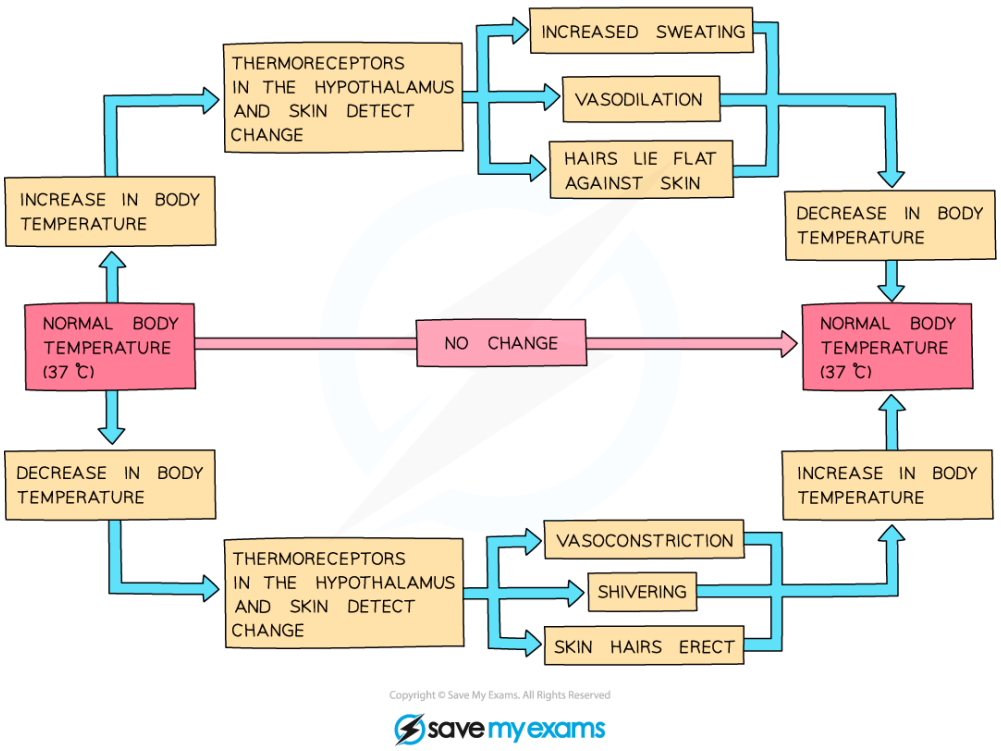
- The **skin** plays an important role in the control of body temperature
- Structures in the skin that are involved with temperature regulation include:
  - sweat glands
  - temperature receptors
  - capillaries
  - hairs
  - hair erector muscles
  - insulating fatty tissue



The skin plays an important role in the control of body temperature

- When skin temperature changes, **temperature receptors** in the skin send nerve impulses to the brain via **sensory neurones**
- The brain responds to this information by sending nerve impulses to **effectors** in the skin that act to maintain normal body temperature, e.g.:
  - in response to an increase in body temperature:
    - **sweat glands** produce sweat which cools the skin by evaporation
    - blood vessels that supply the skin capillaries **dilate**
    - hairs on the skin surface **lie flat**
  - in response to a decrease in body temperature:
    - sweat gland stop producing sweat
    - blood vessels that supply the skin capillaries **constrict**
    - hairs on the skin stand up to **trap an insulating layer of air**
    - **shivering** generates heat in the muscles

Your notes



Your notes

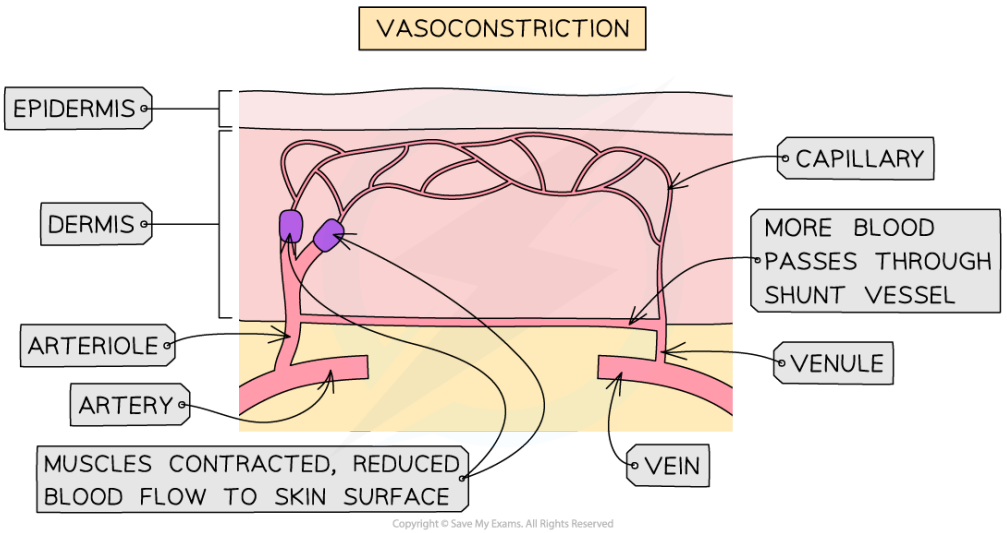
WHEN WE ARE HOT	WHEN WE ARE COLD
SWEAT IS SECRETED BY SWEAT GLANDS THIS COOLS SKIN BY **EVAPORATION.** HEAT ENERGY FROM THE BODY IS LOST AS LIQUID WATER IN SWEAT BECOMES WATER VAPOUR (A STATE CHANGE).	SKELETAL MUSCLES CONTRACT RAPIDLY AND WE **SHIVER.** THESE INVOLUTARY MUSCLE CONTRACTIONS NEED **ENERGY FROM RESPIRATION** AND SOME OF THIS IS **RELEASED AS HEAT.**
HAIRS **LIE FLAT** AGAINST THE SKIN, ALLOWING AIR TO FREELY CIRCULATE. THIS INCREASES HEAT TRANSFER TO ENVIRONMENT BY **RADIATION.**	ERECT HAIRS **TRAP A LAYER OF AIR AROUND THE SKIN** WHICH ACTS AS AN **INSULATOR**, PREVENTING HEAT LOSS BY RADIATION.

Vasoconstriction & vasodilation: extended

- The blood vessels in and below the skin aid temperature regulation by vasoconstriction and vasodilation

Vasoconstriction

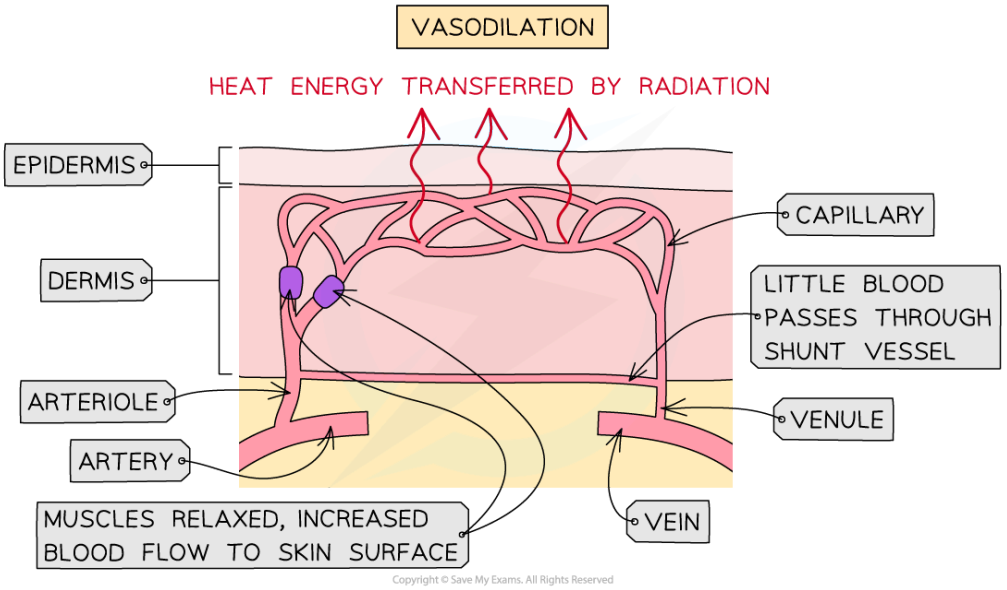
- When we are **cold** the blood vessels that supply capillaries in the skin constrict, or get narrower; this is known as **vasoconstriction**
- Vasoconstriction reduces blood flow to the skin, and so **reduces the heat lost from blood by radiation** at the skin surface



Vasoconstriction reduces blood flow to the skin, and so reduces the heat lost from blood by radiation

Vasodilation

- When we are **hot** the blood vessels that supply capillaries in the skin dilate, or get wider; this is known as **vasodilation**
- Vasodilation increases blood flow to the skin surface, and so **increases heat lost at the skin by radiation**



Vasodilation increases blood flow to the skin surface, and so increases heat lost at the skin by radiation

Your notes

Your notes

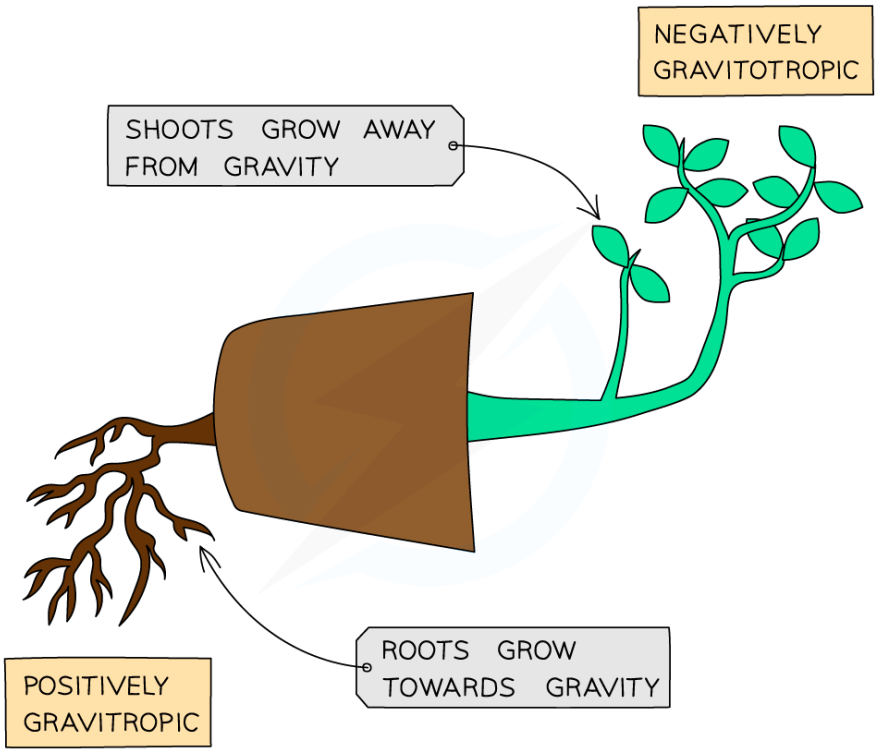
Gravitropism & Phototropism

- Plants can respond to changes in environment (stimuli) for survival, e.g. **light, water, gravity**
- Their responses are usually **much slower** than animals
- They grow either **towards a stimulus** (known as a positive response) or **away from a stimulus** (known as a negative response)
- The responses are known as **tropisms**

Examples of types of tropisms table

Stimulus	Name of response	Definition	Positive response	Negative response
Gravity	Gravitropism	Growth towards or away from gravity	Growth towards gravity (e.g. roots)	Growth away from gravity (e.g. shoots)
Light	Phototropism	Growth towards or away from the direction of light	Growth towards light source (e.g. shoots)	Growth away from light source (e.g. roots)

- It is very important to a plant that its roots and shoots grow in the right directions
- Shoots must grow **upwards**, away from gravity and towards light, so that leaves are able to absorb sunlight
- This means that shoots have a **positive phototropic response** and a **negative gravitropic response**
- Roots need to grow **downwards** into the soil, away from light and towards gravity, in order to anchor the plant and absorb water and minerals from the soil particles.
- This means that roots have a **negative phototropic response** and a **positive gravitropic response**

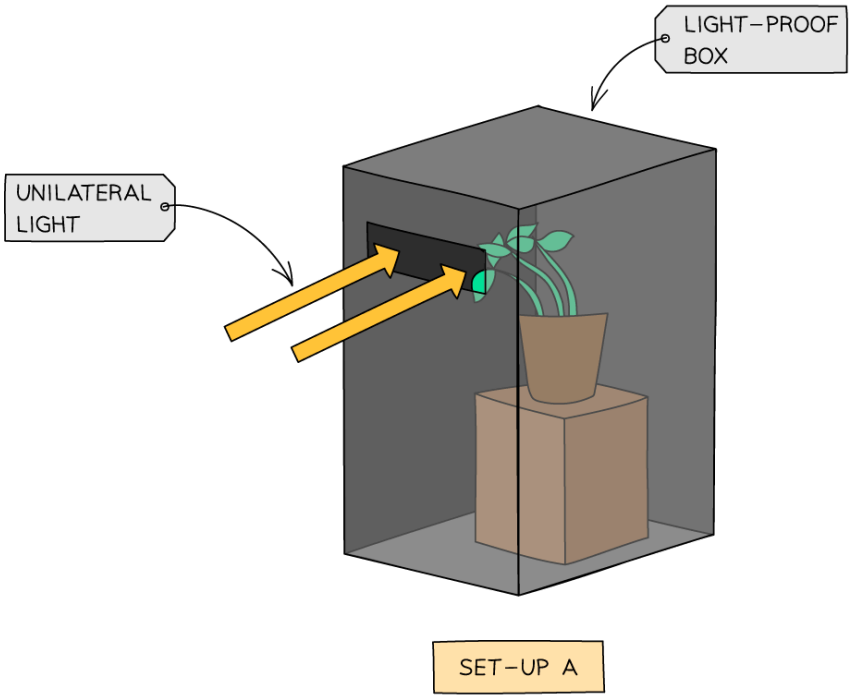


Placing a plant on its side shows the gravitropic responses (also known as geotropic responses)

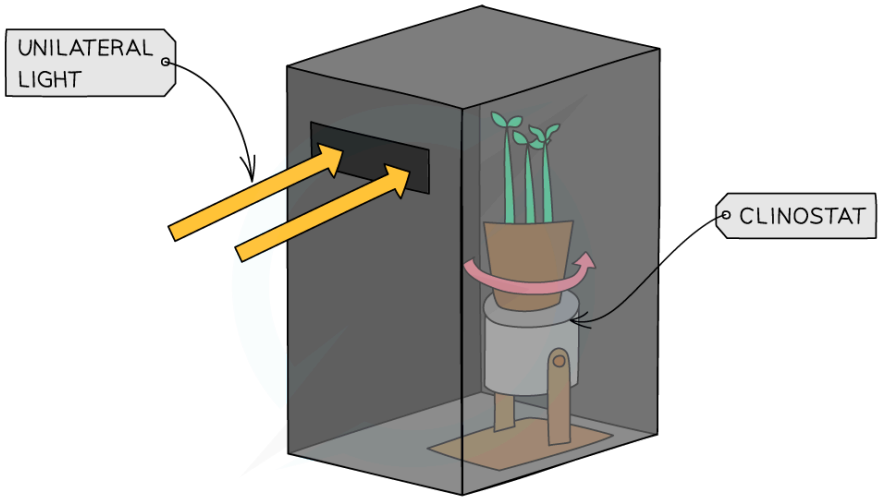
Investigating Tropisms

Investigating Phototropisms

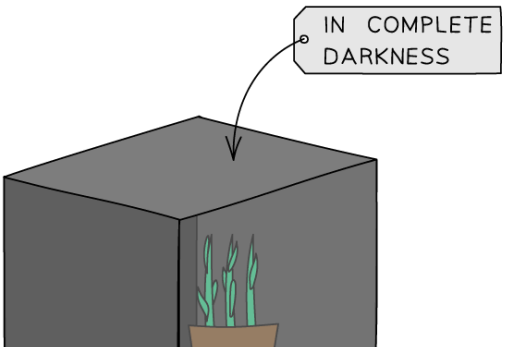
- Three identical plants are set up as shown below (A, B and C)



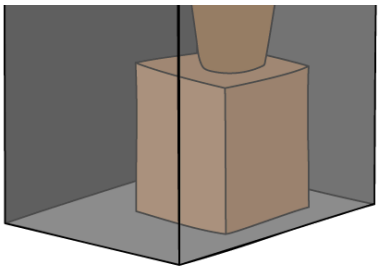
SET-UP A



SET-UP B



Your notes

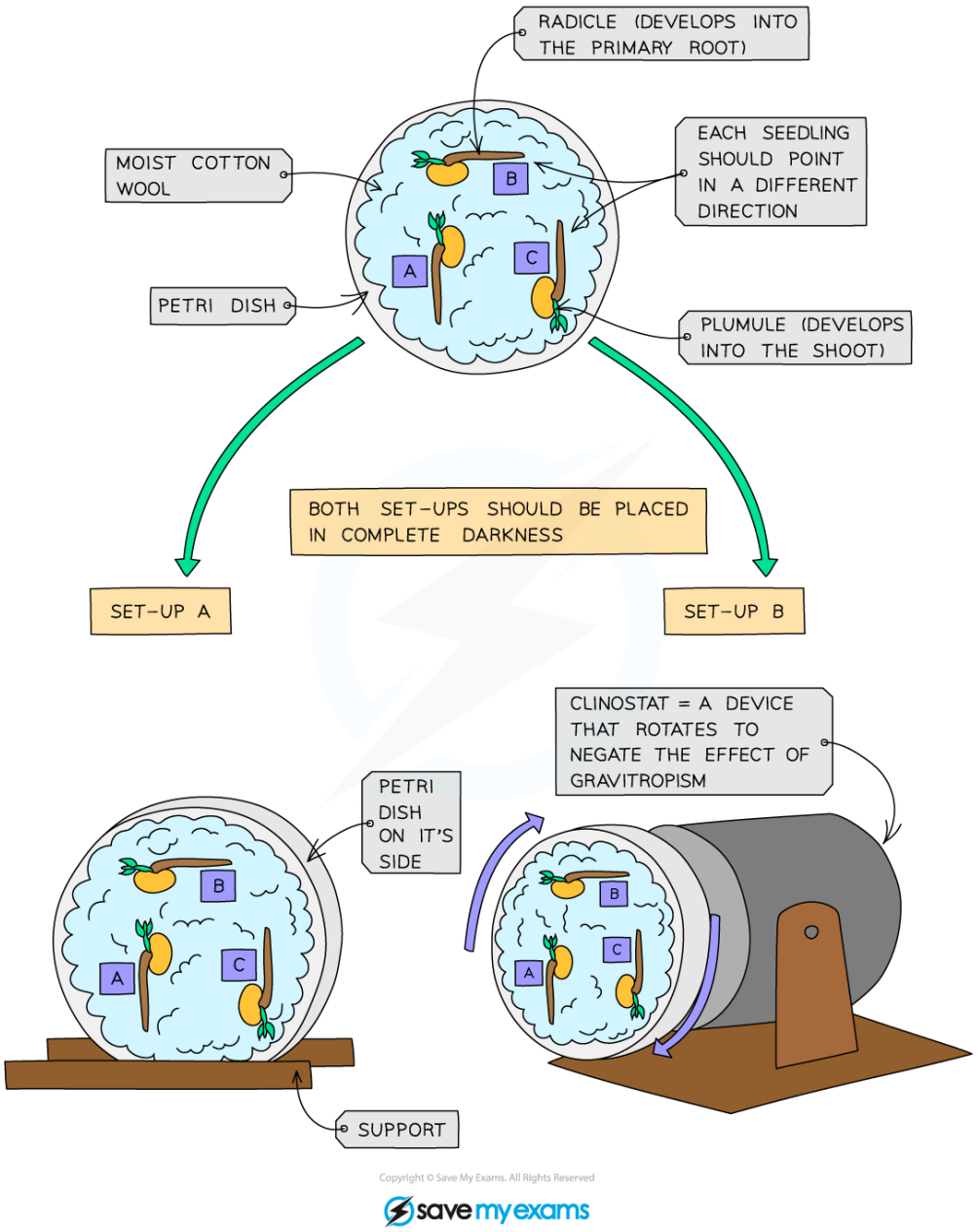


Investigating the phototropic response

- The seedlings in A grow **towards** the light source
- In B the effect of the light only coming from one direction has been **cancelled out** by using a **clinostat** (it revolves slowly and repeatedly, so the shoots are evenly exposed to light)
- This means all sides of the seedlings get an **equal amount of light** so they do not curve towards the light source but grow straight up
- In C the seedlings grow straight up **looking for light** and the plant becomes tall and slender with yellowing leaves due to the lack of light

Investigating Gravitropisms

Your notes

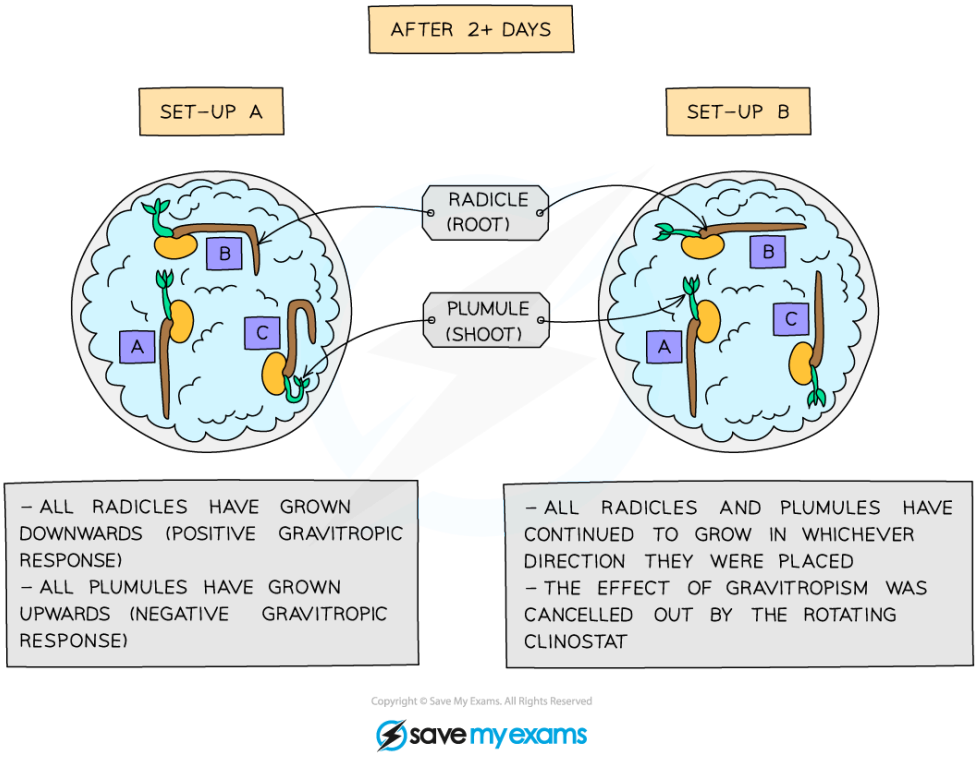


Your notes

Investigating the gravitropic response (set-up)

- Add some damp cotton wool to two petri dishes
- Place 3 bean seedlings in the cotton wool in each petri dish
  - A - radicle facing **downwards**
  - B - horizontally
  - C - radicle (root grows from here) facing **upwards**
- Cover each dish with a lid
- Attach one petri dish to a support so that it's on its side

- Attach the second petri dish to a clinostat (as shown in the diagrams above).
- Place both in a **light-proof box** (so that the seedlings are in complete darkness), leave for two days and then observe growth of the seedlings



Investigating the gravitropic response (results)

- In the first petri dish **all radicles (roots) have grown downwards** (positive gravitropic response) regardless of which way they were initially facing (horizontal, up or down) and **all plumules (shoots) have grown upwards** (negative gravitropic response)
- In the second petri dish, all radicles and all plumules have all grown **neither up nor down** but straight outwards **in whichever direction they were placed** as the **effect of gravity** has been **cancelled out by the revolving of the clinostat** - they have shown no gravitropic response at all
- The experiment needs to be done in a lightproof box in order to **cancel out the effect of light on the growth of the seedlings**

Auxins: Chemical Control of Tropisms: Extended

- Plants respond to stimuli by producing a **growth hormone called auxin** which controls the direction of growth of roots or stems
- Therefore we say plants control their growth **chemically**
- Auxin is mostly made in the **tips** of the growing stems and roots and can diffuse to other parts of the stems or roots; spreading from a high concentration in the shoot tips down

Your notes

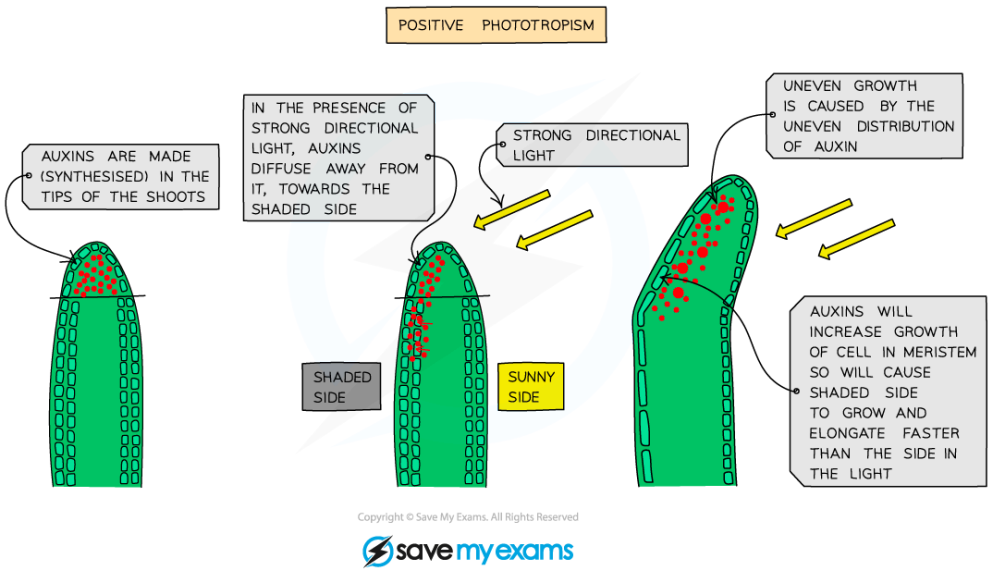
the shoot to an area of lower concentration

- Auxin stimulates the cells behind the tip **to elongate** (get larger); the more auxin there is, the faster they will elongate and grow
  - Only the region behind the tip of a shoot is able to contribute to growth by cell division and cell elongation
  - This part of a shoot is called the meristem

Your notes

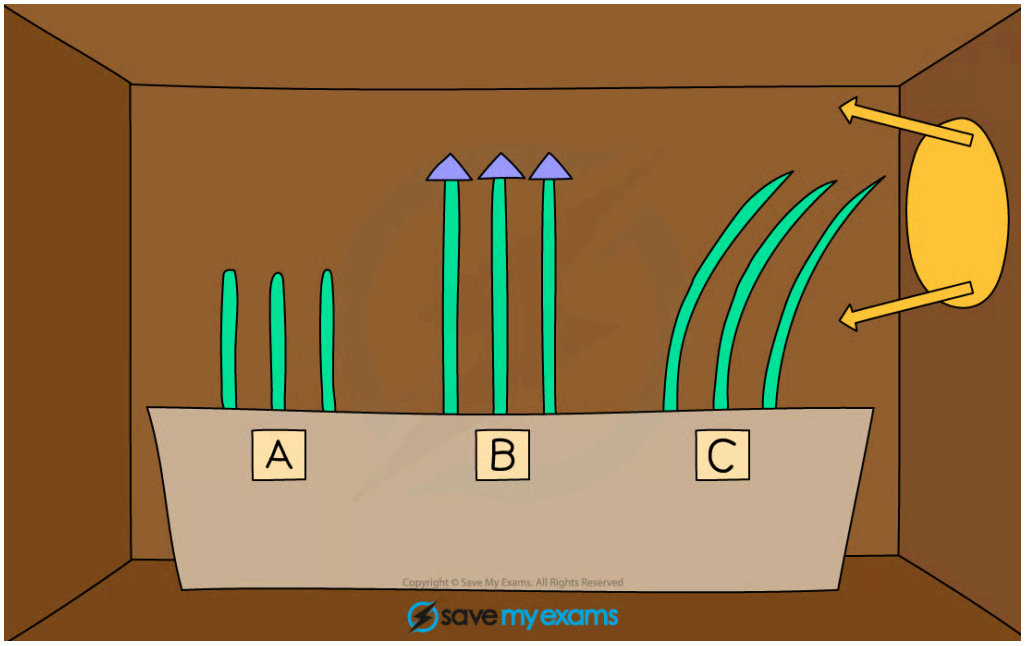
How does phototropism occur in plants?

- If light shines all around the tip, auxin is distributed evenly throughout and the cells in the meristem grow at the same rate - this is what normally happens with plants growing outside
- When light shines on the shoot predominantly from one side though, the auxin produced in the tip **concentrates on the shaded side**, making the cells on that side **elongate** and grow faster than the cells on the sunny side
- This unequal growth on either side of the shoot **causes the shoot to bend** and grow in the direction of the light



Positive phototropism in plant shoots

- The role of auxin can be tested using seedlings placed in a box that has a slit on one side, only allowing light in from one direction:



Investigating the phototropic response set-up

Investigating the phototropic response results table

	Seedling A	Seedling B	Seedling C
Treatment	The tips of the stems have been removed	No light reaches the tips	More light reaches one side of the tips
Effect on auxin concentration	No auxin is produced	Equal concentration of auxin on both sides of the tip	Greater concentration of auxin on the shaded side
Result	The stems do not grow longer	The stems grow evenly and longer on both sides	The cells on the darker side of the stems grow longer and faster than the cells in the light
Reason	This proves that auxin is made in the tip and is needed to stimulate cell elongation and therefore growth. Without the tip, and therefore without auxin, there is no	This proves that it is the effect of light on auxin that causes phototropism. There is no uneven distribution of auxin throughout the shoot tip, so growth is even	This proves the shoots grow towards the light because there is an uneven distribution of auxin in the shoot tip, caused by the response of auxin to light

Your notes

	further growth in the stem		

Your notes

How does gravitropism occur in plants?

- Auxin plays a role in a plants response to gravity, affecting plant **shoots** and **roots** in **different ways**
- When **shoots grow away from gravity** it is known as **negative gravitropism**
  - Gravity modifies the distribution of **auxin** so that it accumulates on the **lower side** of the shoot
  - As seen in the phototropic response, **auxin increases the rate of growth in shoots**, causing the shoot to grow **upwards**
- When **roots grow towards gravity** it is known as **positive gravitropism**
  - In roots, **higher concentrations** of auxin results in **a lower rate of cell elongation**
  - The auxin that accumulates at the **lower side** of the root **inhibits cell elongation**
  - As a result, the lower side grows at a **slower rate** than the upper side of the root
  - This causes the root to bend **downwards**

Examiner Tips and Tricks

You should be able to explain the results of an experiment like this into the effect of light on the growth of shoots.

Make sure you understand the importance of the key word "cell elongation". When the plant grows due to auxin it does so because the existing cells get larger, not because of cell division to create new cells. This is why it is important to be specific with your use of language in your answer.