Edexcel International A Level (IAL) Biology

Your notes

Plant Hormones

Contents

Your notes

Effects of Plant Hormones

- Just like animals, the survival of plants is dependent on their ability to **respond to changes** in their environment; this **maximises their survival chances** e.g.
  - Growing towards light **maximises the rate of photosynthesis** and therefore glucose production
  - Producing harmful or foul-tasting chemicals in response to being eaten by a herbivore **reduces the likelihood of being eaten**
  - Producing flowers at the right time of year increases the chances of **reproducing successfully**
- Plants can respond to **several types of stimuli** e.g.
  - Light
  - Gravity
  - Physical objects
  - Herbivory
  - Water
  - Physical touch
- Unlike many animals, plants do not possess a nervous system; the responses of plants rely on **chemical substances** that are released or altered in response to a stimulus

Phytochrome

- **Phytochromes** are **plant pigments** that react to different types of light, leading to different plant responses
- Phytochrome pigments exist in two forms
  - **P_R** is the **inactive form** of phytochrome, it absorbs light from the **red** part of the spectrum (wavelength 660 nm)
  - **P_{FR}** is the **active form** of phytochrome, it absorbs light from the **far red** part of the spectrum (wavelength 730 nm)
- Absorption of different wavelengths of light causes a **reversible conversion between the P_R and P_{FR}** forms of phytochrome
- When **P_R absorbs red light** (660 nm) **it is converted into P_{FR}**
  - When **P_{FR} absorbs far red light** (730 nm) **it is converted back into P_R**
  - In the **absence of red light,** the unstable P_{FR} **gradually converts back into P_R**

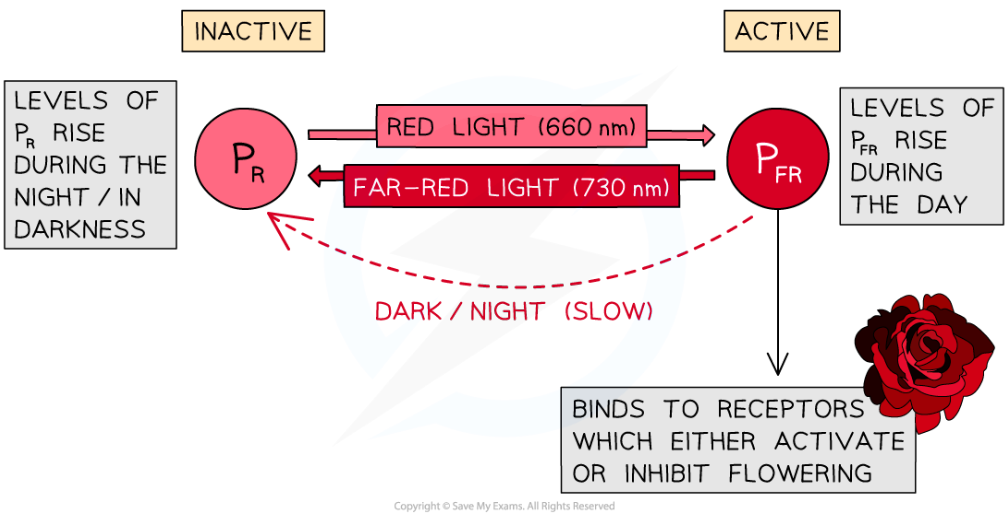
Phytochrome and germination

Your notes

- Early observations of light exposure and seed germination showed that **seeds exposed to red light would germinate**, while **seeds exposed to far-red light would not**.
- It is now thought that phytochrome is responsible for these observations
  - Exposure to even a short burst of red light **converts P_R into P_{FR}**, **triggering germination** in seeds
  - Far-red light causes **P_{FR} to be converted back into P_R**, reversing the effects of any red light exposure and **preventing germination**

Phytochrome and Flowering

- Flowering in plants is controlled by the **stimulus** of night length
  - Nights are shorter during the spring and summer and longer in the autumn and winter
  - Some plants flower when nights are short and some flower when nights are long
- When the nights reach a certain length, genes that control flowering may be **switched on or off,** leading to the **activation or inhibition of flowering**
  - Genes that are switched on **are expressed**, leading to **production of the polypeptides** for which they code, while genes that are switched off **are not expressed**, so the polypeptides for which they code **are not produced**
- The length of night can be detected by a plant because it determines the quantities of different forms of a pigment called **phytochrome** in the leaf
- **During the day** levels of **P_{FR}** rise
  - Sunlight contains more wavelengths at 660 nm than 730 so the conversion from P_R to P_{FR} occurs more rapidly in the daytime than the conversion from P_{FR} to P_R
- **During the night** levels of **P_R** rise
  - Red light wavelengths are not available in the darkness and P_{FR} converts slowly back to P_R



P_R is converted to P_{FR} in a reversible reaction which controls flowering

- E.g. long day plants
  - Long day plants flower when the nights are **short** e.g. in summer
    - When nights are short, the **day length is longer**, hence the term 'long day plants'
  - In **long day plants** high levels of the **active form of phytochrome activate flowering**
  - Flowering occurs due to the following process
    - Days are long so **P_R is converted to P_{FR} at a greater rate** than P_{FR} is converted to P_R
    - The **active form of phytochrome**, P_{FR}, is present at **high levels**
    - High levels of P_{FR} **activate flowering**
      - P_{FR} activates expression of genes that stimulate flowering
        - It is thought that P_{FR} acts as a transcription factor
      - The active gene is transcribed and translated
      - The resulting protein causes flowers to be produced rather than stems and leaves

Phytochrome and transcription

- Evidence suggests that in addition to their role in germination and flowering, phytochromes are also involved in plant responses to light and gravity
- Phytochromes are thought to **influence gene expression** in plants by acting as **transcription factors**
  - P_R is converted into P_{FR} in the presence of red light
  - P_{FR} can move into the nucleus via the nuclear pores
  - P_{FR} **binds to a protein in the nucleus** known as phytochrome-interacting factor 3 (**PIF3**)
  - Once bound to P_{FR}, PIF3 can **initiate transcription**
- It is thought that P_{FR} and PIF3 together are able to activate various different genes and so control **many different aspects of plant growth and development**

Growth factors

- Plants can respond to stimuli in various ways, including by **altering their growth**
  - E.g. a seedling will bend and grow towards the light because there is more growth on the shaded side than on the illuminated side
- This type of **directional growth response** is referred to as a **tropism**
  - Phototropism is a growth response to **light**

- Geotropism is a growth response to **gravity**
  - The response to gravity is also known as gravitropism
- Tropisms can be **positive** or **negative**
  - Positive tropisms involve growth **towards** a stimulus
    - E.g. positive phototropism is a growth response towards light
  - Negative tropisms involve growth **away from** a stimulus
    - E.g. negative geotropism is a growth response away from gravity i.e. upwards
- The growth responses of plants rely on chemical substances that are released in response to a stimulus
- These chemical **growth factors** act in a similar way to the hormones that are found in animals
  - Plant growth factors are sometimes referred to as **plant hormones** as they are **chemical messengers**
- Growth factors are produced in the growing parts of a plant before moving **from the growing regions to other tissues** where they **regulate cell growth** in response to a directional stimulus
  - E.g. **auxin** is a growth factor that **stimulates cell elongation in plant shoots** and **inhibits growth in cells in plant roots**
- Other examples of plant hormones along with some of their regulatory roles include
  - **Gibberellins**
    - Stem elongation
    - Flowering
    - Seed germination
  - **Cytokinins**
    - Cell growth and division
  - **Abscisic acid** (ABA)
    - Leaf loss
    - Seed dormancy
  - **Ethene**
    - Fruit ripening
    - Flowering

Indoleacetic acid

- **Indoleacetic acid**, or **IAA,** is a type of **auxin**

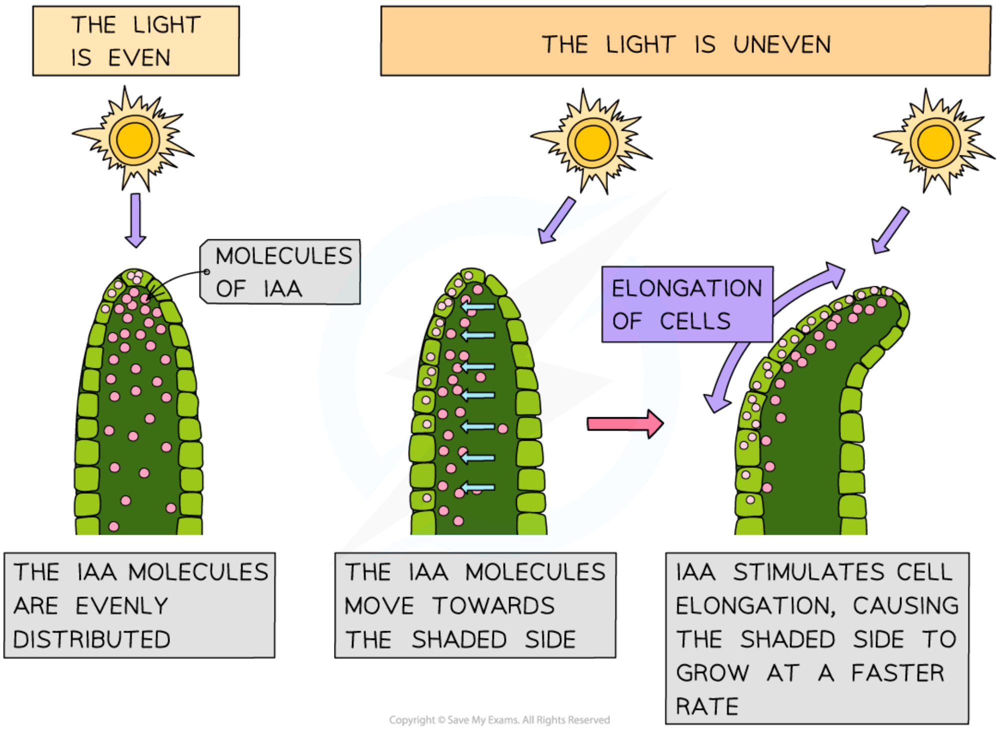
Your notes

- **Auxins** are a group of plant growth factors that influence many aspects of plant growth, e.g.
  - **Apical dominance**; the suppression of the growth of side shoots by auxins in the growing shoot tip
  - Promoting the growth of roots at **low concentrations** and inhibiting the growth of roots at **high concentrations**
  - **Phototropism** in shoots
- It is thought that **IAA brings about plant responses** such as phototropism by **altering the** transcription **of genes inside plant cells**
  - Altering the expression of genes that code for proteins involved with cell growth can affect the growth of a plant
- IAA is produced by cells in the growing parts of a plant before it is **redistributed** to other plant tissues
  - IAA can be transported from cell to cell by **diffusion and active transport**
  - Transport of IAA over longer distances occurs in the **phloem**
- The redistribution of IAA is affected by **environmental stimuli** such as light and gravity, leading to an uneven distribution of IAA in different parts of the plant
  - This brings about **uneven plant growth**

IAA in plant shoots

- Light affects the growth of plant shoots in a response known as **phototropism**
- The **concentration of IAA** determines the **rate of cell elongation** within the stem
  - A **higher concentration of IAA** causes an **increase** in the rate of cell elongation by increasing the stretching ability of cell walls
  - If the concentration of IAA is **not uniform** across the stem then **uneven cell growth** can occur
- When light shines on a stem from one side, IAA is transported **from the illuminated side of a shoot to the shaded side**
- An **IAA gradient** is established, with **more on the shaded side** and **less on the illuminated side**
- The higher concentration of auxin on the shaded side of the shoot causes a **faster rate of cell elongation**, and the shoot bends towards the source of light

Your notes

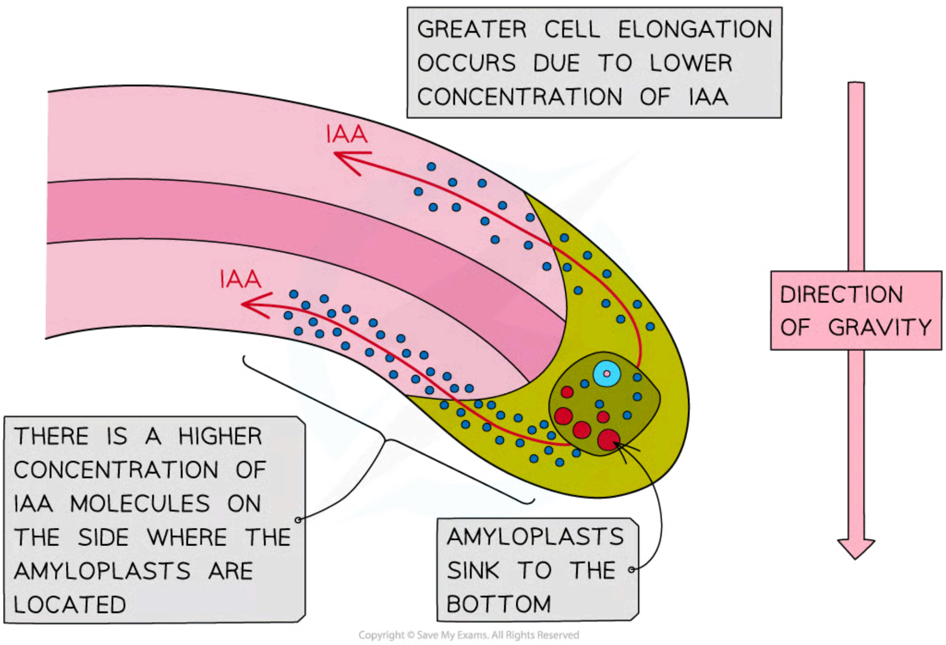


IAA stimulates cell elongation in shoots

IAA in roots

- Roots respond to gravity in a response known as **geotropism**
- In roots, **IAA concentration also affects cell elongation**, but **high concentrations of IAA** result in a **lower** rate of cell elongation
  - Note that this is the **opposite effect** to that of IAA on **shoot cells**
- IAA is transported **towards the lower side** of plant roots
- The resulting high concentration of auxin 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**, causing the **root to bend downwards**

Your notes



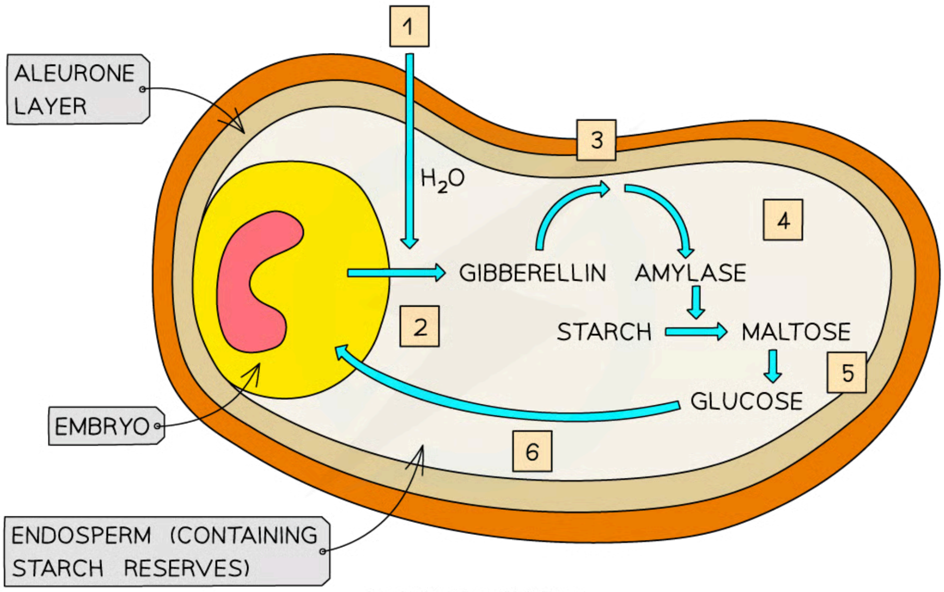
IAA inhibits cell elongation in shoots. Note that you do not need to know about the role played by amyloplasts in detecting the direction of gravity

Gibberellins

- **Gibberellins** are a type of plant growth regulator involved in controlling **seed germination, stem elongation, flowering,** and **fruit development**
- When a barley seed is shed from the parent plant, it is in a state of dormancy, containing very little water and being metabolically inactive
  - This allows the seed to survive harsh conditions until the conditions are right for successful germination, e.g. the seed can survive a cold winter until temperatures rise again in spring
- The barley seed contains
  - An **embryo**
    - This will grow into the new plant when the seed germinates
  - An **endosperm**
    - This is a starch-containing energy store surrounding the embryo
  - An **aleurone layer**
    - This is a protein-rich layer on the outer edge of the endosperm
- When the conditions are right the barley seed starts to **absorb water** to begin the process of **germination**
- This stimulates the **embryo** to produce **gibberellins**

- Gibberellin molecules diffuse to the **aleurone layer** and stimulate the cells there to **synthesise amylase**
  - In barley seeds it has been shown that gibberellin does this by causing an **increase in the transcription of genes coding for amylase**
- The amylase **hydrolyses starch** molecules in the **endosperm**, producing soluble **maltose** molecules
- The maltose is **converted to glucose** and transported to the **embryo**
- This glucose can be **respired** by the embryo, providing the embryo with the **energy** needed for **growth**

Your notes



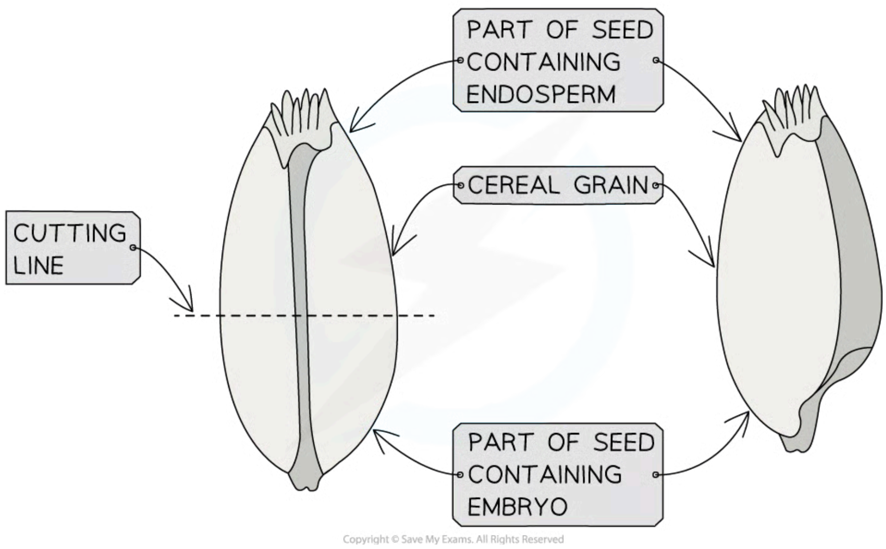
1	WATER ABSORBED
2	GIBBERELLINS SYNTHESISED BY EMBRYO
3	GIBBERELLIN STIMULATES ALEURONE LAYER CELLS TO SYNTHESISE AMYLASE
4	AMYLASE HYDROLYSES STARCH TO FORM MALTOSE
5	MALTOSE CONVERTED TO GLUCOSE
6	GLUCOSE TRANSPORTED TO EMBRYO, PROVIDING ENERGY FOR GROWTH

Gibberellins in barley seeds cause the synthesis of amylase enzymes which break down starch stores in the endosperm

Your notes

Amylase in Germinating Cereal Grains

- Cereal grains such as barley contain
  - An **embryo**
    - This will grow into the new plant when the seed germinates
  - An **endosperm**
    - This is a starch-containing energy store surrounding the embryo
  - An **aleurone layer**
    - This is a protein-rich layer on the outer edge of the endosperm
- Barley seeds are shed from the parent plant in a state of **dormancy**, but when conditions are right for **germination** the starch in the endosperm is **broken down** into first maltose and then glucose, which provides a source of energy for the developing embryo
- The breakdown of the endosperm is stimulated by production of the plant growth factor **gibberellin** in the seed **embryo**, which **initiates the production of amylase** in the aleurone layer
  - Amylase breaks down amylose in starch into maltose
- The effect of **gibberellin concentration** on the **production of amylase** in germinating barley seeds can be investigated using a technique called a **starch agar assay**
  - As part of this process, cereal grains need to be cut in half to **remove the embryo** part of the seed; the embryo in a germinating seed would normally produce gibberellin, so removing it allows the investigator to **control the amount of gibberellin** the grain is exposed to
    - The embryo is found in the more pointed end of the seed, so this section must be discarded during the investigation



Cutting the grain in half allows the part of the seed containing the embryo to be removed and discarded; this removes the part of the seed that produces gibberellin, allowing the investigator to control the gibberellin exposure of the remaining part of the grain

Apparatus

- Measuring cylinders and pipettes
- Marker pen
- Cereal grains e.g. barley
- 3 % sodium hypochlorite solution
- Filter cloth e.g. muslin
- Distilled water
- Beakers
- Scalpel
- Forceps
- Cutting tile
- 1 g dm^{-3} gibberellic acid solution
- Petri dishes containing starch agar gel
- Sticky tape
- Iodine
- Large beaker for waste iodine solution
- Ruler

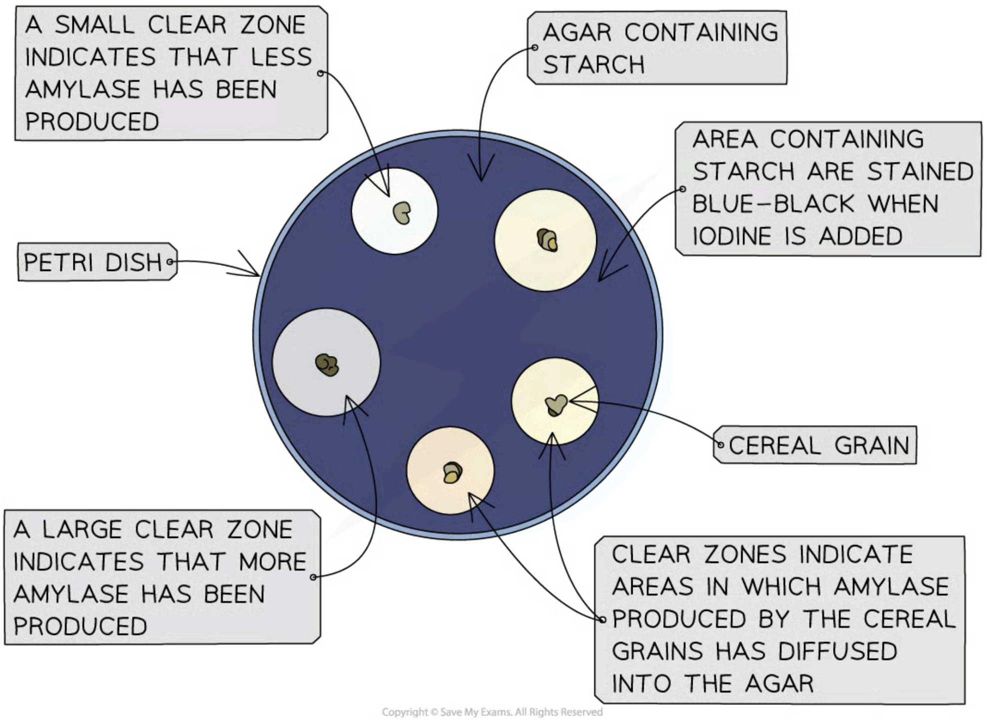
Method

1. Use measuring cylinders and pipettes to make up several gibberellic acid solutions at different concentrations; place these in labelled beakers
2. Remove any outer husks from cereal grains
   - This allows the shape of the grain to be seen clearly, helping to identify the half of the grain that **contains the embryo** in step 3
3. Cut seeds horizontally using a scalpel on a cutting tile and discard the seed half containing the embryo
   - This prevents any **gibberellin produced by the embryo** from influencing the results
4. Place grain halves into sodium hypochlorite solution for 5 minutes
   - This **sterilises** the grains
5. Wash the seeds with distilled water, draining the water through a filter cloth; this should be repeated several times to remove all of the sodium hypochlorite solution
   - The sodium hypochlorite solution will smell of chlorine, so washing should be repeated **until this smell is no longer present**
6. Use forceps to place the grain halves into gibberellin solutions at different concentrations, cover lightly and leave for 12–48 hours
   - Covering **prevents contamination**, but doing so lightly ensures that the covers are not air tight so that **oxygen can enter**
7. Place several grain halves from one gibberellin concentration onto a sterile starch agar petri dish and label dish with relevant gibberellin concentration; place seeds with cut half facing downwards
8. Lightly tape the lid onto the petri dish with 2–4 small pieces of sticky tape and leave for 24–48 hours
   - Any **amylase** being produced inside the seed will **diffuse** out of the cut seed and **into the starch agar**, digesting the starch and leaving **areas of agar around the seed in which no starch is present**
9. Repeat steps 7–8 for seeds at all gibberellin concentrations
10. Pour iodine solution onto the surface of each petri dish, ensuring that it covers the entire surface of the agar and that the lid of each dish is only raised enough to allow iodine to be poured
    - Only lifting the lid slightly will **prevent contamination** of the agar with any **other potential sources of starch**
11. Leave for a few minutes until the starch in the agar becomes stained with the iodine, and then pour excess iodine into a waste container
    - Areas of the agar containing starch will stain **blue-black**
12. Measure the diameter of the clear zone around each cereal grain, recording the results for each gibberellin concentration in a table
    - The **larger the clear area**, the **more amylase was produced** by the cereal grain

Your notes

- If several grains were used at each concentration then an **average** can be calculated

13. Plot a graph of gibberellin concentration against diameter of clear agar area

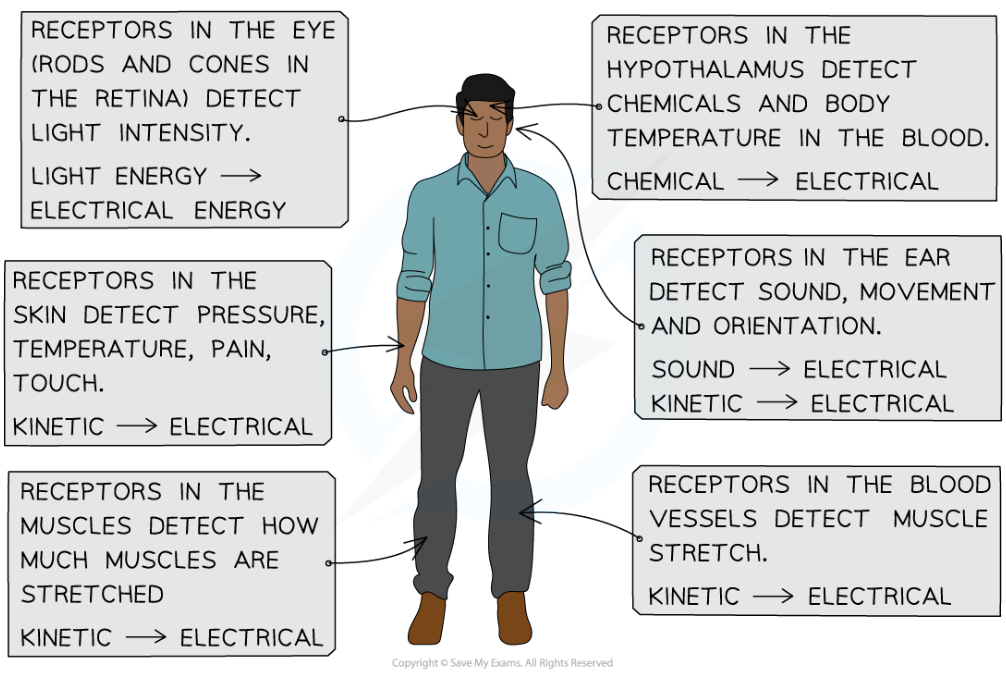


The diameter of the clear zone around each cereal grain indicates the amount of amylase released; the larger the clear zone, the more amylase has been produced by the grain

Your notes

Nervous & Hormonal Coordination

- Both plants and animals must **respond to changes** in their **external** and **internal** environments in order to survive
  - They need to
    - Find favourable external conditions e.g. avoiding locations that are too hot or cold
    - Find food
    - Avoid harm e.g. from predators or high blood glucose
- While plants use chemical signals to co-ordinate responses to stimuli, **animals** bring about coordination by **both nervous and hormonal control**
- Changes in the environment, or **stimuli** (singular **stimulus**) are detected by specialised **receptor cells**
  - Receptor cells are located in the **sense organs** e.g. the nose and eyes
  - Receptor cells can also be found inside the body e.g. pressure receptors in the blood vessels
- 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**
  - Effectors can be either **muscles** or **glands** e.g.
    - An arm muscle would respond to a hot surface by contracting to move the hand away
    - The pancreas responds to high blood sugar by secreting insulin



Receptors are cells that detect stimuli in the internal and external environment

The nervous system

- The human nervous system consists of
  - **Central nervous system** (CNS) – the **brain** and **spinal cord**
  - **Peripheral nervous system** (PNS) – all of the **nerves** in the body
- The nervous system allows detection of stimuli in our surroundings and the **coordination** of the body's **responses** to the stimuli
- 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 nerves connect the receptors in the sense organs with the CNS, and connect 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

- An example of this nerve pathway in action might be

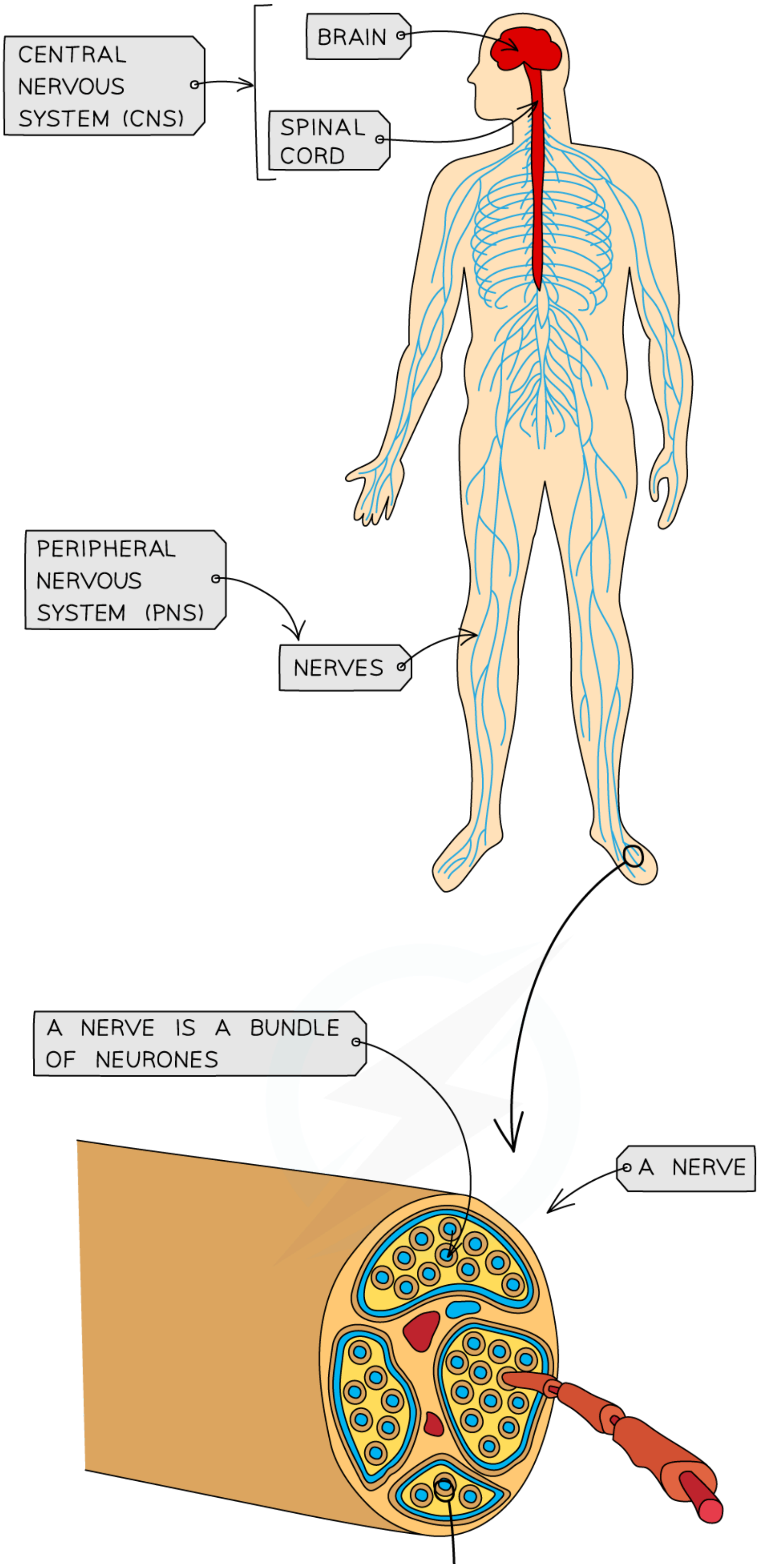
Your notes

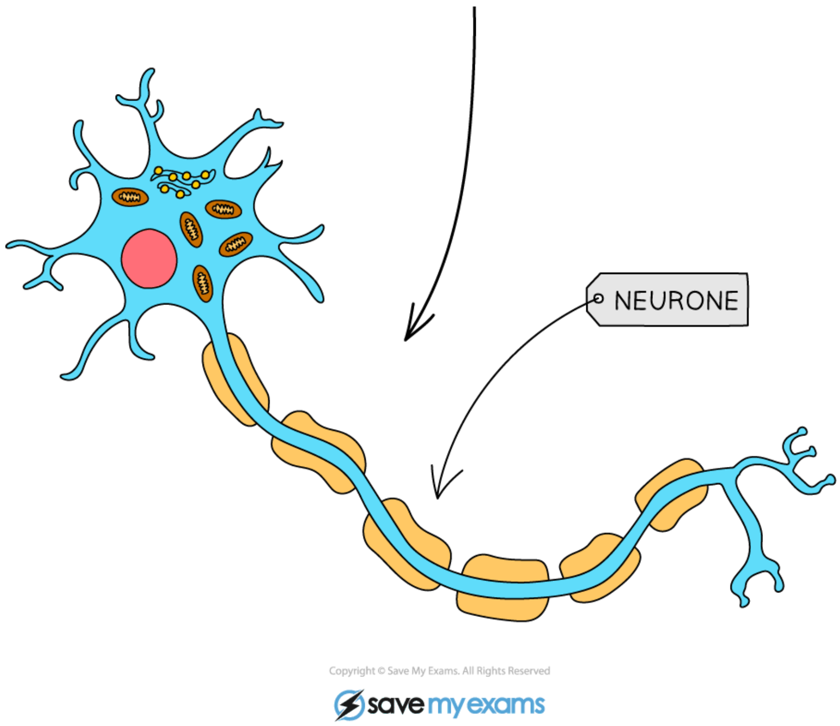
hot surface → pain receptor in skin of hand → sensory neurone → CNS → motor neurone → arm muscle

- The muscle in the arm responds by contracting to move the hand away from the hot surface

Your notes

Your notes


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



The nervous system allows the detection of stimuli and the co-ordination of appropriate responses

The hormonal system

- Hormones are **chemical substances** produced by **endocrine glands** and carried by the **blood**
  - Endocrine glands are **ductless** and secrete hormones directly into the **blood**
  - Hormones are sometimes known as **chemical messengers**
- Hormones **transmit information from one part of an organism to another** and bring about **change** by altering the **activity** of one or more **specific target organs**
  - Hormones can leave the blood and bind to **specific receptors** on the cell surface membranes of target organs
- Hormones are slower in action than nerve impulses and are therefore used to control functions that **do not need instant responses**
- Endocrine glands that produces hormones in animals are known collectively as the **endocrine system**
  - Endocrine glands can be stimulated to secrete hormones by the action of **another hormone** or by the arrival of a **nerve impulse**
- The pathway of hormone action is as follows

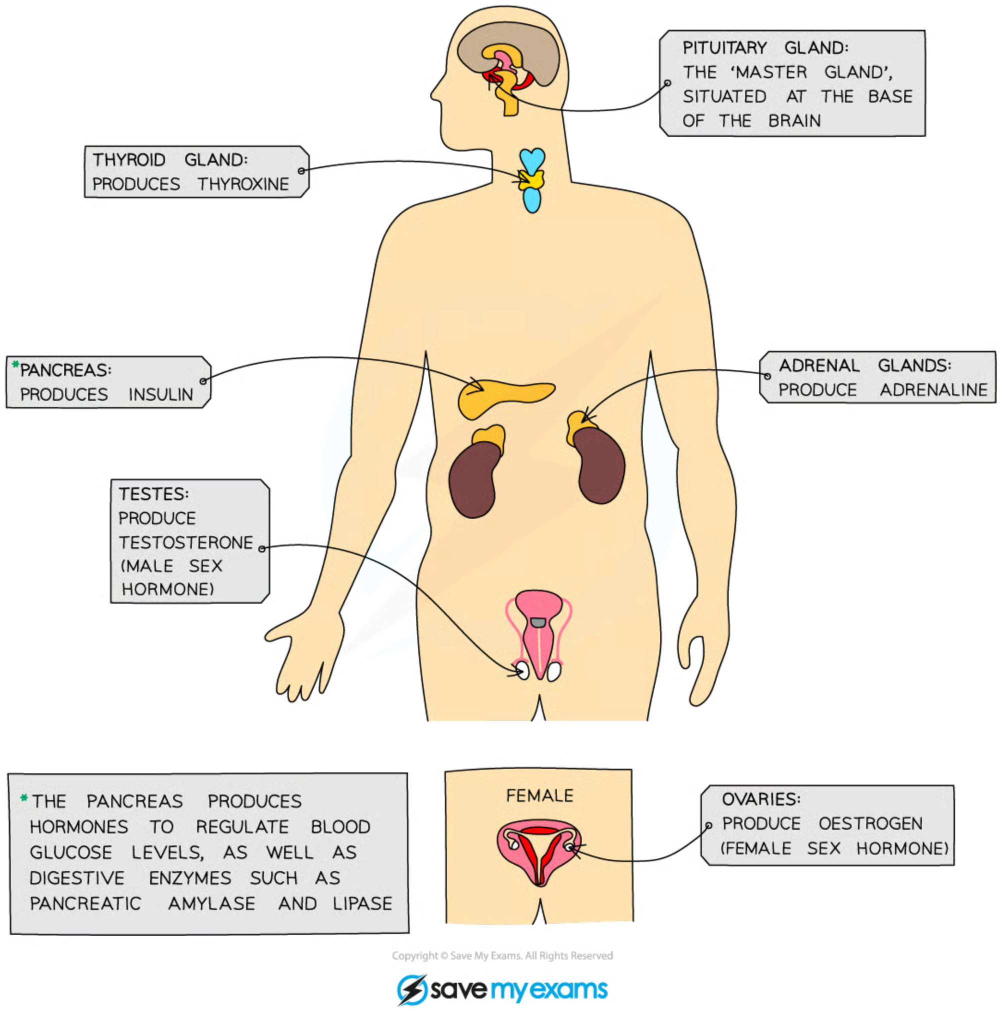
stimulus → receptor → hormone → effector

- An example of this pathway in action might be

high blood sugar → cells in the pancreas → insulin → liver cells

Your notes

- The liver cells respond to insulin by converting glucose into glycogen



Hormones are secreted into the blood by the endocrine glands

Comparison of Nervous and Hormonal control Table

	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

Your notes