DP IB Biology: HL

Your notes

9.3 Growth in Plants

Contents

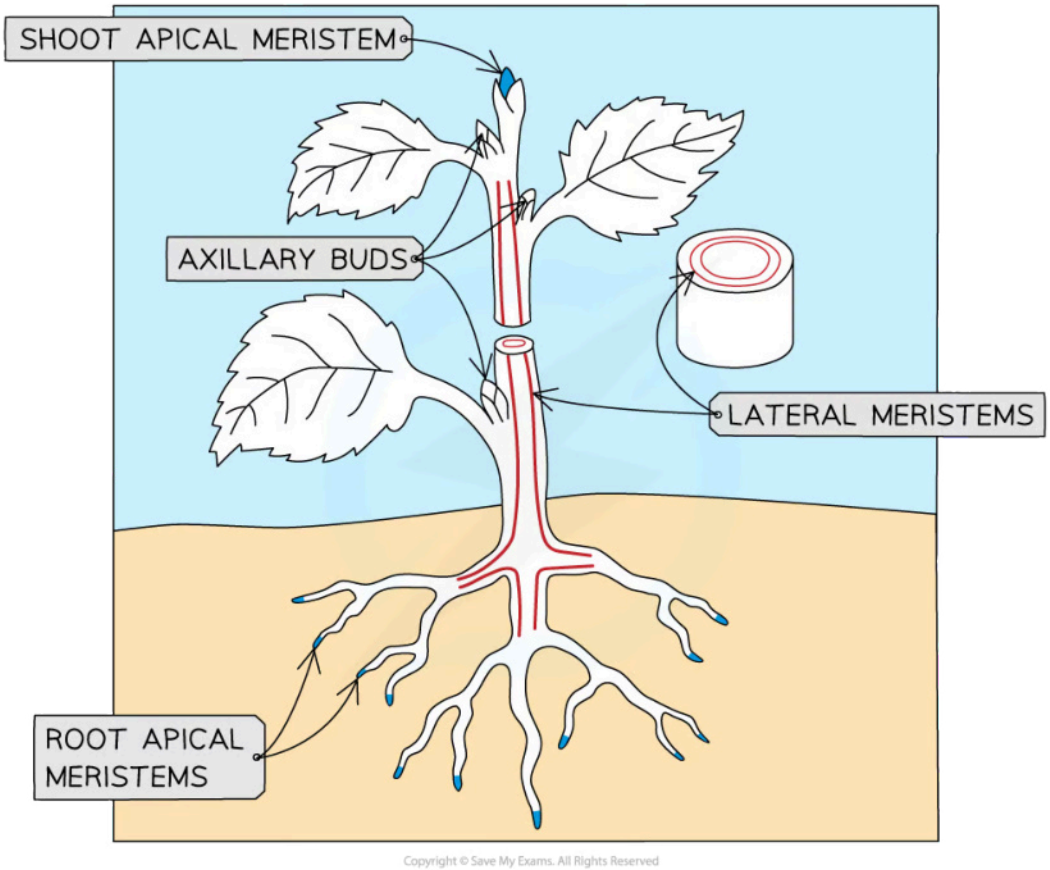
9.3.1 Plant Growth

Your notes

Plant Growth

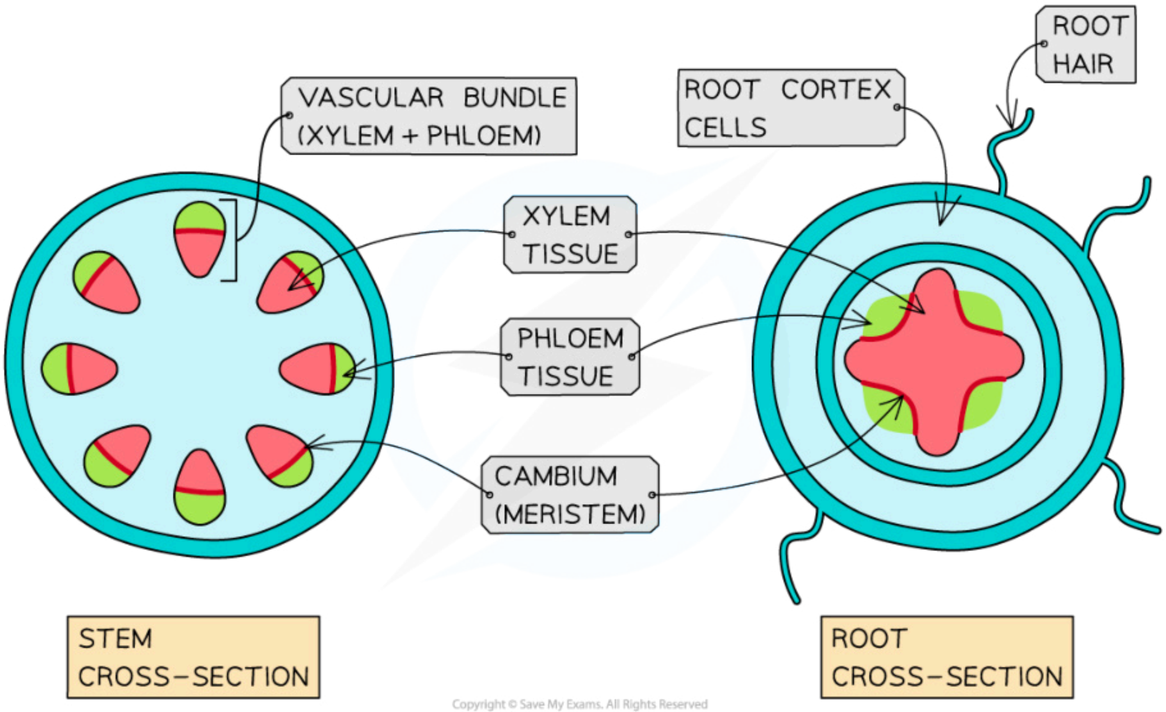
- Plant growth occurs in regions known as **meristems**
  - The cells in these regions are known as **meristem cells**
- Meristem cells are **undifferentiated**; they actively divide by mitosis to produce **new plant tissue**
- Meristems can be found in the **growing tips of plant roots and shoots**
  - A meristem at the tip of a shoot is a **shoot apical meristem**
  - A meristem at the tip of a root is a **root apical meristem**
  - Meristem tissue with the potential to form **new side branches** from the main plant stem can be found in regions known as **axillary buds**
    - Axillary buds are those that grow in-between the main stem and the branch of a leaf
    - The growth of the axillary buds is inhibited by the plant chemical auxin released from cells in the tip of the shoot apical meristem
    - This **inhibition** of axillary bud growth by the shoot apex is known as **apical dominance**
- Meristems can also be found **parallel to the sides of a stem** e.g. within the **vascular bundles** that contain the xylem vessels and the phloem
  - These are known as **lateral meristems** and enable plant stems to **grow in diameter**
  - Lateral means 'from the side'
- The regions of meristem tissue in the **vascular bundles** are known as **cambium**

Your notes



The growing parts of plants are known as meristems, and can be found in the shoot apex (shoot apical meristem), the root apex (root apical meristem), and the sides of the stem (lateral meristem)

Your notes



Lateral meristem tissue is known as cambium. It can be found between the xylem and phloem in stems and roots.

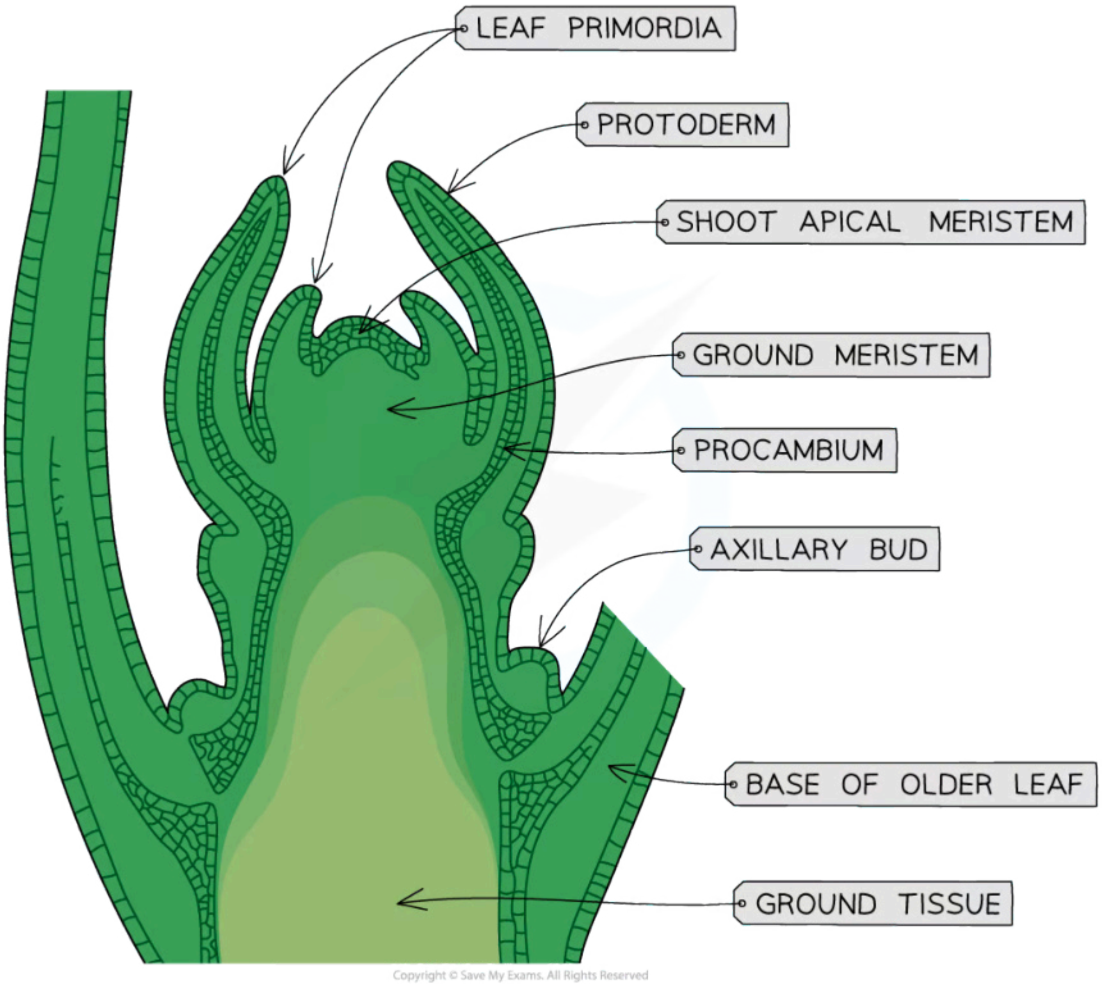
- **Plant growth at meristems can continue indefinitely** and is therefore said to be **indeterminate**
  - Animal growth is different to plant growth in that animals grow until they reach their full adult size and then stop; animal growth is therefore **determinate**
  - Note that while the growth of some individual plant organs, e.g. leaves or flowers, is determinate, **plants can grow an indeterminate number of these organs from their meristems**
- It is often possible to grow **whole new plants from just a single plant cell**
  - Such plant cells are totipotent
  - In some cases fully differentiated plant cells are able to do this

Stem Extension & Leaf Development

Your notes

- Plant stems grow longer at the tip due to **cell division in the shoot apical meristem**
- Small cells in the shoot apical meristem **divide by mitosis to produce two identical daughter cells**
  - Of the two daughter cells produced by each round of division, one remains in the meristem while the other moves away to form new tissue elsewhere
- The cells that leave the meristem grow rapidly, **differentiating into different cell types** which themselves give rise to **different plant tissues** e.g.
  - **Ground meristem cells** give rise to **ground tissues**
    - Ground tissues are any tissues that are **not** part of the plant's vascular system or its outer protective layers e.g.
      - Collenchyma tissue cells have thickened cell walls and form **supportive tissue**
      - Parenchyma tissue cells **carry out essential plant functions** such as photosynthesis and carbohydrate storage
  - **Protoderm cells** give rise to **epidermal tissue**
    - Epidermal tissue is a **layer of cells that covers the outside of the plant**, forming a barrier between the internal tissues and the external environment
  - **Procambium cells** give rise to **vascular tissue**
    - Vascular tissue **transports water, minerals**, and **assimilates** around the plant
    - The vascular tissue contains the **xylem** and **phloem**
- Cell differentiation is determined by **chemicals called hormones** in the plant tissues
- **Leaves develop** from structures called leaf primordia **at the sides of the shoot apical meristem**

Your notes

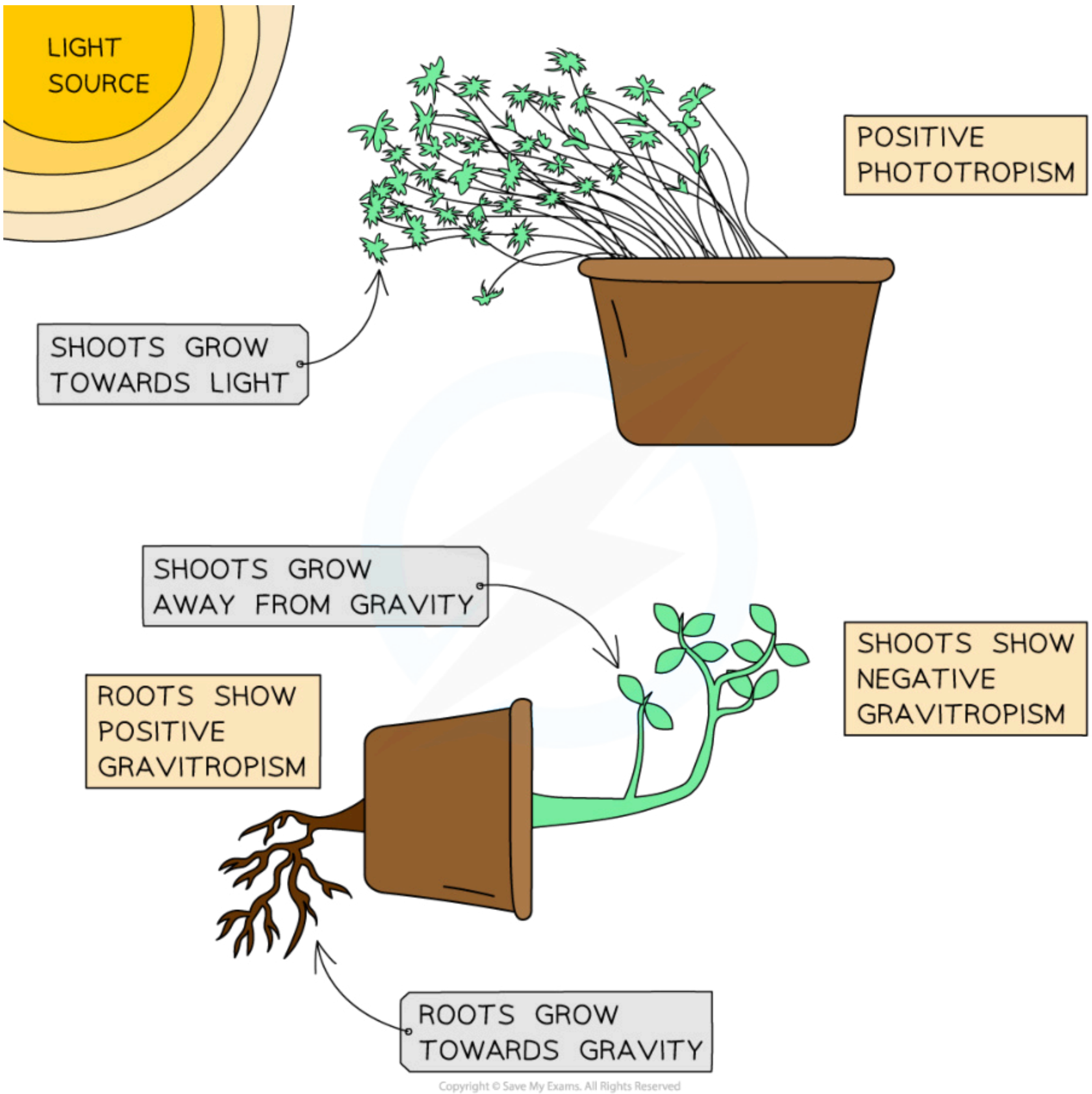


Mitosis at the shoot apical meristem produces cells which differentiate to form different plant tissues.

Plant Tropisms

Your notes

- Plant growth can be affected by **factors in the external environment** such as light, gravity, water, and the presence of objects
- These growth responses are known as **tropisms**
  - Tropisms can be **towards a stimulus; positive tropisms,** or **away from a stimulus; negative tropisms**
  - Tropisms enable plants to **maximise their chances of survival** e.g.
    - Growing towards light ensures a **maximum rate of photosynthesis**
    - Growing away from or towards gravity ensures that **seedlings grow the right way up**
    - Growing towards water enables roots to **maximise their water uptake**
    - Growing up and around an object may allow a plant to **gain height quickly** and so **maximise light absorption for photosynthesis**
- Tropisms are **regulated by chemicals** produced in plants known as **plant hormones**
- Examples of tropisms include
  - **Phototropism**
    - Plant response to **light**
    - Plant **stems grow towards light**; this is positive phototropism
  - **Gravitropism**
    - Plant response to **gravity**
    - Plant **stems grow away from gravity**; this is negative gravitropism
    - Plant **roots grow towards gravity**; this is positive gravitropism
    - Gravitropism is also known as **geotropism**



Plants can respond to environmental factors such as light and gravity; these responses are called tropisms and they can be either positive or negative.

Your notes

9.3.2 Plant Hormones

Your notes

Plant Hormones & Shoot Growth

- **Plant hormones** are responsible for most communication within plants
  - Plant hormones are not the same as hormones in animals but they are **chemical messengers** so the name hormone is often used
  - Plant hormones are sometimes referred to as **plant growth regulators**
- **Auxins** are a group of plant hormones that influence many aspects of plant growth
  - A common auxin is known as **IAA** (indole-3-acetic acid)
- In shoots, auxin is produced **in cells at the growing tip** before moving away into the surrounding tissues
- Auxin has an important role in **regulating shoot growth**
  - **In shoots, auxin causes cells to elongate**, leading to stem growth
    - Note that **in roots, auxin inhibits cell growth**; the **opposite effect** to that in shoot cells
    - Note that **at very high concentrations, auxin can also inhibit shoot growth**
  - Auxin released from the shoot apical meristem **inhibits the growth of axillary buds**
    - This is known as **apical dominance**
    - The strength of the inhibitory effect on axillary buds **depends on the concentration of auxin**; concentrations are lower further away from the shoot apex so axillary buds are more likely to grow lower down the plant
    - Note that **cytokinins**, another plant hormone, promotes the growth of axillary buds, so the **relative concentrations of auxin and cytokinins is also important**
    - Cutting off the shoot apex causes a decrease in auxin concentration and therefore promotes shoot growth; this is why pruning (cutting back plant stems) can often help to grow bushier plants!
- **Gibberellins** are another group of plant hormones involved in regulating stem growth

Examiner Tip

You may have noticed already that plant hormones are complicated! In animals hormones have target tissues and their effects on those tissues are consistent. In plants, however, hormones can act on many tissues and their effects can vary depending on hormone concentration, interactions with other hormones, and the type of tissue involved. From this section you need to know about **the impact of auxin on shoot elongation** and **apical dominance**.

Auxin & Gene Expression

Your notes

- It is thought that **auxin brings about plant responses** such as phototropism by **altering the expression of genes inside plant cells**
  - A gene is expressed if it is successfully transcribed and translated into a polypeptide
- When light falls on a plant, **light energy is absorbed by photoreceptor proteins** known as **phototropins**, causing a **change in their 3D shape**
- The altered shape of the phototropins allows them to **bind to receptors inside the cell**, affecting the **expression of certain genes**
- It is thought that the affected genes could code for glycoproteins called **PIN3 proteins**
- PIN3 proteins are thought to be involved with the lateral transport of auxin across **stems exposed to sunlight**, or across **stems and roots affected by gravity**

Auxin Efflux Pumps

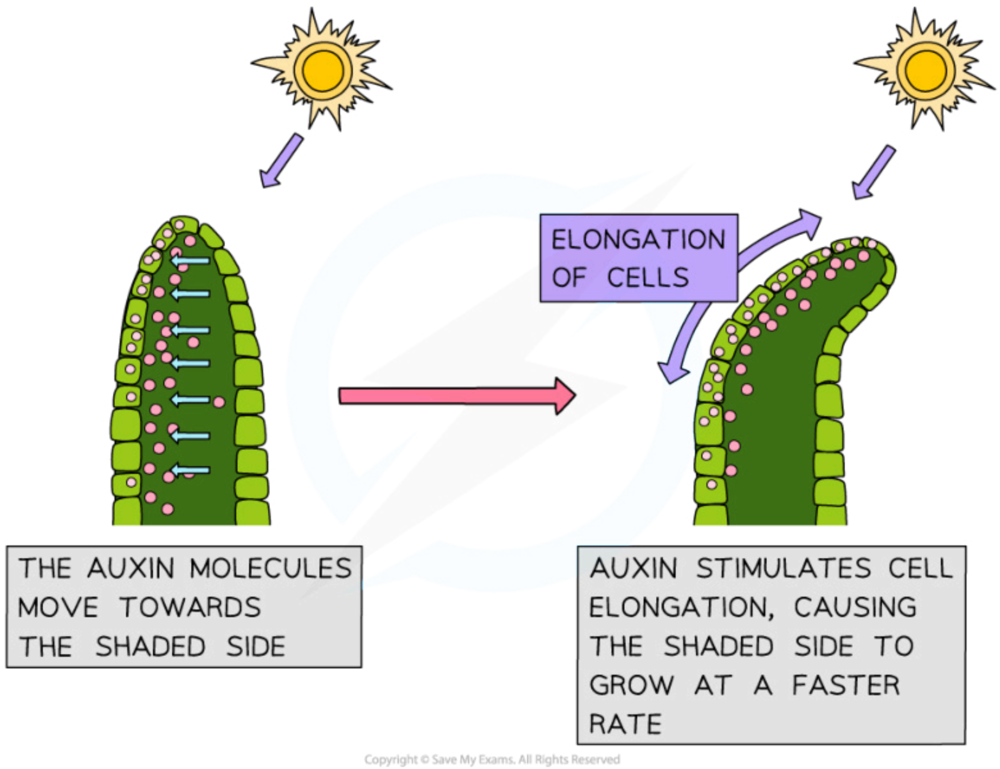
Your notes

- The **PIN3 proteins** that are thought to be involved with the **lateral transport of auxin** in stems and roots are also known as **efflux pumps**
  - The term '**efflux**' refers to an **outward flow of a substance**; in this case auxin is moved out of one cell and into another
- These efflux pumps are important in **establishing an auxin** gradient across a stem or root **in response to a stimulus** such as light or gravity
  - E.g. Light is thought to **affect the expression of genes that code for the PIN3 protein efflux pumps**; light shining on one side of a stem more than the other can therefore lead to an **uneven distribution of efflux pumps**, creating an auxin gradient
- The cells in a stem or root with a lateral auxin gradient **will grow differently depending on the concentration of auxin to which they are exposed**

Responding to light

- Light affects the growth of plant shoots in a response known as **phototropism**
- The **concentration of auxin** determines the **rate of cell elongation** within the stem
  - A **higher concentration of auxin** causes an **increase in the rate of cell elongation**
  - If the **concentration of auxin is not uniform** across the stem then **uneven cell growth can occur**
- When light shines on a stem from one side, **auxin is transported,** by PIN3 proteins, **from the illuminated side of a shoot to the shaded side**
- An **auxin gradient** is established, with **more auxin 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

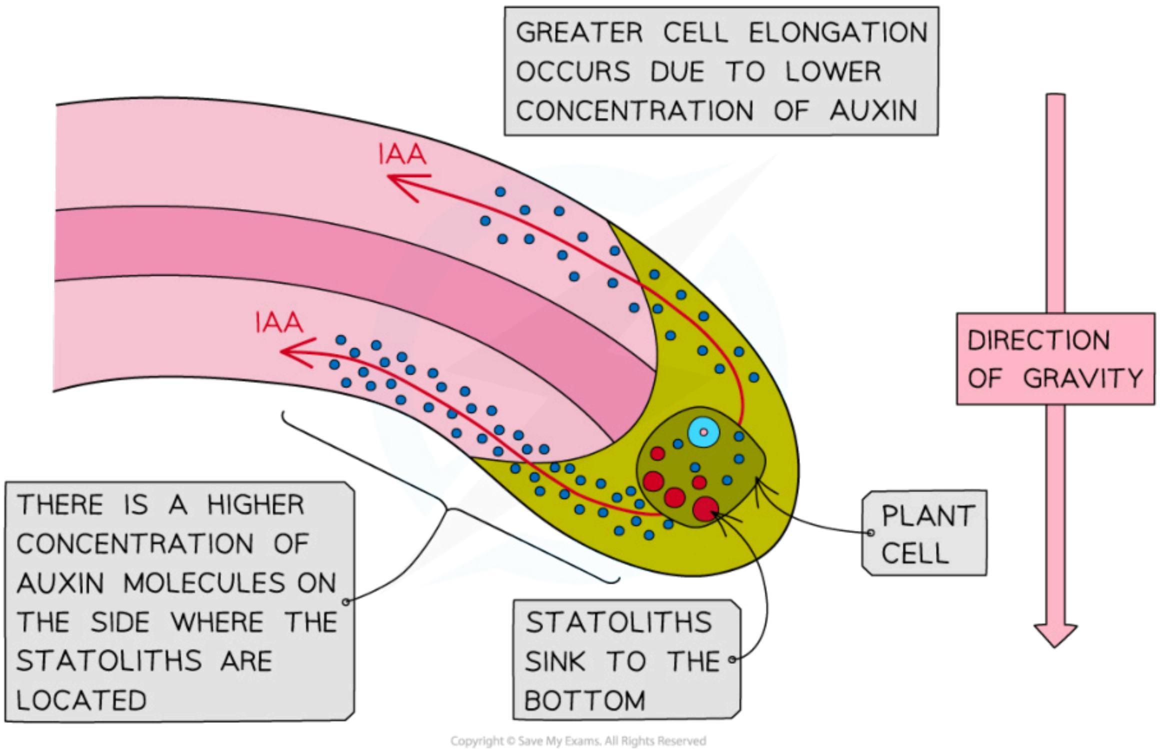


Higher concentrations of auxin on the shaded side of a stem increases the rate of cell elongation so that the shaded side grows faster than the illuminated side

Responding to gravity

- Roots respond to gravity in a response known as **gravitropism**
  - Gravitropism is sometimes known as **geotropism**
- In roots, **auxin concentration also affects cell elongation**, but **higher concentrations of auxin result in a lower rate of cell elongation**
  - Note that this is the **opposite effect** to that of auxin on **shoot cells**
- Plant cells use organelles called **statoliths** to detect the direction of gravity
  - Statoliths are **starch-filled grains**
  - They **accumulate on the lower side** of plant cells due to gravity
- PIN3 proteins **transport auxin towards the lower side** of the root cells
- 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

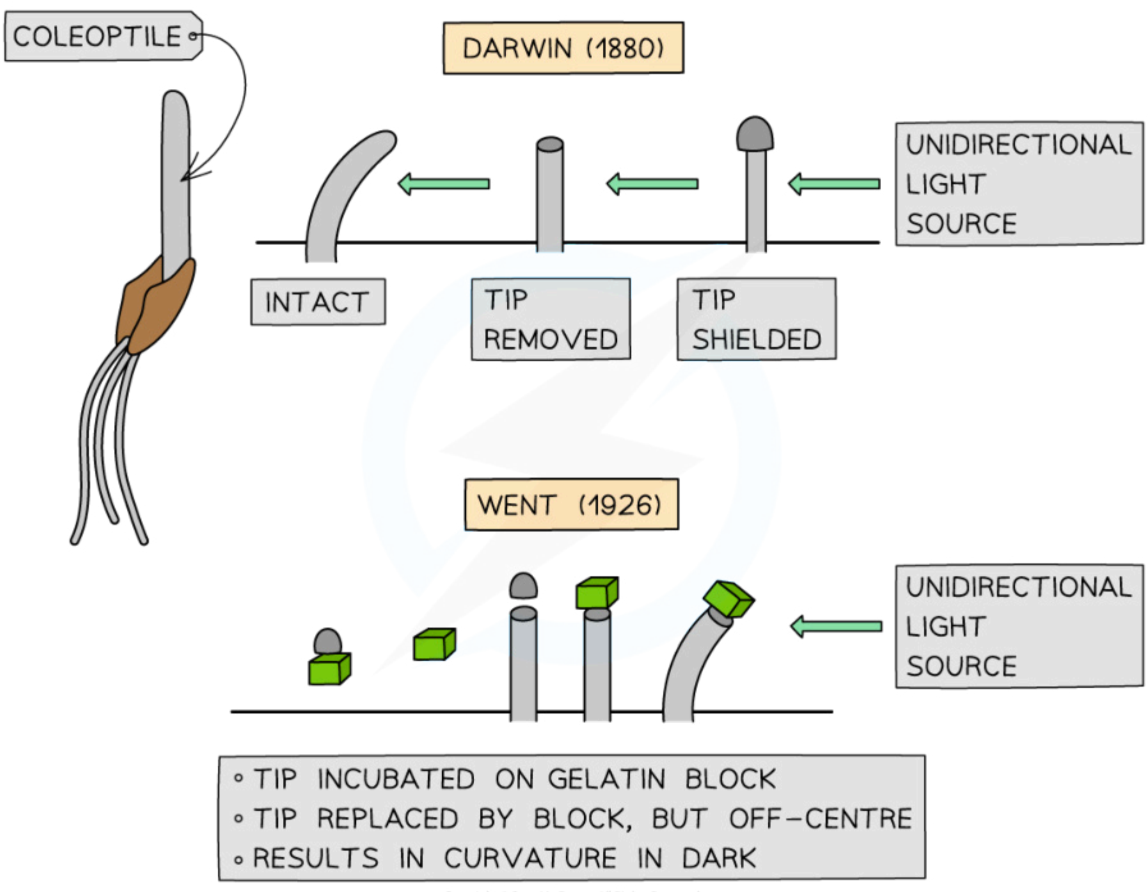


Auxin inhibits cell elongation in the lower side of roots, causing the cells in the lower side of the root to elongate at a slower rate than the upper side

Genomics & the Role of Plant Hormones

NOS: Developments in scientific research follow improvements in analysis and deduction; improvements in analytical techniques allowing the detection of trace amounts of substances have led to advances in the understanding of plant hormones and their effect on gene expression

- Early research on plant hormones was carried out by scientists such as Charles **Darwin** (yes, *the* Charles Darwin) in the 1800s, and Nikolai **Cholodny** and Frits **Went** in the early 1900s
  - **Darwin** was able to demonstrate the **importance of an unknown 'influence'** in the bending of coleoptiles (young plant seedlings) towards light
  - **Went** was able to isolate Darwin's 'influence' and identify it as **auxin**
  - **Cholodny** and **Went** independently proposed that an **auxin gradient was responsible for plant tropisms**



Studies on plant tropisms carried out by Charles Darwin and Frits Went. Darwin demonstrated that an 'influence' was produced in the tips of plant shoots, while Went showed that an auxin gradient was enough to cause shoot bending

Your notes

Your notes

- This early research on tropisms, while essential in progressing scientific understanding at the time, was **unable to provide detail on the mechanisms underlying these plant responses** beyond the suggestion that an auxin gradient was involved
- Modern analytical techniques mean that scientists today can find out about **processes taking place at a cellular level** in ways that earlier researchers could not
- An example of this is the science of **genomics**, which has enabled scientists to make discoveries about the **influence of gene expression on plant responses**
  - Genomics is **the study of genes**, including their structure and function
  - One method used in genomics is an analytical technique known as a **microarray**
    - A series of DNA probes are attached to a surface
    - Tissue samples are added to the microarray, and **if a gene is being expressed** in the cells, the probes emit fluorescence
    - This shows **which genes are being expressed in particular tissue types at particular times**
- Microarray research has shown that **certain genes are expressed more often** in cells on the **underside of a plant root** and on the **shaded side of a plant stem**
- Auxin has been shown to **affect the expression of certain genes**
- Research of this nature often involves organisms that are **already well studied**; scientists can make use of existing knowledge of their genetics and cell biology
  - A famous example of such a species in plants is ***Arabidopsis thaliana*** (thale cress)
  - *A. thaliana* is known as a **model organism** due to its frequent use in scientific research

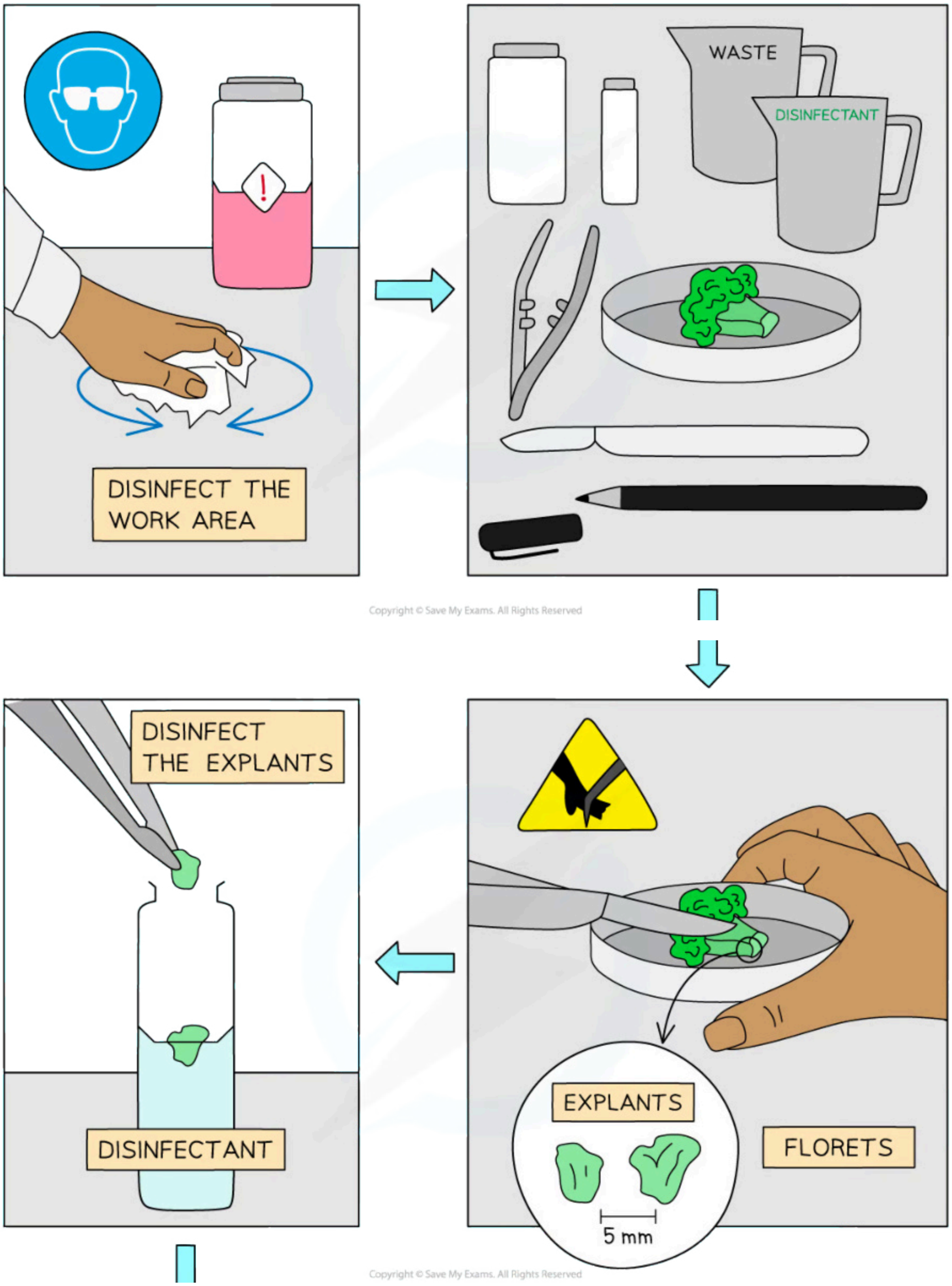
9.3.3 Micropropagation

Your notes

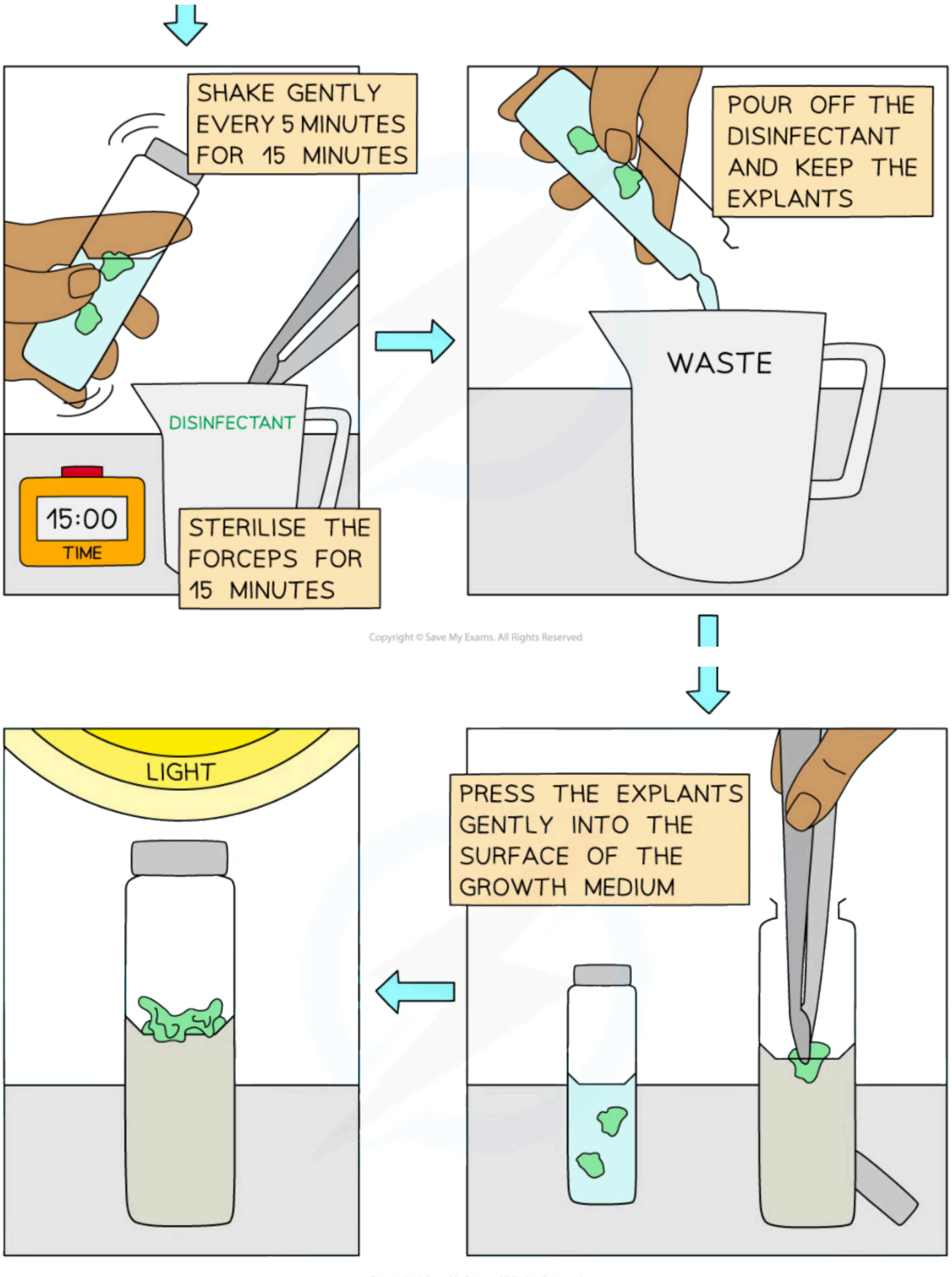
Micropropagation of Plants

- The nature of plant growth means that plants can be grown by a process known as **micropropagation**
  - Micropropagation is a form of **tissue culture** in which **plant cells are cultivated on nutrient growth media** (singular medium) such as agar gel
- Micropropagation produces **new adult plants** from **small samples of plant tissue** in a **laboratory setting**
- Micropropagation can be carried out in plants because **many plant cells can** differentiate into any other type of plant cell, meaning that **an entire plant can be reproduced from any totipotent cells**
- Micropropagation involves the following process
  - A small piece of plant tissue is cut; this is called an **explant**
    - Ideally the explant is taken from **meristematic tissue** such as the tip of the growing shoot, as the cells are more likely to be totipotent
  - The **explant is sterilised** to ensure that any new plants are free of infection
  - The explant is transferred to a **sterile growth medium,** such as agar gel, containing **nutrients** and **plant hormones**
    - The explant is allowed to develop into a **callus:** a ball of tissue containing **undifferentiated cells**
  - The nutrient medium will often contain a **combination of plant hormones,** such as cytokinins and **auxin**, to encourage growth of **different types of tissue**
    - A high ratio (>10:1) of auxin to cytokinins leads to root formation, while a less high ratio (<10:1) leads to shoot formation
  - Once the new plant has developed roots and shoots, it is **moved to soil** where growth can continue

Your notes


DISINFECT THE WORK AREA
WASTE
DISINFECTANT
DISINFECT THE EXPLANTS
DISINFECTANT
EXPLANTS
FLORETS
5 mm

Your notes



Cauliflower can be cultured using a simple micropropagation procedure in the school laboratory

Your notes

Use of Micropropagation for Rapid Bulking Up

- Micropropagation is a valuable process in the production of **large numbers of healthy plants**
  - Explants can be **as small as a single cell** so **many new individuals can be grown from one parent plant**
  - Plants grown from an explant in agar **take up less space** than those grown using traditional cultivation
  - It is carried out in **sterile laboratory conditions** meaning that the resulting new plants are **free of bacterial, viral, and fungal infection**
- Micropropagation produces **plants that are** clones **of the parent** plant so it can be used to produce **many new individuals from one parent with desirable characteristics**
  - This is useful in commercial growing; once a new desirable variety has been bred or discovered **more identical copies can be grown** by micropropagation
- Plants that are **at risk of extinction in the wild** can be cloned and **more individuals grown** by micropropagation
  - The new individuals will be disease-free and can be **planted in the wild to improve wild population numbers**
  - Desirable plants such as orchids that suffer due to illegal collection and trade can be **grown in the lab and sold legally rather than stolen** from the wild
    - Orchids are especially challenging to grow from seed and micropropagation has proved more successful
  - Explants can be **preserved by freezing**, ready for use if needed in the future if a plant species goes into decline