Edexcel

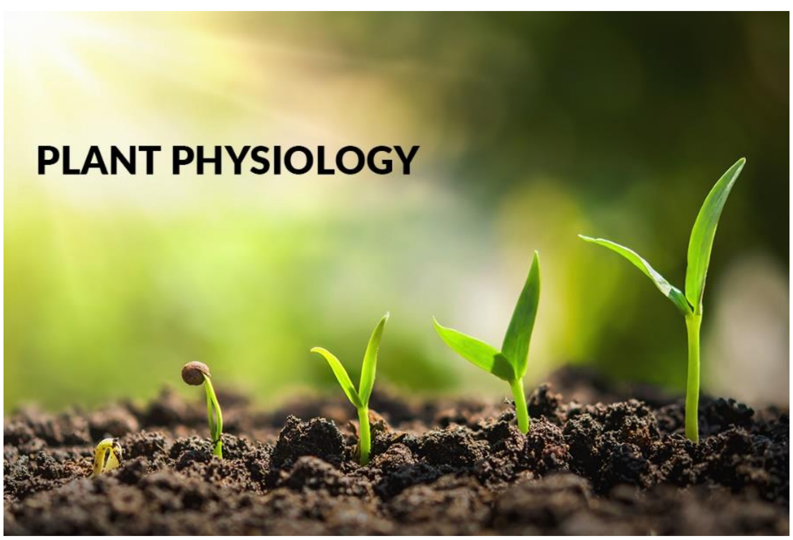
IGCSE

Biology

CODE: (4BI1)

Unit 03

Plant physiology



3.10 Plants and food

PLANTS MAKE STARCH

All the foods shown in Figure 10.1 are products of plants. Some, such as potatoes, rice and bread (made from cereals such as wheat or rye), form the staple diet of humans. They all contain starch, which is the main storage carbohydrate made by plants.

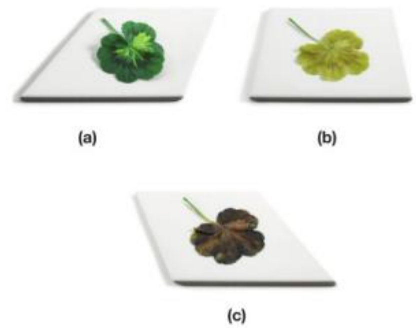


Figure 10.3 Testing a leaf for starch. (a) Leaf before test (b) Decolourised leaf (c) Leaf after test, stained blue-black with iodine solution.

WHERE DOES THE STRACH COME FROM?

You have now found out three important facts about starch production by leaves:

- it uses carbon dioxide from the air
- it needs light
- it needs chlorophyll in the leaves.

As well as starch, there is another product of this process which is essential to the existence of most living things on the Earth - oxygen. When a plant is in the light, it makes oxygen gas.

Starch is composed of long chains of glucose. A plant does not make starch directly, but first produces glucose, which is then joined together in chains to form starch molecules. A carbohydrate made of many sugar sub-units is called a **polysaccharide.**

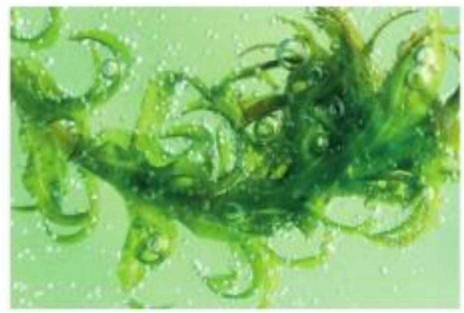


Figure 10.5 The bubbles of gas released from this pondweed contain a higher concentration of o

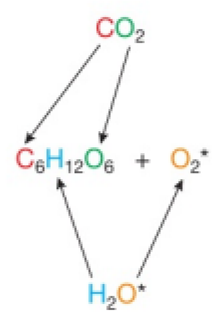
PHOTOSYNTHESIS

Plants use the simple inorganic molecules carbon dioxide and water, in the presence of chlorophyll and light, to make glucose and oxygen. This process is called **photosynthesis**.

it is summarized by the equation

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

$$\text{or:} \quad 6CO_2 + 6H_2O \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$



(*oxygen labelled with ^{18}O)

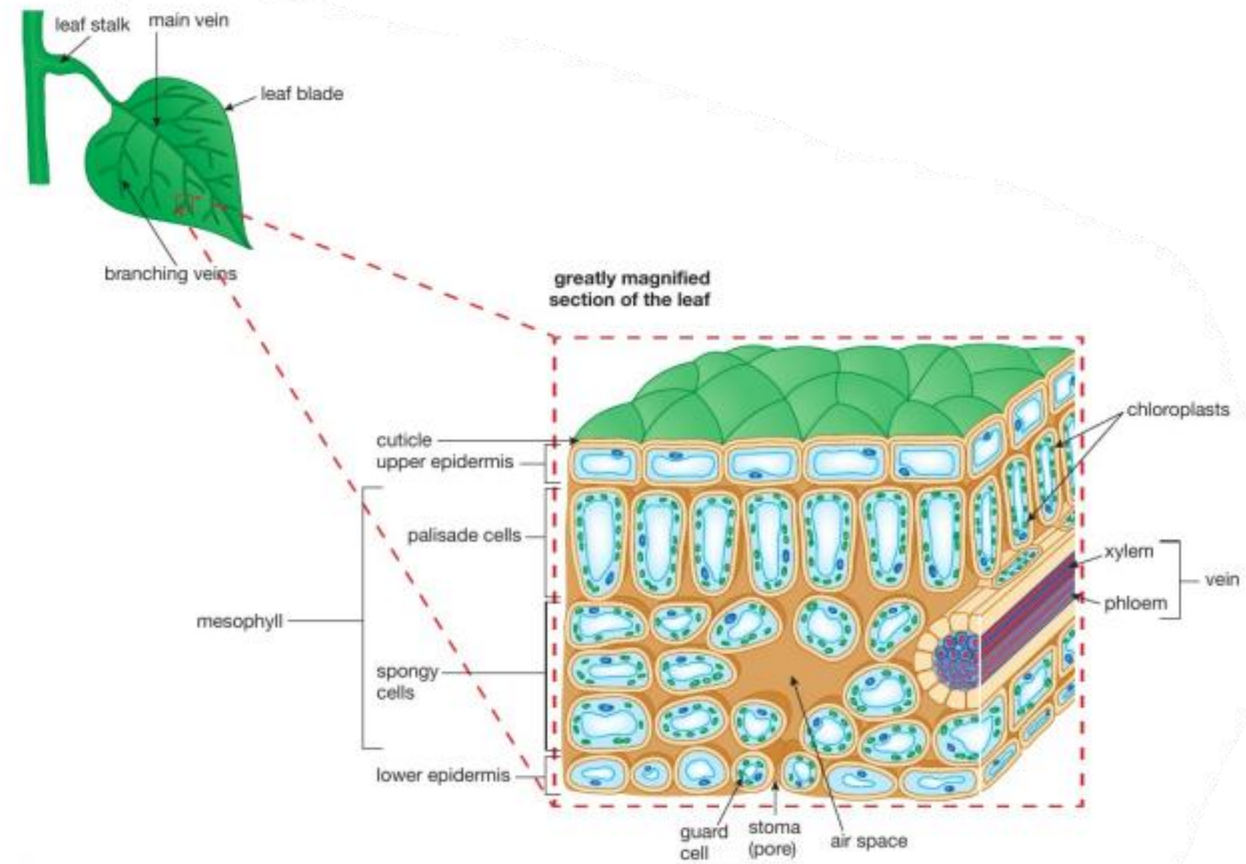
THE STRUCTURE OF LEAVES?

Inside the layers of cells with different functions.

The two outer layers of cells (the upper and lower **epidermis**) have few chloroplasts and are covered by a thin layer of a waxy material called the **cuticle**. This reduces water loss by evaporation and acts as a barrier to the entry of disease-causing microorganisms such as bacteria and fungi.

The lower epidermis has many holes or pores called stomata (a single pore is a **stoma**). Usually, the upper epidermis contains fewer or no **stomata**. They also allow oxygen and water vapour to diffuse out. Each stoma is formed as a gap between two highly specialised cells called **guard cells**, which can change their shape to open or close the stoma.

In the middle of the leaf are two layers of photosynthetic cells called the mesophyll ('mesophyll' just means 'middle of the leaf"). Just below the upper epidermis is the **palisade mesophyll** layer. This is a tissue made of long, narrow cells, each containing hundreds of chloroplasts, and is the main site of photosynthesis.



▲ Figure 10.6 External and internal features of a leaf

Below the palisade layer is a tissue made of more rounded, loosely packed cells, with air spaces between them, called the **spongy mesophyll layer**. These cells also photosynthesise, but have fewer chloroplasts than the palisade cells.

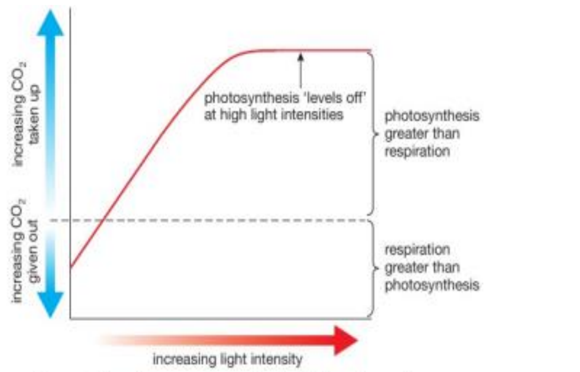
Water and mineral ions are supplied to the leaf by vessels in a tissue called the **xylem**. This forms a continuous transport system throughout the plant. Water is absorbed by the roots and passes up through the stem and through veins in the leaves in the **transpiration stream.**

The products of photosynthesis, such as sugars, are carried away from the mesophyll cells by another transport system, the **phloem**. The phloem supplies all other parts of the plant, so that tissues and organs that can't make their own food receive products of photosynthesis. The veins in the leaf contain both xylem and phloem tissue, and branch again and again to supply all parts of the leaf.

Photosynthesis and respiration

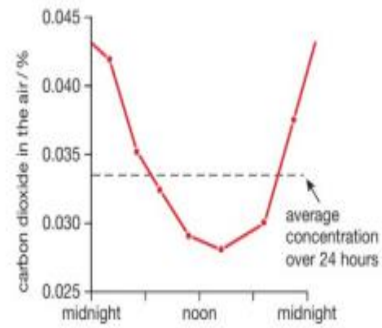
Plants use photosynthesis to provide animals with food and oxygen, while also removing carbon dioxide from the air. In bright light, plants process photosynthesis faster than respiration, resulting in carbon dioxide uptake and surplus oxygen production. However, plants only produce more than they use up in dim light.

Scientists found that the air around plants changes in carbon dioxide concentration throughout the day, with the lowest levels found in the afternoon during photosynthesis. At night, carbon dioxide levels rise due to less absorption by plants and increased respiration from all organisms.



The point where the curve crosses the dashed line shows where photosynthesis is equal to respiration – there is no net gain or loss of CO_2.

▲ Figure 10.7 As the light intensity gets higher, photosynthesis speeds up, but eventually levels off in very bright light.



▲ Figure 10.8 Photosynthesis affects the concentration of carbon dioxide in the air around plants. Over a 24-hour period, the concentration rises and falls, as a result of the relative levels of photosynthesis and respiration.

Investigation the effects of light on gas exchange by a leaf

Hydrogen carbonate indicator solution is very sensitive to changes in carbon dioxide concentration. When the solution is made, it is equilibrated with atmospheric air, which has a CO_2 concentration of 0.04%. If extra CO_2 is added to the solution, or if CO^2 is taken away from the solution, it changes colour

Table 10.1 Changes to hydrogen carbonate indicator solution with different concentrations of carbon dioxide.

Condition	Indicator colour
high concentrations of CO_2 (more than 0.04%)	yellow
CO_2 in normal air (0.04%)	orange
low concentrations of CO_2 (less than 0.04%)	purple

Factors affecting the rate of photosynthesis

Photosynthesis rates level off when light intensity increases, as the plant's ability to absorb and fix carbon dioxide decreases. The concentration of carbon dioxide in the air, which is typically 0.03 to 0.04%, holds back the rate. A plant in a closed container with higher carbon dioxide concentrations can photosynthesise faster. High light intensity and carbon dioxide levels can limit photosynthesis, with low temperatures slowing reactions and high temperatures reducing enzymes.

Light intensity, carbon dioxide concentration and temperature can all act as what are called **limiting factors** in this way. This is easier to see as a graph (Figure 10.10).

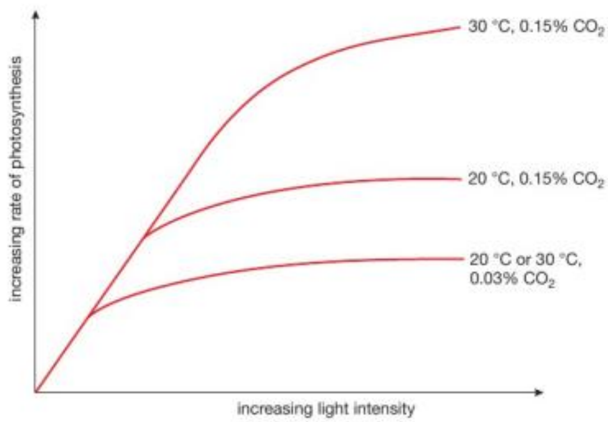


Figure 10.10 Light intensity, carbon dioxide concentration and temperature can all act as limiting factors on the rate of photosynthesis.

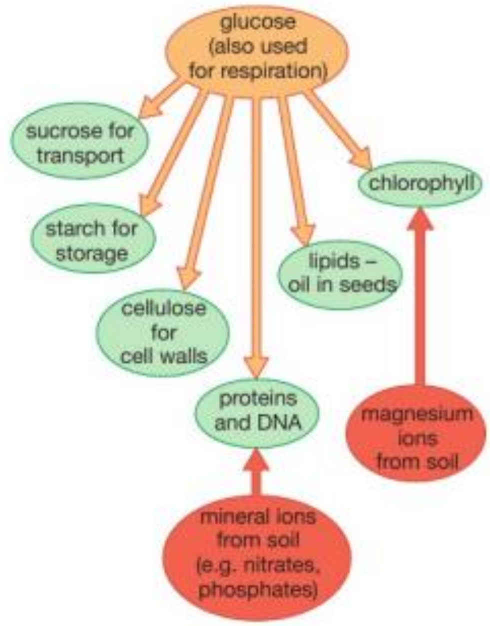


Figure 10.12 Compounds that plant cells can make from glucose.

The plan's uses for glucose

Glucose is a single sugar unit (a **monosaccharide**). Plant cells can convert it into other sugars, such as a monosaccharide called **fructose** (found in fruits) and the **disaccharide sucrose**, which is the main sugar carried in the phloem. It can also be changed into another polymer, the polysaccharide called **cellulose**, which forms plant cell walls.

Mineral nutrition

Soil water absorbs nitrate, phosphate, potassium, and magnesium ions, essential for plant cell composition, DNA production, respiration and photosynthesis enzymes, and chlorophyll molecule formation.

Water culture experiments

A plant takes only water and mineral ions from the soil for growth. Plants can be grown in soil-free cultures (water cultures) if the correct balance of minerals is added to the water. In the nineteenth century, the German biologist Wilhelm Knop invented one example of a culture solution. Knop's solution contains the following chemicals (per dm3 of water):

0.8 g	calcium nitrate
0.2 g	magnesium sulfate
0.2 g	potassium nitrate
0.2 g	potassium dihydrogenphosphate
(trace)	iron(III) phosphate

Chemicals in a complete culture solution provide essential elements for plants to produce proteins, DNA, chlorophyll, and other compounds. If magnesium sulfate is replaced with calcium sulfate, a deficient solution is produced. Comparing complete and deficient solutions allows

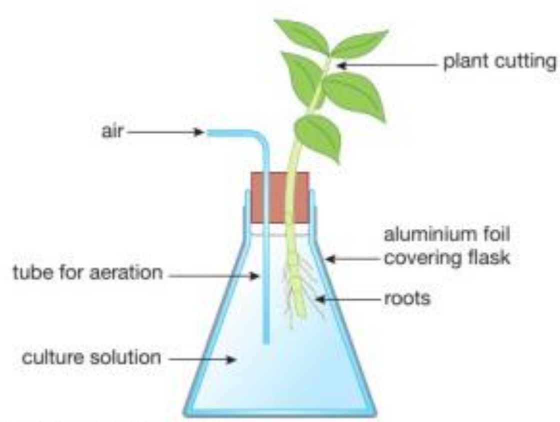


Figure 10.13 A simple water culture method

for plant growth, using apparatuses for cuttings and cotton wool for seedlings.

Mineral ion	Use	Deficiency symptoms
nitrate	making amino acids, proteins, chlorophyll, DNA and many other compounds	limited growth of plant; older leaves turn yellow  Figure 10.14 (b) A plant showing symptoms of nitrate deficiency.
phosphate	making DNA and many other compounds; part of cell membranes	poor root growth; younger leaves turn purple  Figure 10.14 (c) A plant showing symptoms of phosphate deficiency.
potassium	needed for enzymes of respiration and photosynthesis to work	leaves turn yellow with dead spots  Figure 10.14 (d) A plant showing symptoms of potassium deficiency.
magnesium	part of chlorophyll molecule	leaves turn yellow  Figure 10.14 (e) A plant showing symptoms of magnesium deficiency.

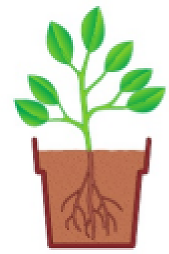


Figure 10.14 (a) A healthy bean plant

Figure 10.15 Lettuce plants grown by hydroponics

3.11 Transport in plants

OSMOSIS

Osmosis is the name of a process by which water moves into and out of cells. In order to understand how water moves through a plant, you need to understand the mechanism of osmosis. Osmosis happens when a material called a **partially permeable membrane** separates two solutions.

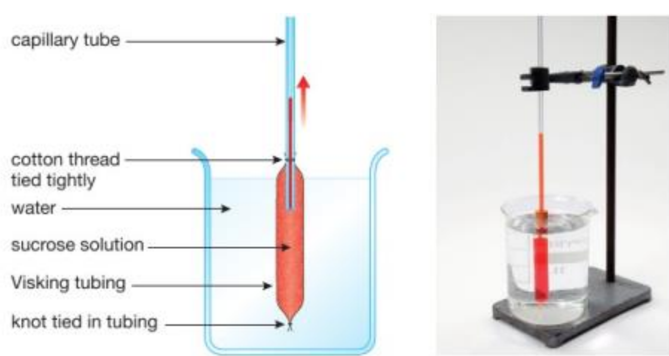


Figure 11.1 Water enters the Visking tubing 'sausage' by osmosis. This causes the level of liquid in the capillary tube to rise. In the photograph, the contents of the Visking tubing have had a red dye added to make it easier to see the movement of the liquid.

The level in the capillary tube rises as water moves from the beaker to the inside of the Visking tubing. This movement is due to osmosis. You can understand what's happening if you imagine a highly magnified view of the Visking tubing separating the two liquids (Figure 11.2).

How 'free' the water molecules are to move is called the **water potential**. The molecules in pure water can move most freely, so pure water has the highest water potential. The more concentrated a solution is, the lower is its water potential. In the model in Figure 11.2, water moves from a high to a low water potential. This is a law which applies whenever water moves by osmosis. We can bring these ideas together in a definition of osmosis.

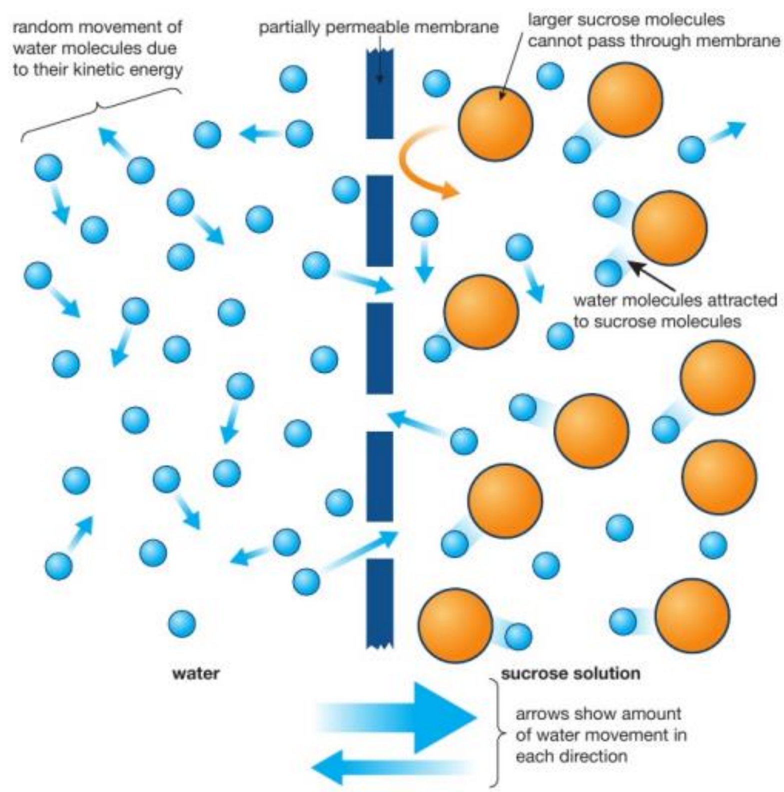


Figure 11.2 In this model of osmosis, more water molecules diffuse from left to right than from right to left.

Osmosis in plant cells

So far we have only been dealing with osmosis through Visking tubing. However, there are partially permeable membranes in cells too. The cell surface membranes of both animal and plant cells are partially permeable, and so is the inner membrane around the plant cell's sap vacuole (Figure 11.3).

Plant cells absorb water through osmosis in pure or dilute solutions, causing swelling and internal pressure, resulting in **turgid** cells with lower water potential.

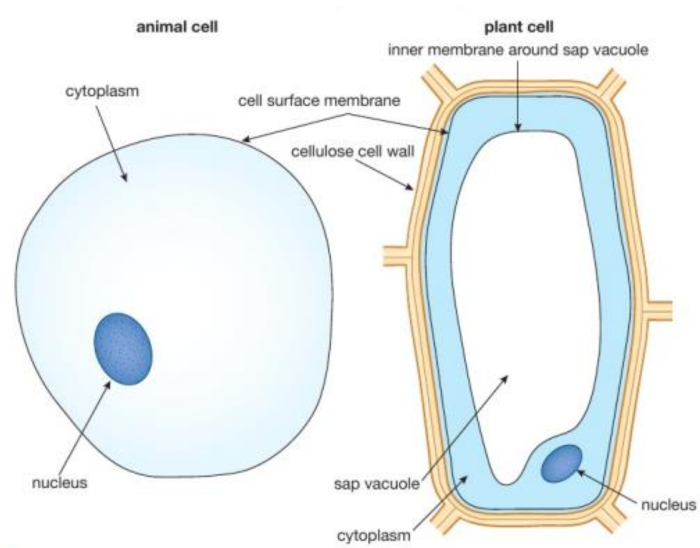


Figure 11.3 Membranes in animal and plant cells

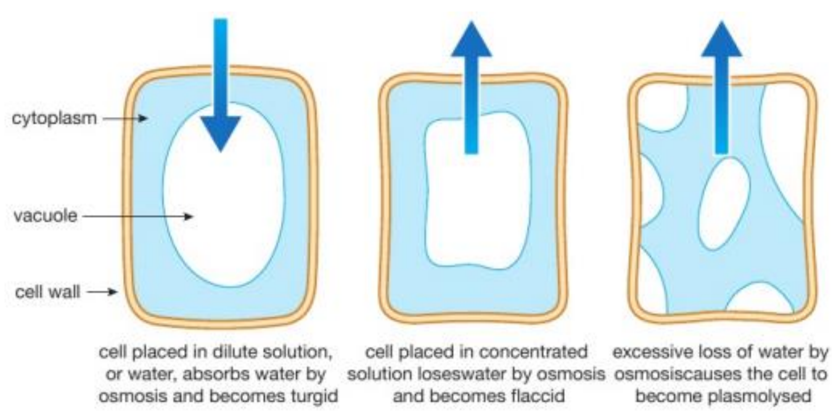
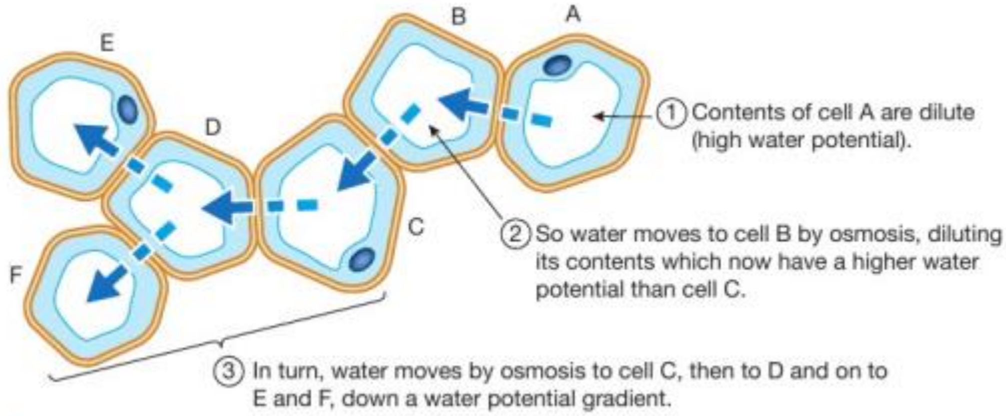


Figure 11.4 The effects of osmosis on plant cells

The cell decreases in volume and the cytoplasm no longer pushes against the cell wall. In this state, the cell is called **flaccid**. Eventually the cell contents shrink so much that the membrane and cytoplasm split away from the cell wall and gaps appear between the wall and the membrane. A cell like this is called **plasmolysed**.

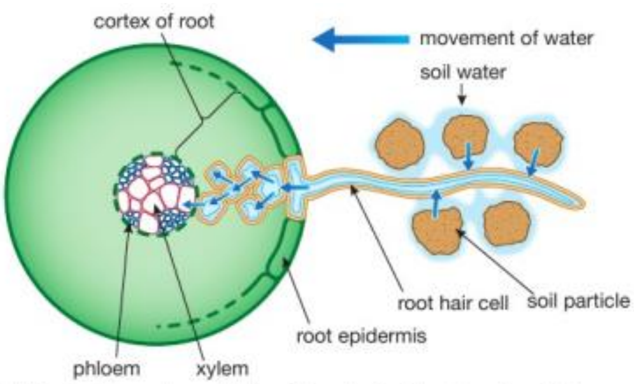
Turgor, a state where plants' cells are turgid, is crucial for supporting non-woody parts like young stems and leaves, allowing photosynthesis, and maintaining stomata function. Overwatering cells can cause **wilting** if they become flaccid.



▲ Figure 11.7 Water moves from cell to cell down a water potential gradient.

Uptake of water by roots

The regions just behind the growing tips of the roots of a plant are covered in thousands of tiny **root hairs** (Figure 11.10). These areas are the main sites of water absorption by the roots, where the hairs greatly increase the surface area of the root epidermis.



▲ Figure 11.11 Water is taken up by root hairs of the plant epidermis and carried across the root cortex by a water potential gradient. It then enters the xylem and is transported to all parts of the plant.

Loss of water by the leaves - transpiration

Osmosis is a process where water moves through leaves, passing through stomata, a waxy cuticle covered by the epidermis. Water evaporates into air spaces between mesophyll cells, then diffuses out through these pores.

This loss of water vapour from the leaves is called **transpiration**. Transpiration causes water to be 'pulled up' the xylem in the stem and roots in a continuous flow

▲ Figure 11.14 Xylem vessels in a stem. The spirals and rings (stained red) are made of lignin.

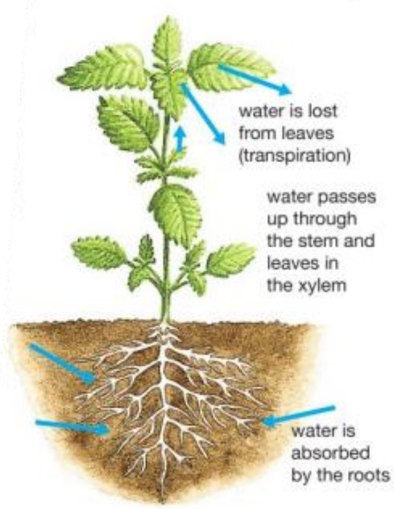
known as the **transpiration stream** (Figure 11.13). The transpiration stream has more than one function. It:

■supplies water for the leaf cells to carry out photosynthesis

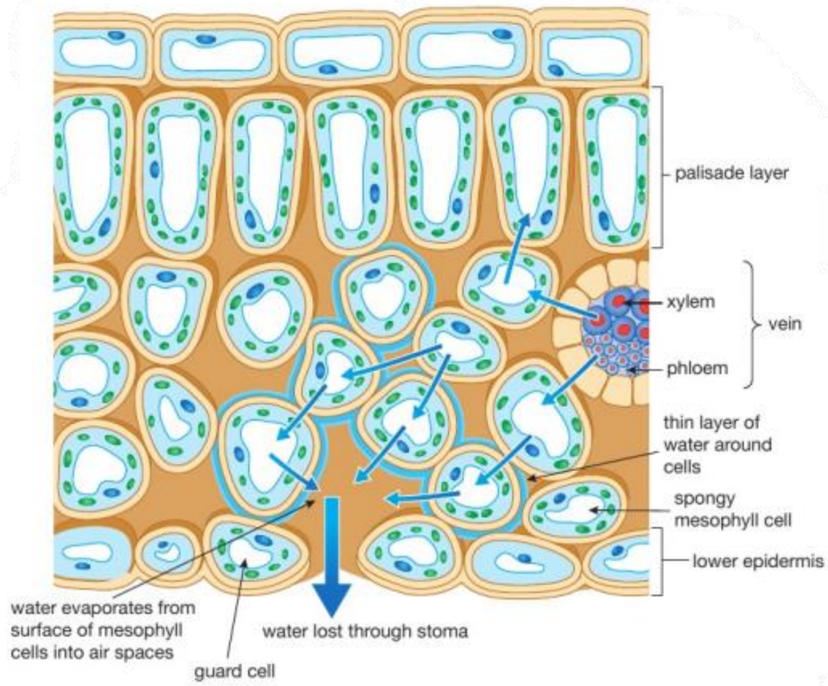
■carries mineral ions dissolved in the water

■provides water to keep the plant cells turgid

■allows evaporation from the leaf surface, which cools the leaf, in a similar way to sweat cooling the human skin.



▲ Figure 11.13 The transpiration stream



▲ Figure 11.12 Passage of water from the xylem to the stomatal pores of a leaf

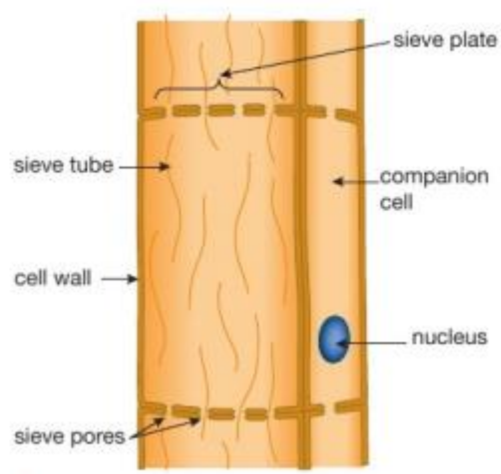
Transport in the xylem

Xylem transports water and minerals throughout the plant. Xylem contains dead cells arranged end-to-end, forming continuous vessels. When they are mature, the vessels contain no cytoplasm. Instead, they have a hollow central space or lumen through which the water passes. The walls of the xylem vessels contain a woody material called lignin (Figure 11.14).

Transport in the phloem

Tubes in the phloem are also formed by cells arranged end-to-end, but they have cell walls made of cellulose, and retain their cytoplasm. The end of each cell is formed by a cross-wall of cellulose with holes, called a **sieve plate**. The **sieve tubes** transport the products of photosynthesis from the leaves to other parts of the plant.

Despite being living cells, the phloem sieve tubes have no nucleus. They seem to be controlled by other cells that lie alongside the sieve tubes, called **companion cells** (Figure 11.15).



▲ Figure 11.15 Xylem vessels in a stem

Structure of a steam

In a young stem, xylem and phloem are grouped together in areas called vascular bundles. Unlike in the root, where the vascular tissue is in the central core, the **vascular bundles** are arranged in a circle around the outer part of the stem (Figure 11.16).

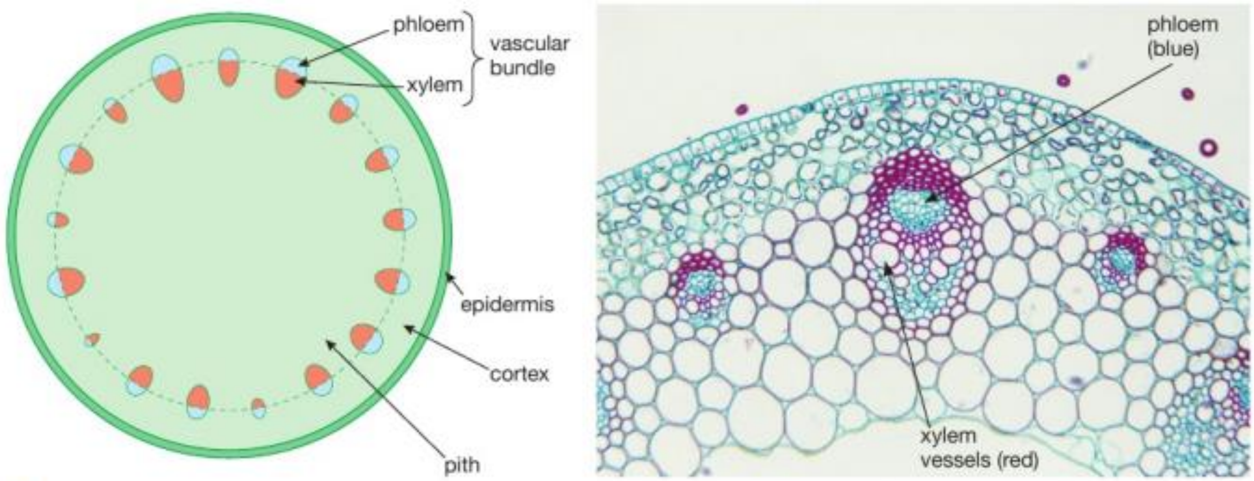


Figure 11.16 (a) This cross-section of a stem shows the arrangement of xylem and phloem tissue in vascular bundles. (b) Three vascular bundles in part of a stem section. The outer red cells are lignified fibres for extra support.

Control of transition by stomata

Stomata are typically found on the lower surface of leaves in most plant species to reduce water loss due to direct sunlight and less air movement. The arrangement of stomata is an adaptation to reduce water loss. Guard cells, with a banana shape, swell up and bend outwards when water enters them. In the dark, they lose water and become flaccid, closing the stoma. This change is linked to guard cells containing chloroplasts and using energy to accumulate solutes.

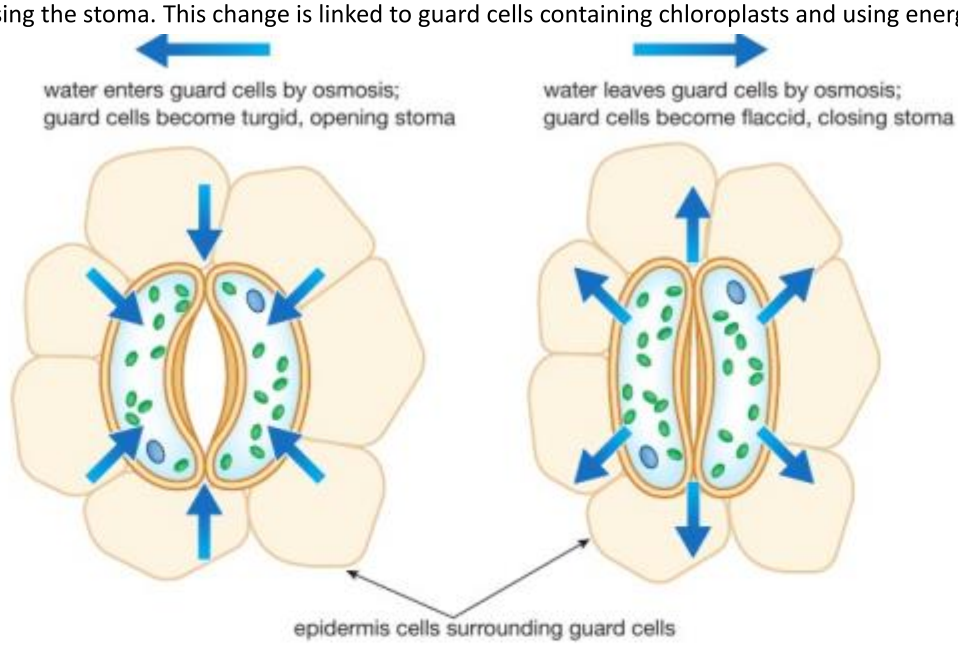


Figure 11.18 When the guard cells become turgid, the stoma opens. When they become flaccid, it closes.

FACTORS AFFECTING THE RATE TRANSPIRATION

There are four main factors which affect the rate of transpiration:

■**Light intensity** - The rate of transpiration increases in the light, because of the opening of the stomata in the leaves, so that the leaf can photosynthesise.

■**Temperature** - High temperatures increase the rate of transpiration, by increasing the rate of evaporation of water from the mesophyll cells.

■**Humidity** When the air around the plant is humid, this reduces the diffusion gradient between the air spaces in the leaf and the external air. The rate of transpiration therefore decreases in humid air and speeds up in dry air.

■**Wind speed**- The rate of transpiration increases with faster air movements across the surface of the leaf. The moving air removes any water vapour which might remain near the stomata.

MEASURING THE RATE OF TRANSPIRATION; POTOMETERS

A potometer measures the rate of transpiration or water uptake by plants. There are two types: weight and volume potometers. Weight potometers measure the loss of mass from a potted plant over time, with most mass lost due to water evaporation during transpiration. Volume potometers find water uptake by leafy shoots by magnifying it in a capillary tube. Potometers come in various shapes and sizes, with more complex versions featuring a horizontal capillary tube.

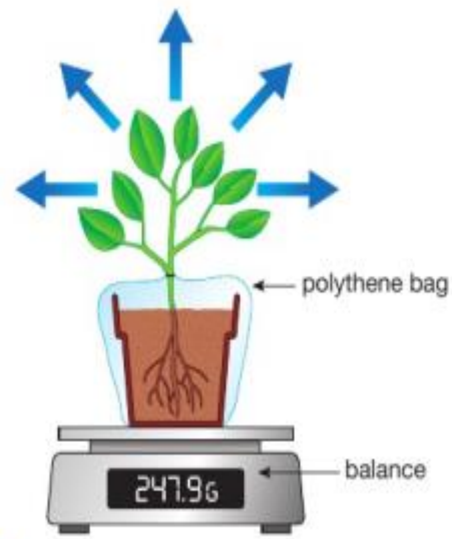


Figure 11.19 A 'weight' potometer

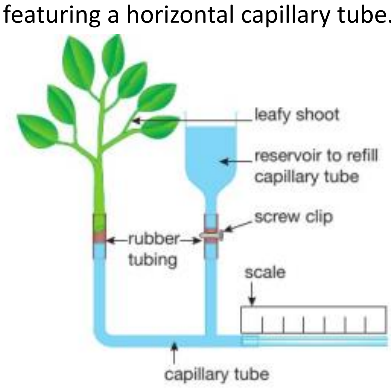


Figure 11.20 A commercial potometer with a water reservoir

3.12 Chemical coordination in plants

Tropisms

The growth response of a plant to a directional stimulus is called a **tropism**. If the growth response is towards the direction of the stimulus, it is a positive tropism, and if it is away from the direction of the stimulus, it is a negative tropism. The stem of the plant in Figure 12.2 is showing a positive **phototropism** and a negative **geotropism**, which both make the stem grow upwards.

Figure 12.3 The shoots of these cress seedlings are showing a positive phototropism.

Table 12.1: The main responses of plants to directional stimuli (tropisms).

Stimulus	Name of response	Response of shoots	Response of roots
light	phototropism	grow towards light source (positive phototropism)	most species show no response; some grow away from light (negative phototropism)
gravity	geotropism	grow away from direction of gravity (negative geotropism)	grow towards direction of gravity (positive geotropism)

Detecting the light stimulus – plant homones

A **coleoptile** is a protective sheath that covers the first leaves of a cereal seedling. It protects the delicate leaves as the shoot emerges through the soil (Figure 12.4). Coleoptiles have a simple structure and are easy to grow, so they are often used to investigate tropisms.

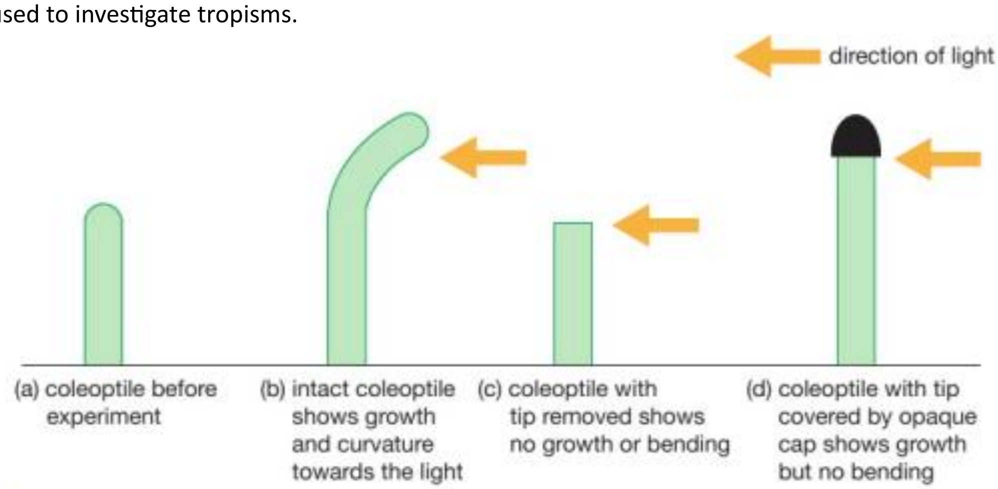


Figure 12.5 Darwin's experiments with phototropism (1880)

Since plants don't have a nervous system, biologists began to look for a chemical messenger (or plant **hormone**) that might be the cause of phototropism in coleoptiles. Between 1910 and 1926 several scientists investigated this problem. Some of their results are summarised in Figure 12.6.

Since these experiments were carried out, scientists have identified the hormone responsible. It is called **auxin**. Several other types of plant hormone have been found. Like auxin, they all influence growth and development of plants in one way or another, so that many scientists prefer to call them plant **growth substances** rather than plant hormones.

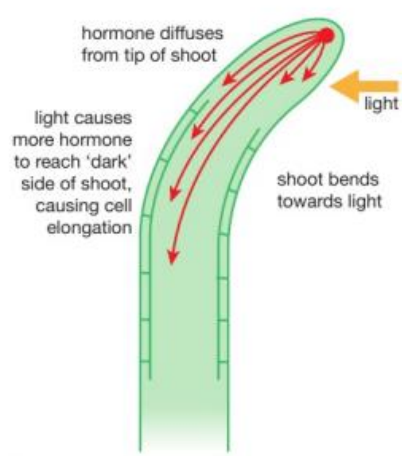
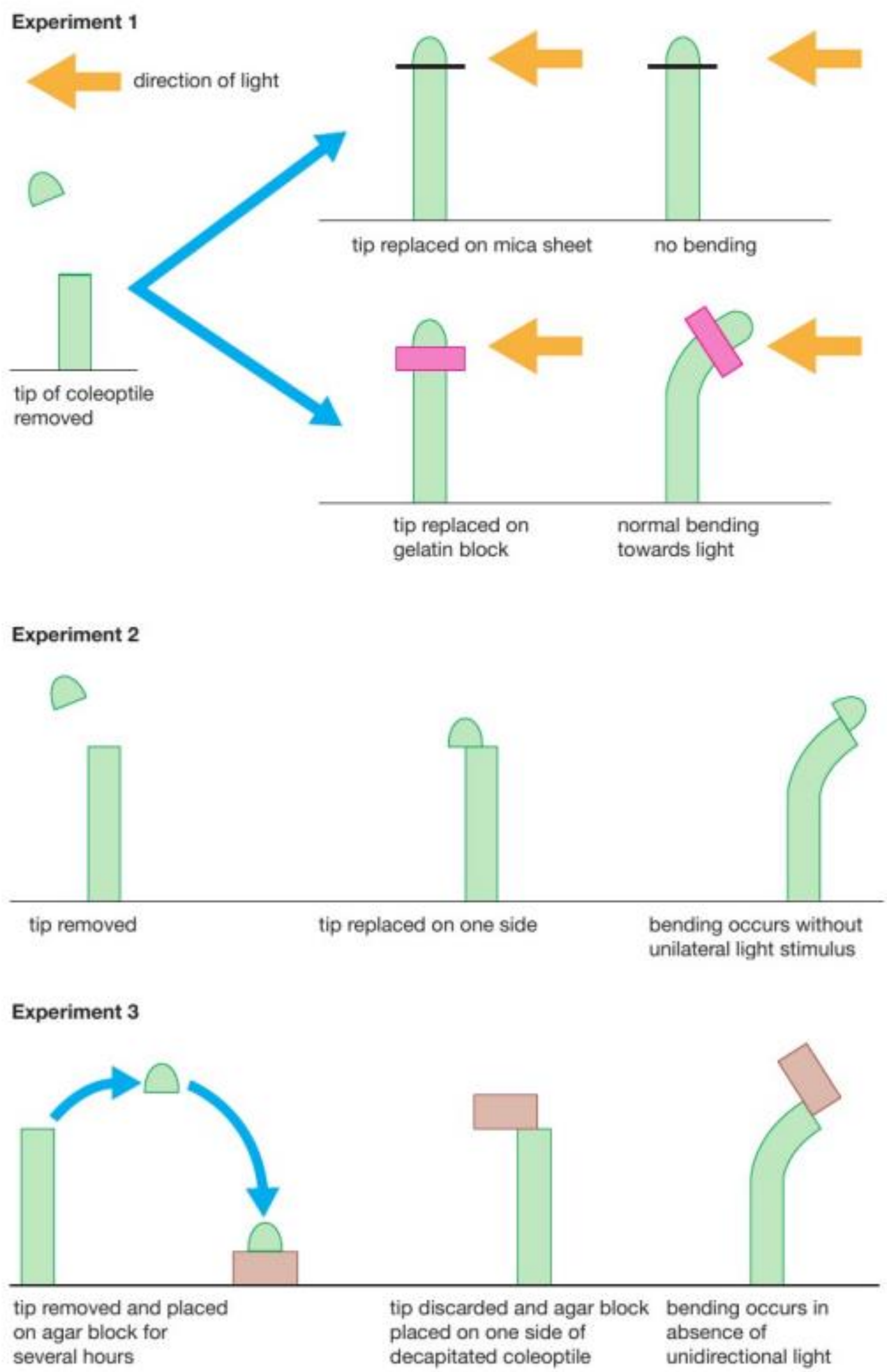


Figure 12.7 How movement of a plant hormone causes phototropism.



▲ Figure 12.6 Experiments on coleoptiles that helped to explain the mechanism of phototropism.

Using a clinostat to show tropisms

A clinostat is an electric motor-driven device that rotates a cork disc with germinating seeds attached. It can be turned 90° to rotate horizontally or vertically. The clinostat is used to demonstrate tropisms, such as geotropism in roots. Two clinostats are turned on their sides, with one switched on and the other off. The radicles of the beans on the control clinostat grow downwards under gravity, while those on the moving clinostat grow horizontally. The changing direction of the gravitational stimulus cancels out the geotropic response.

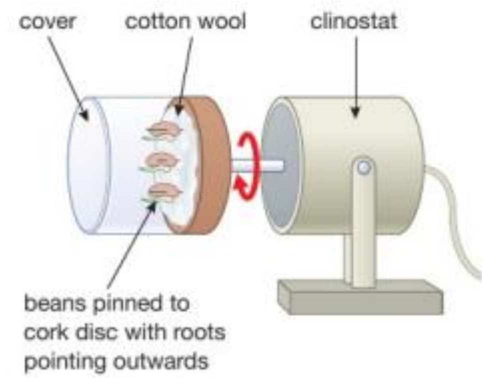


Figure 12.8 A clinostat

3.13 Reproduction in plants

SEXUAL AND ASEXUAL REPRODUCTION

You have seen how animals can reproduce sexually and asexually (Chapter 9). Plants can also carry out both types of reproduction. Table 13.1 summarises some of the differences between the two methods of reproduction.

Table 13.1 Sexual and asexual reproduction compared.

Feature of the process	Sexual reproduction	Asexual reproduction
gametes produced	yes	no
fertilisation takes place	yes	no
genetic variation in offspring	yes	no
has survival value in:	changing environment	stable environment

ASEXUAL REPRODUCTION IN PLANTS

There are many different methods of asexual reproduction in plants. Most involve some part of the plant growing, and then breaking away from the parent plant before developing into a new plant (Figure 13.1).

Gardeners often take advantage of the ways that plants can reproduce asexually. They use runners, bulbs and tubers to produce more plants.

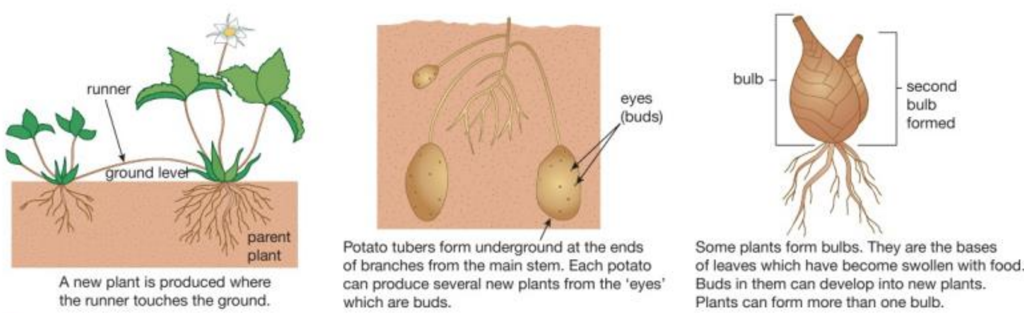


Figure 13.1 Some methods of asexual reproduction in plants

Another type of asexual reproduction is to grow plants from **cuttings**. A piece of a plant's stem, with a few leaves attached, is cut from a healthy plant. This is planted in damp soil or compost, where it will grow roots and develop into a new plant (Figure 13.2).

▲ Figure 13.2 These geranium cuttings have started to grow roots

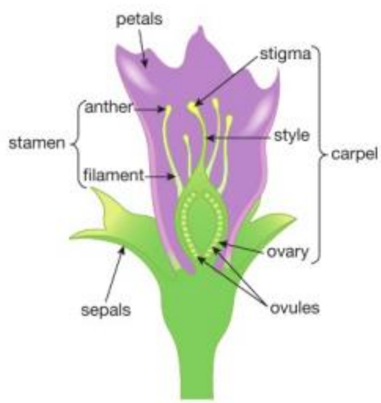
SEXUAL REPRODUCTION IN PLANTS

Plants produce specialised, haploid gametes in their flowers. The male gametes are contained within the **pollen grains** and the female gametes are egg cells or **ova**. Just as in animals, the male gametes must be transferred to the female gametes. This takes place through **pollination**, which is normally carried out either by wind or insects. Following pollination, fertilisation takes place and the zygote formed develops into a **seed**, which, in turn, becomes enclosed in a **fruit**.

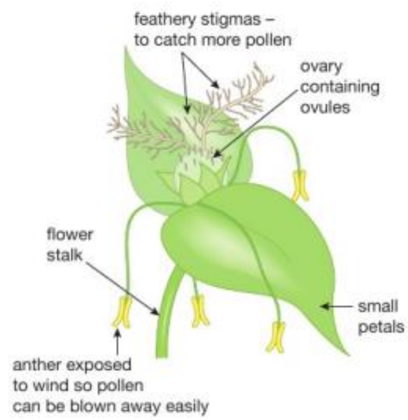
Production of gametes and pollination

The gametes are produced by meiosis in structures in the flowers. Pollen grains are produced in the **anthers** of the **stamens**. The ova are produced in **ovules** in the **ovaries**.

In pollination, pollen grains are transferred from the anthers of a flower to the **stigma**. If this occurs within the same flower it is called **self-pollination**. If the pollen grains are transferred to a different flower, it is called **cross-pollination**. Pollination can occur by wind or by insect in either case.



▲ Figure 13.3 The main structures in an insect-pollinated flower.



▲ Figure 13.4 The main structures in an wind-pollinated flower.

Fertilization

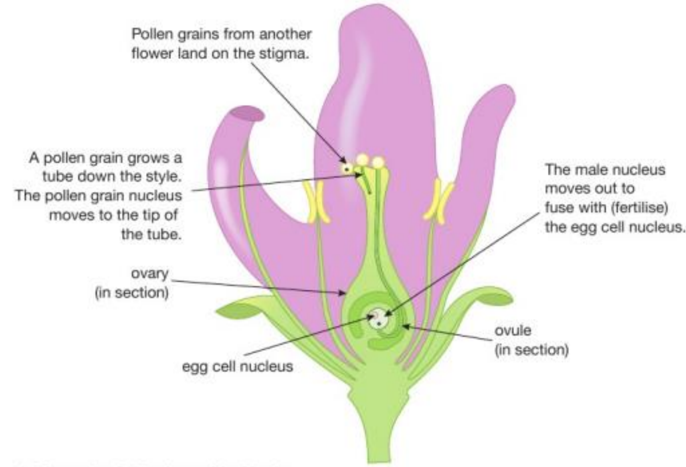
Pollination transfers the pollen grain to the stigma. However, for fertilisation to take place, the nucleus of the pollen grain (the male gamete) must fuse with the nucleus of the ovum, which is inside an ovule in the ovary. To transfer the nucleus to the ovum, the pollen grain forms a **pollen tube,** which grows down through the tissue of the **style** and into the ovary. (figure 13.5)

Table 13.2 Differences between insect-pollinated and wind-pollinated flowers.

Feature of flower	Type of flower	
	Insect-pollinated	Wind-pollinated
position of stamens	enclosed within flower so that insect must make contact	exposed so that wind can easily blow pollen away
position of stigma	enclosed within flower so that insect must make contact	exposed to catch pollen blowing in the wind
type of stigma	sticky so pollen grains attach from insects	feathery, to catch pollen grains blowing in the wind
size of petals	large to attract insects	small
colour of petals	brightly coloured to attract insects	not brightly coloured, usually green
nectaries	present – they produce nectar, a sweet liquid containing sugars as a 'reward' for insects	absent
pollen grains	larger, sticky grains or grains with hooks, to stick to insects' bodies	smaller, smooth, inflated grains to carry in the wind

Seeds and food formation

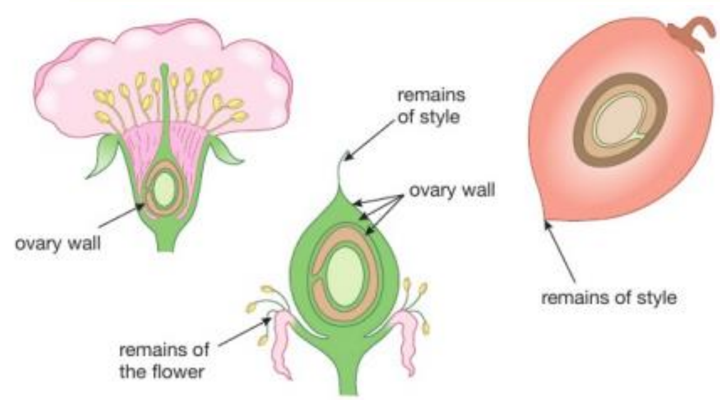
Once fertilisation has occurred, a number of changes take place in the ovule and ovary that will lead to the fertilised ovule becoming a seed and the ovary in which it is found becoming a fruit. Different flowers produce different types of fruits, but in all cases the following four changes take place.



▲ Figure 13.5 Pollination and fertilisation

1. The zygote develops into an embryonic plant with small root (**radicle**) and shoot (**plumule**).
2. Other contents of the ovule develop into a food store for the young plant when the seed germinates.
3. The ovule wall becomes the seed coat or **testa**.
4. The ovary wall becomes the fruit coat; this can take many forms depending on the type of fruit.

Figure 13.6 summarises these changes as they occur in the plum flower, which forms a fleshy fruit.



▲ Figure 13.6 How a plum fruit forms

GERMINATION

A seed contains a plant embryo, consisting of a root (radicle), shoot (plumule) and one or two seed leaves, called **cotyledons**. It also contains a food store, either in the cotyledons or another part of the seed.

The seeds of plants such as peas or beans have two cotyledons. They are called dicotyledonous plants, or **dicots**. Seeds of grasses and other narrow- leaved plants, such as irises and orchids have only one cotyledon. They are monocotyledonous plants, or **monocots**.

The conditions needed for germination

The growth of a new plant from a seed is called **germination**.
Germination needs the following conditions:

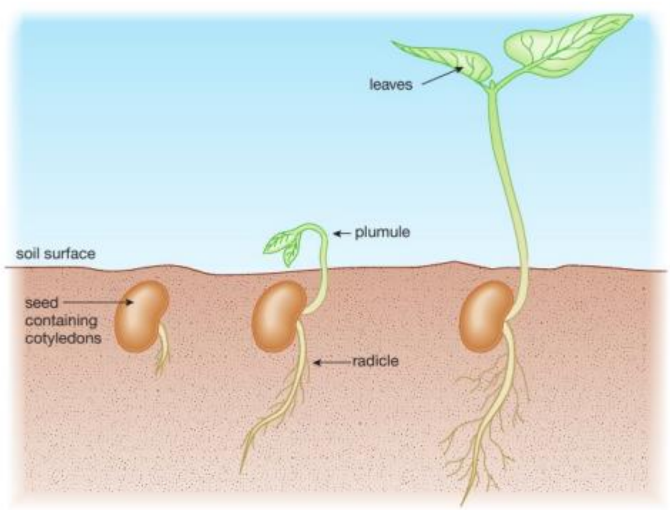
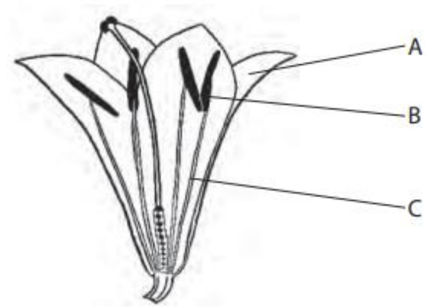


Figure 13.7 Germination in the broad bean. In this species, the cotyledons contain a food store. They remain below the ground when the seed germinates. In other species (e.g. the French bean), they are carried above the ground during germination.

■Warm temperatures, so that enzymes can act efficiently (see Chapter 1)
■Water, for chemical reactions to take place in solution
■Oxygen, for respiration.

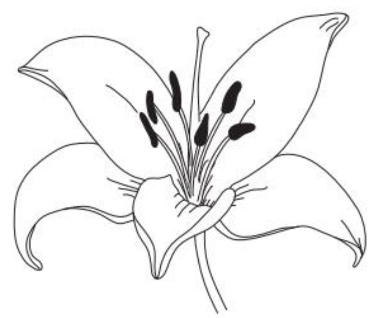
Revision questions

1. Plants can reproduce sexually or asexually.
Plants that reproduce sexually can be pollinated by insects or by wind.
(a) State three ways in which the structure of insect-pollinated flowers differs from the structure of wind-pollinated flowers.



(b) The diagram shows a flower from a plant.
Name the structures labelled on the diagram.
(c) The flower in the diagram is insect pollinated.
An insect carrying pollen lands on the flower. Describe the events that lead to seed formation.

2.The diagram shows an insect pollinated flower called a lily
(a) Describe the features of an insect pollinated flower that help it to attract insects.



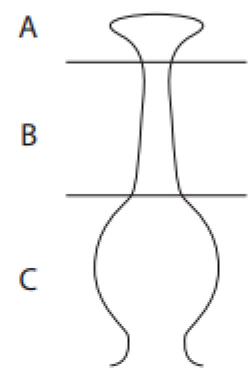
(b) Sexual reproduction in flowering plants and mammals involves the process of gamete formation by meiosis followed by fertilisation. Use the words from the box to complete the table about sexual reproduction in flowering plants and mammals. Each word can be used once, more than once or not at all.

anther	copulation	fallopian tube	ovary	ovule
placenta	penis	pollination	seed	testes
uterus	vagina	zygote		

	In flowering plants	In mammals
female gametes are made in the		
male gametes are made in the		
gametes are brought together by		
fertilisation takes place in the		
embryos develop in the		

(c) Cell division in an organism can take place by mitosis or by meiosis. Give three ways in which mitosis differs from meiosis
(d) Suggest why a flower grower may want his coloured flowers to reproduce asexually

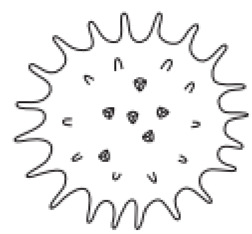
3)The drawing shows part of a flower involved in sexual reproduction. The drawing has been separated into three sections A, B and C.



(a) Complete the table by giving the correct letter for the section that matches each statement. Each letter may be used once, more than once or not at all. The first one has been done for you

Statement	Section letter
This is the stigma	A
This is where fertilisation occurs	
This is where the pollen grains land at pollination	
This is where most pollen tube growth occurs	
This is where a seed will develop	

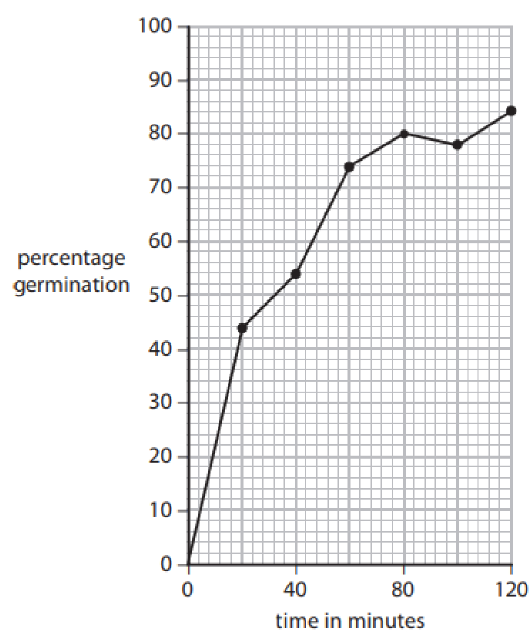
(b) The drawing shows a pollen grain from an insect-pollinated flower as seen using a microscope.



Suggest how the structure of this pollen grain shows it is from an insect-pollinated flower.

(4) Pollen grains were placed in a solution that helps them to germinate (grow a pollen tube). A microscope was used to observe the pollen grains for two hours.

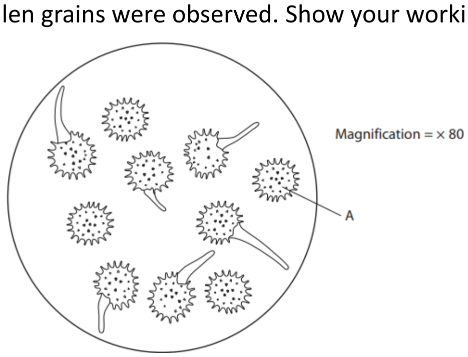
The percentage of pollen grains that had started to germinate was measured during the two-hour period. The graph shows the results.



(i) Describe how the percentage germination changed during the two-hour period.

(ii) The drawing shows pollen grains seen using the microscope at one time during the two hours.

Use the drawing and the graph to determine the time when these pollen grains were observed. Show your working.



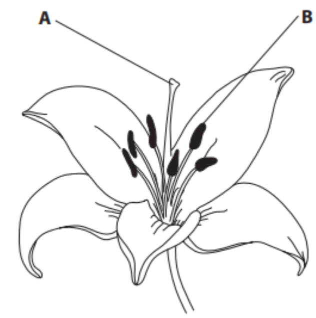
(iii) Calculate the actual size of the pollen grain labelled A. Show your working.

(d) Explain the benefit to the plant of producing offspring by sexual reproduction rather than by asexual reproduction.

(5) Flowers are reproductive organs. They help flowering plants with sexual reproduction.

(a) Suggest how sexual reproduction makes it more likely that a species can adapt to a changing environment

(b)The diagram shows part of a lily. A lily is an insect-pollinated flower



(c) Name the structure labeled in A ,B.

(d)Describe what is meant by insect – pollution

(e)Describe the events that follow pollination and how they lead to seed formation

(6) Read the passage below. Use the information in the passage and your own knowledge to answer the questions that follow.

Bees

Photographer: Eigene Aufnahme, August 2006

Bees are insects that are important for the pollination of flowers of many plants. Bees are attracted to flowers to collect a sweet substance called nectar. After collecting nectar they return to their nest. Some of the nectar is used to make honey. Humans keep bees in small homes called hives and collect some of the honey. The bees live in a group called a colony inside the hive and they do not mate as individual pairs like most insects.

Each bee colony consists of a single fertile queen bee and her many infertile female offspring called worker bees. The colony also contains her male offspring called drones.

Under normal circumstances the fertile queen bee will fly out of the hive to mate with a number of drones from different hives. The queen takes the risk of mating in this way so that her offspring have extra genetic variation that may help to combat disease. The sperm are stored in the queen's body and released a few at a time as the eggs are laid. Some of the eggs may be fertilised by the sperm and some may not be fertilised. Fertilised eggs develop into worker bees with diploid body cells. Unfertilised eggs develop into drones.

The body cells of the fertile queen bee contain 32 chromosomes. The sperm cells produced by a single drone contain 16 chromosomes which are genetically identical to those of the other drones. If a queen bee mates with only one drone all the worker bees in the hive receive identical alleles from the drone and all the genetic variation comes from the queen. If the queen mates with two or more drones from different hives there will be greater variation in the worker bees.

It has been difficult to improve the characteristics of bees by selective breeding because bees do not mate as individual pairs. However, in the colony there are a small number of virgin queen bees that have not yet mated. These virgin queen bees can be used in selective breeding to form new colonies.

(a) What is meant by the term pollination (line 1)?
(b) Suggest why the bees collect nectar (lines 2 and 3).
(c) Suggest what is meant by the term fertile (line 7).
(d) Suggest how having 'extra genetic variation' may help the bees to combat disease (lines 12 and 13).
(e) How many chromosomes would you expect to find in an unfertilised bee egg?
(f) Explain what determines the genetic variation in worker bees
(g) Suggest two characteristics of a colony that would encourage a beekeeper to use the colony for selective breeding.

(7) (a) The table lists some processes used in plant reproduction.
In each box, place a tick (9) if the process helps to produce offspring with genetic variation, or a cross (8) if it produces offspring with no genetic variation. The first one has been done for you.

Process	Genetic variation in offspring
runners producing new plants	×
micropropagation	
wind-pollination	
taking cuttings	
self-pollination of a flower	

(b) The photograph shows an eight-celled human embryo produced in human reproduction.

Describe the events that take place at fertilisation and up to the production of the eight-celled human embryo.