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Growing Plants

To grow healthy plants they need a suitable environment. This includes:

- light for photosynthesis
- warmth for enzymes to work at their fastest rate
- a humid atmosphere to prevent too much water loss
- water to keep the leaves turgid and for photosynthesis
- fertiliser to provide nutrients
- a growing medium eg. soil or compost

If these conditions are not met, the plant can become unhealthy and show the following signs.

An Unhealthy Plant

Stunted growth due to lack of nutrients.

Signs of Pest Damage such as discolouration of leaves, curled leaves or holes in leaves

Yellow leaves due to lack of nutrients. A lack of cholorphyll means less photosynthesis takes place

Fungal Infections such as **damping off in seedlings.** White mould is often seen and stems collapse.

Aphids suck the cell sap so reducing the glucose available to the plant to produce energy in respiration

Wilting of Leaves due to a lack of watering. Plants lose water by transpiration faster than it can be replaced from the soil

Poor crop yield including fruits and flowers

Nutrition In Plants

(a) Nutrients

Plants require three main **macro-nutrients** for healthy growth. These macro-nutrients are required in large amounts and are:

1. **Nitrogen (N)** which is needed to make proteins and is therefore needed for **leaf and shoot growth**. A plant lacking in nitrogen will have yellow leaves (a condition known as chlorosis) and will have stunted growth. However, too much nitrate can lead to crops growing tall and spindly and therefore falling over. It also can lead to reverse osmosis which draws water out of the roots, burning them.
2. **Phosphorus (P)** which is needed to make DNA. A plant lacking in phosphorus will have very poor **root growth** and will have purplish leaves.
3. **Potassium (K)** (sometimes called potash by gardeners) which is needed for the enzymes controlling photosynthesis and respiration to work. A plant lacking potassium will have yellow leaves with dead spots. It is also needed for formation of fruit and flowers so a plant lacking potassium will produce few **fruit and flowers**.

Micro-nutrients are required by plants in much smaller quantities. These include calcium, magnesium and copper and are sometimes called **trace elements.**

Fertilisers

In nature, plants grow, die and then decompose releasing their nutrients back into the soil. However, if plants are grown for food they are harvested and so the nutrients they contain are not recycled. The farmer therefore has to add nutrients to the soil in the form of **fertilisers.** There are two different categories of fertilisers, organic and inorganic.

Organic Fertilisers

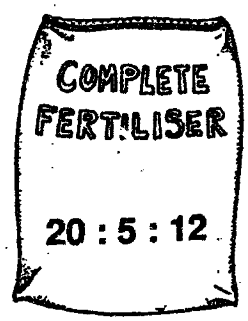
These are made from the dead and decaying organic matter. They are completely natural and contain no **artificial** chemicals. Examples include:

- Farmyard Manure, which consists of the faeces and urine of farm animals
- Garden compost, which is made from the decayed remains of garden and household waste.
- Green manure which is when a leguminous crop such as peas are grown then ploughed back into the soil. Legumes contain bacteria in nodules in their roots, which can fix atmospheric nitrogen. The legumes are therefore rich in nitrogen and this is returned to the soil when they are ploughed in.

Organic fertilisers are cheap but can be difficult and time consuming to apply. They add humus to the soil therefore improving crumb structure. They contain both macro and micronutrients but these are not in known quantities. They release their nutrients into the soil slowly over a long period of time, which is good long term but does not add nutrients to the soil immediately.

Inorganic Fertilisers

These contain all three macro-nutrients. The ratio of nitrogen, phosphorus and potassium is shown on fertiliser packaging as follows:



This means that there is a ratio of 20 parts nitrogen to 5 parts phosphorus to 12 parts potassium.

Different crops need different ratios of the three macro-nutrients.

- **brassicas** such as cabbage require good leaf growth so are given fertilisers high in nitrogen, **2:1:1**
- **tomatoes** require good fruits and flowers so are given fertilisers high in potassium, **1:1:2**
- **grasses** require high levels of nitrogen to enable them to grow quickly and give them a deep green colour, **2:1:1**
- **legumes** such as peas and beans can fix their own nitrogen using bacteria in their nodules and so require little extra nitrate but can be given extra potassium for fruiting, **0:1:2**
- **root crops** such as carrots require good root growth so are given fertilisers high in phosphorus, **1:2:1**
- general purpose fertilisers have equal ratios of the three macro nutrients, **1:1:1**

Inorganic fertilisers can be added to the soil in the form of granules or powder which can be spread easily. Granules are generally better because they do not get blown away. Inorganic fertilisers are more expensive but they do not improve crumb structure. They do not contain micro-nutrients, but they do contain large, known amounts of NPK. They also release their nutrients quickly. Nitrate is very soluble and over application can lead to it leaching into rivers causing eutrophication.

pH and Soil Nutrients

Plants can only absorb nutrients from the soil when they are dissolved in the soil water. In the soil, positively charged nutrient ions (cations) are often attached to the negatively charged surfaces of the humus and clay (these are called cation exchange surfaces). This means that they are not dissolved in the soil water and therefore not available to the plant.

Soil pH influences the availability of nutrients in the soil in a number of ways.

1. At neutral pH the cations are released from the cation exchange surfaces and this therefore increases the concentration of potassium, magnesium and calcium in soil solution.

2. At very low soil pH's (acidic conditions) aluminum ions become soluble and these can kill the plant. This can occur as a result of acid rain.

3. Nitrates become available in neutral to alkaline pH's.

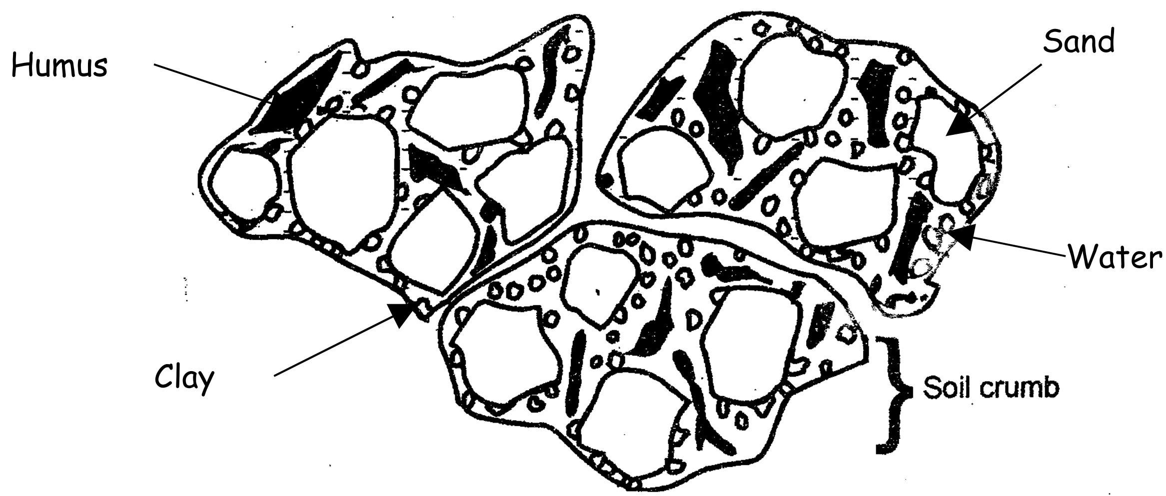
4. Liming raises the pH of the soil solution therefore making more nutrients available and allowing plants to grow more successfully.

5. Liming also improves drainage in clay soils by causing clay particles to stick together (flocculate) producing larger particles with larger air spaces.

Soil Crumbs

Soil is made up of both organic and inorganic components. The inorganic particles, clay, silt and sand, are held together by humus, to form irregular shaped lumps with diameters of less than 1cm. These are known as soil crumbs. A good crumb structure helps to prevent soil erosion, aerates the soil and improves soil drainage.

Humus in the form of Farmyard manure helps to produce a good crumb structure as well as release nutrients as it decomposes.



Poor drainage in soils results in waterlogging. This is when all the air spaces are filled up with water. Lack of air in the soil prevents respiration of soil organisms and plant roots, so there will be few organisms in a waterlogged soil and plant growth will be stunted.

Management of Soils

Soil can be cultivated by hand using the following tools:

Rake -produces a tilth, levels soil and can be used to produce a seed drill

Fork -for turning the soil over to bury weeds and digging up potatoes

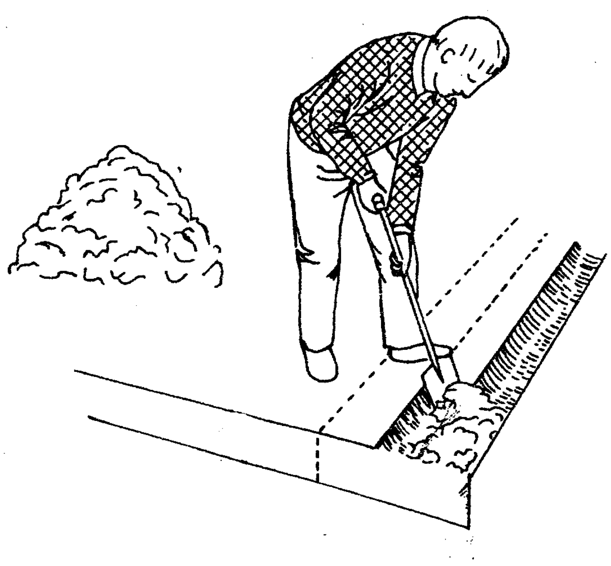
Hoe -for weeding

Spade-for digging trenches

Preparing Soil By Hand

Soils should be dug over in autumn rather than spring because weeds will decay over winter and frost will help to break up heavy soils. Single digging involves digging a trench at one end of the plot. Then transferring the soil from the next trench into this trench and so on until the last trench is filled with soil from the first. If the bottom of the trench is forked before being covered with soil this is called Bastard Trenching. Single digging:

(b) helps aerate the soil
(c) allows removal of perennial weeds such as bindweed
(d) allows FYM to be incorporated into the soil
(e) breaks up the soil to improve drainage



After single digging the soil is raked to remove large stones and produce a good tilth. However, too much raking destroys soil crumbs. A good tith is important for seed germination and plant growth because it allows good drainage and aeration so the soil does not become waterlogged and therefore the seeds will not be washed away and will have oxygen for respiration.

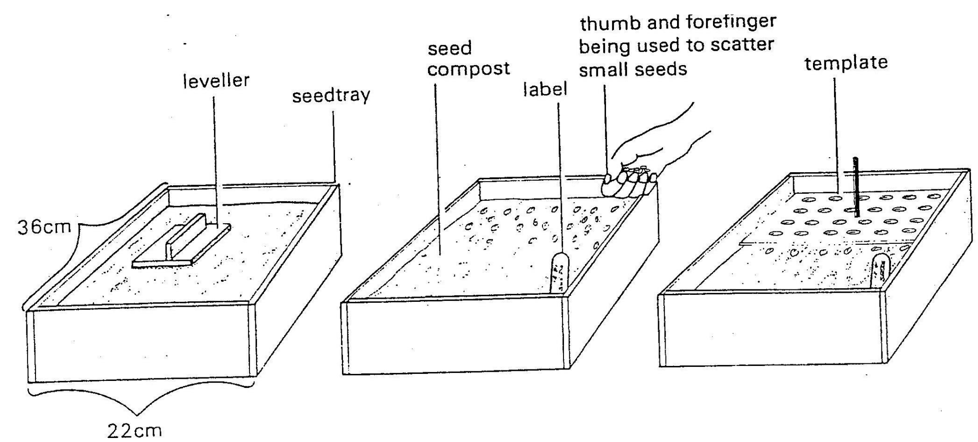
Preparing Soil By Machine

A plough is used to cultivate large areas of land. It is used for deep cultivation and turns the soil over burying any weeds. After this a harrow may be used which cultivates the surface breaking up clods and clumps of soil to provide a fine tilth for sowing.

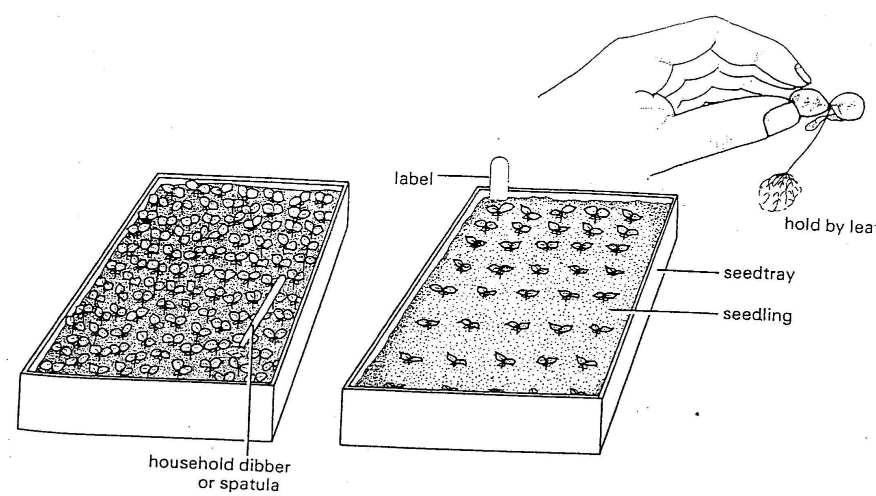
Using large machinery may result in soil compaction. This reduces air spaces and drainage. A plough pan is a compact layer of soil below the depth of the plough which can result from long term use of the plough.

Growing A Glasshouse Crop eg Tomatoes

1. Fill the seed tray three quarters full of moist compost and firm it down with a leveller. Scatter the seeds thinly over the surface and cover the seeds to a depth of twice their height. Firm down the compost again. Place the tray in a larger tray of water so the water can rise up through the compost. Label it and place in a warm environment.



2. As soon as the seedlings are large enough to handle prick them out into another seed tray. This should be done as early as possible to prevent damage to their roots. The seedlings should be handled by their leaves to prevent damage to their stems and their roots should be disturbed as little as possible. Space the seedlings in lines far enough apart to allow them to grow without competition.



3. The growing seeds should be placed in a warm place with plenty of light but out of direct sunlight and watered regularly.
4. When the roots have reached the bottom of the tray re-pot into a larger pot.
5. The tomatoes will need to be supported using a cane because they are weak stems.
6. Once the plants are growing remove any side shoots to enable them to grow tall and produce a good crop of large fruits.
7. Feed the tomatoes with fertiliser rich in potassium to ensure good flower and fruit formation.
8. Water and feed regularly.

Growing An Outdoor Vegetable Crop eg. Carrots

1. Prepare soil to produce a good tilth
2. Use a garden line to mark out where the seeds are to be planted.
3. Produce a seed drill with the edge of a rake approximately 1 cm deep
4. Sow the seeds thinly in the drill
5. Lightly rake the correct depth of fine soil over the seeds with the edge of a rake
6. Water the seeds thoroughly in dry weather
7. When the seeds start to germinate thin them out so that they are about 2 cms apart. This gives the plants room to grow and develop and allows a large crop.
8. Continue to weed around the plants to reduce competition and water if necessary.

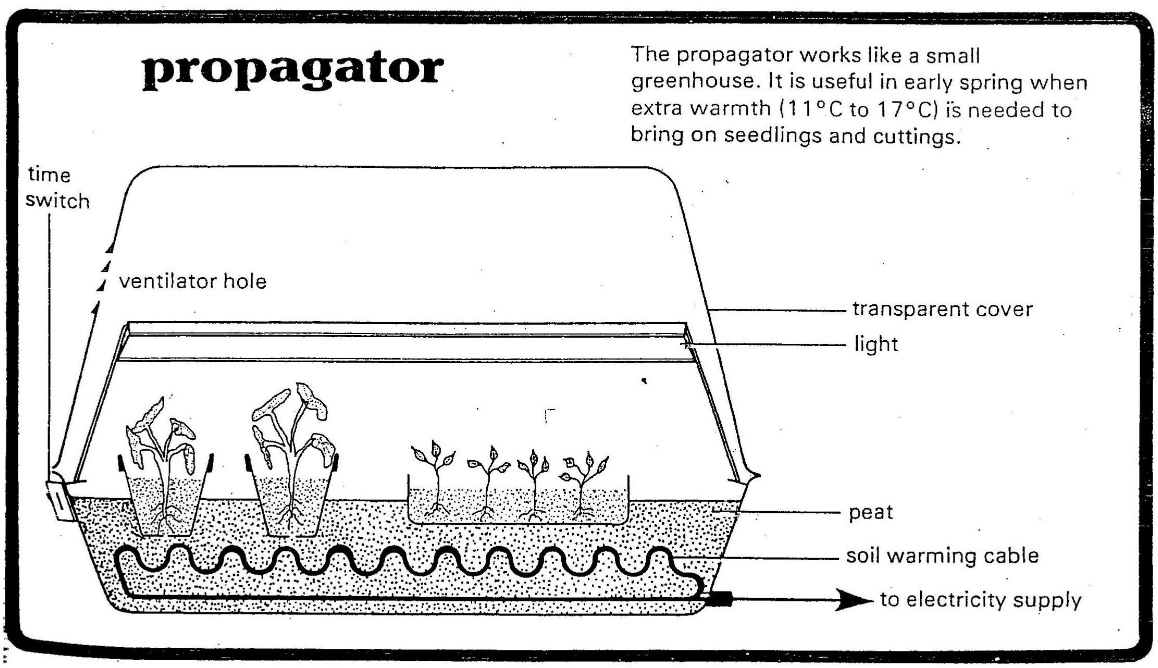
Controlled Environments

Glasshouses or Polytunnels allow growers to control the amount of heat, light, water, nutrients and CO_2 the plant receives.

Heating

Electric heating fans can be connected to a thermostat which turns them on when the temperature falls below a fixed level and cuts them off when the fixed temperature is reached. Heating is needed in the winter in order to keep the glasshouses frost free and in early spring to allow seeds to germinate and seedlings to grow earlier than outside. In addition heating provides an ideal temperature for enzymes to work so that reactions in photosynthesis occur as rapidly as possible.

Using a **heated propagator** means that you do not need to heat the whole greenhouse to a high temperature, so it saves money.

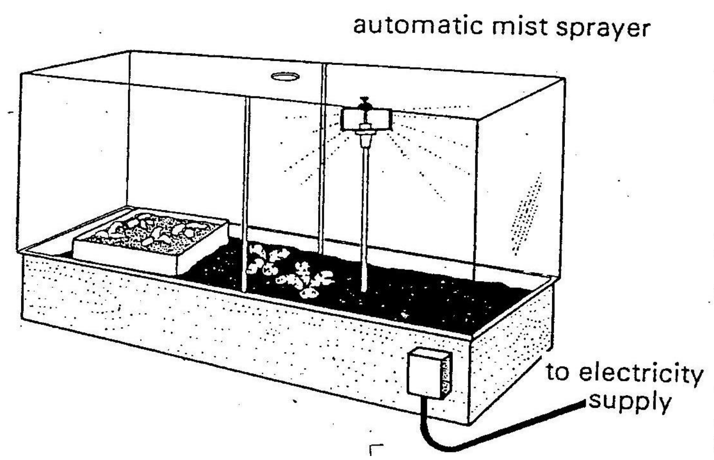


Soil warming cables in propagators warm the soil for maximum growth. A Perspex or plastic cover helps keep the air moist and prevent plants wilting.

Carbon dioxide
Free standing paraffin and gas heaters can be used in large structures to provide CO_2 for photosynthesis. They also supply heat.

Ventilation
This is provided by windows which open either automatically or by hand. Plants need a constant supply of carbon dioxide for photosynthesis and oxygen for respiration. Good ventilation prevents air becoming too humid and so helps prevent fungal infections such as damping off.

Irrigation
Plants need a constant supply of water in order to keep their leaves turgid. A **mist propagator** has a fine mist spray of water that switches on when the air begins to dry out. An advantage is that they keep the air humid so reducing transpiration and so preventing water loss from plants. They are also good for cuttings that lack roots and are therefore unable to replace lost water.



Capillary matting can also be used as a means of self watering. This is placed along the bench in the greenhouse or propagator with one end trailing into a water trough. The water is drawn along the matting by capillary action and up through the base of pots into the compost. It provides water directly to the roots and does not wet the leaves that in bright sunlight can result in scorching.

Lighting
Sometimes fluorescent tubes can be used to provide artificial light to increase the time for which the plant can photosynthesise.

Reproduction In Plants

a) Vegetative Reproduction

Vegetative reproduction is asexual reproduction. It does not require any fertilisation and only involves one plant. The offspring produces are all genetically identical to the parent plant because they have the same genes as the parent.

Advantages:

- Lots of new plants can be produced very quickly and cheaply
- All the new plants will be identical so the grower can be sure of their colour

Disadvantages:

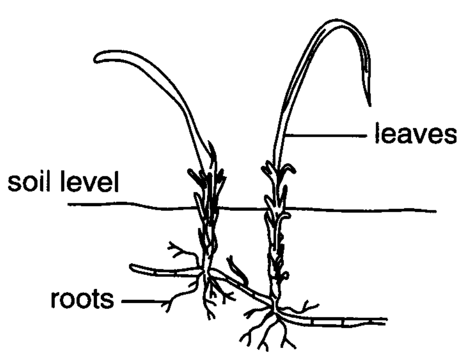
- There is no variation in the offspring so the plants will not be able to evolve by natural selection
- Any diseases in the parent plant will be easily spread to the next generation

There are a number of methods by which plants can reproduce vegetatively.

(i) Rhizomes

Eg. Ginger, asparagus

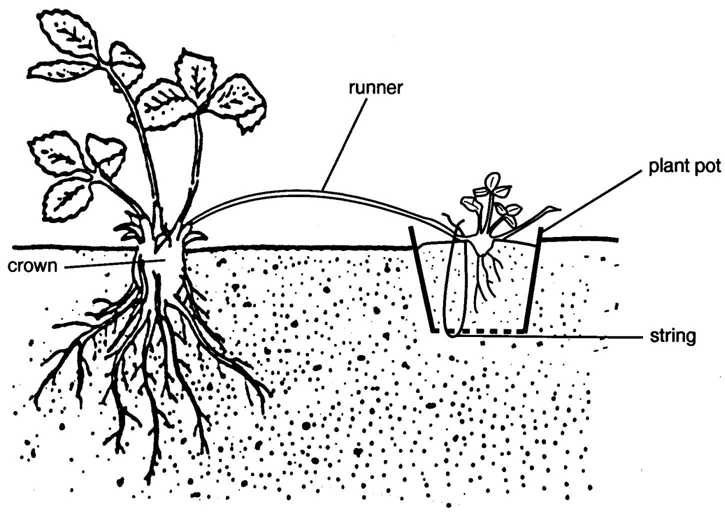
The plant produces an underground stem. From this underground stem a new plant grows.



(ii) Runners

Eg. Strawberries

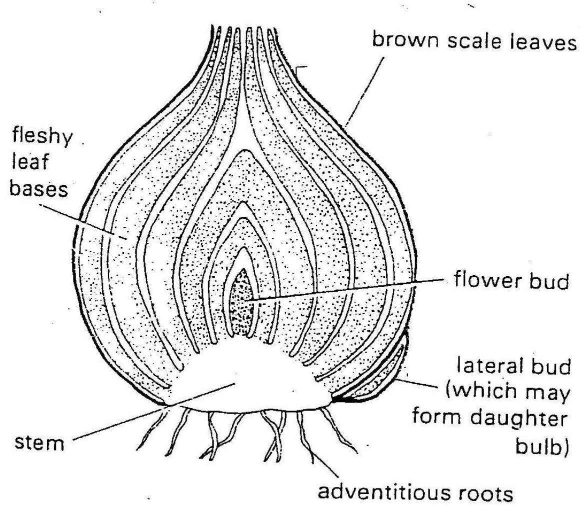
Strawberries propagate themselves by growing **runners** (above ground stems) with very long internodes. Each node grows into a new plant.



(iii) Bulbs

Eg. Onions

A bulb consists of a short stem on which are growing overlapping leaves called **scale** leaves. These leaves are swollen with food stores. The new flower stem starts growing from the centre. As it grows it will start to use the food stored in the fleshy leaves. The whole bulb is covered in protective scales.



b) Sexual Reproduction

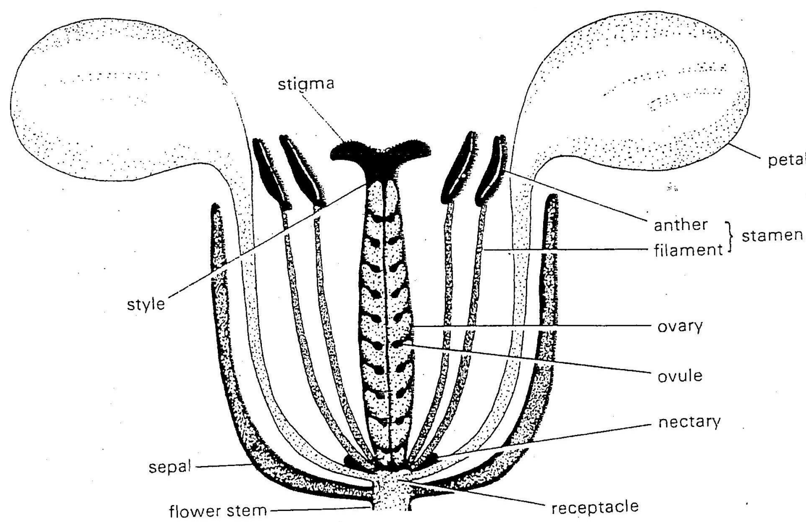
Flowers are the organs of sexual reproduction implants. Seeds produced grow into new plants, which are genetically different from either parent because they contain a mixture of genes from both parents.

Advantages

- All the offspring produced are genetically different. This variation allows new varieties to be produced that, for example, have a higher yield.

Disadvantages

- More than oneplant is needed so that pollination and fertilisation can occur
- Takes longer than asexual reproduction because the new plant has to grow from seed.



Anther - produces hundreds of male sex cells (gametes) called pollen.

Stigma - where the pollen from other flowers collects; it is often sticky so that the new pollen does not blow away.

Ovary - holds the ovules or eggs. As the flower dies, the ovary begins to grow and will form a **fruit**.

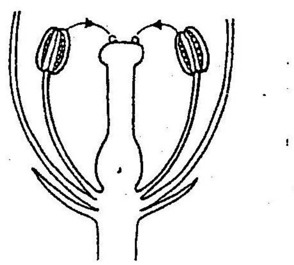
Ovule - an ovule or egg is a tiny female sex cell. Each ovule will develop into a **seed** if it is fertilised.

Sepal: - protects the flower in bud.

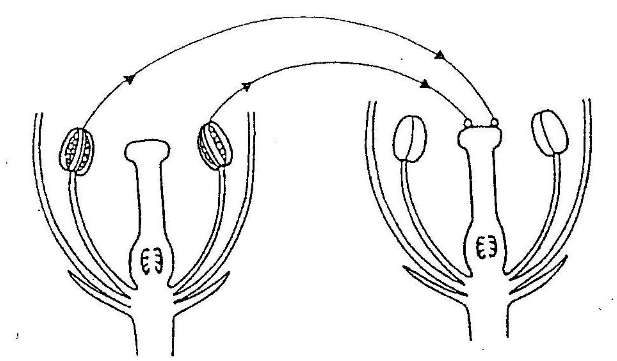
Pollination

Pollination is the transfer of pollen from the anthers of a flower to the stigma of another flower of the same species. It can occur in two ways:

a) Self pollination: This is the transfer of pollen form the anthers of one flower to the stigma of the **same** flower. The advantage of this is that no other plant is needed. The disadvantage is that there is no exchange of genetic material so all plants will be very similar to the parent. Self pollination can be avoided by removing the stamens of the flower before breeding so that only pollen from another flower can fertilise it.



b) Cross-pollination: This is the transfer of pollen from the anthers of one flower to the stigma of another flower of the same species. This results in increased variation in the seeds due to mixing of alleles from different plants. The pollen can be transported either by wind or by insects:



Insect pollinated flowers

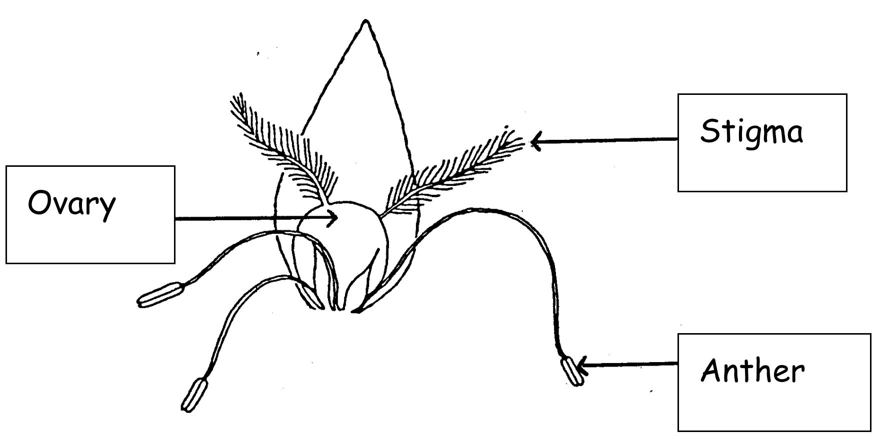
These are flowers in which the pollen is carried from flower to flower on the bodies of insects. These flowers have the following adaptations:

- large, brightly coloured, scented petals to attract insects
- nectar to attract insects which feed on it. This is produced by nectaries in the base of the flower and is a sticky, sweet substance.
- anthers positioned inside the flower in such a way that insects brush past them when they collect the nectar and so get covered in pollen.
- sticky stigmas positioned in such a way that insects deposit the pollen onto them and the pollen then sticks to them
- large pollen grains produced in relatively small quantities so that they stick to the insects. The likelihood of them reaching another plant is high so only small amounts of pollen are needed.

Wind pollinated flowers

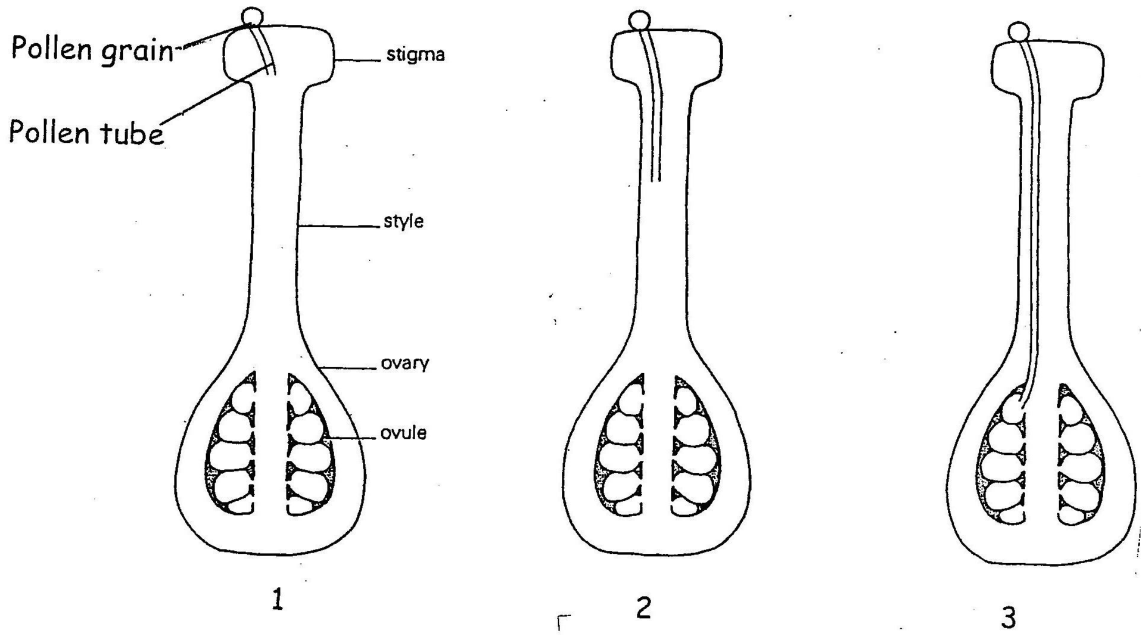
Pollen is carried from flower to flower by currents of air. The flowers have the following adaptations:

- the petals are small and green and they do not produce nectar. They do not need to attract insect and do not want to waste energy producing unnecessary features.
- the anthers are large and hang outside the flower so that they are easily shaken by the wind causing the pollen to fall off.
- the stigmas are large and feathery and also hang outside the flower so that they are able to trap any air borne pollen.
- they produce light pollen so that it is easy to transport by the wind. They produce large quantities of pollen because it is less likely to reach the stigma of other plants. It is wind pollinated flowers that cause hay fever.



If plants are grown in enclosed structures like polytunnels or glasshouses it is important that pollination still occurs. This can be achieved by introducing insect pollinators or artificial wind generators.

Fertilisation

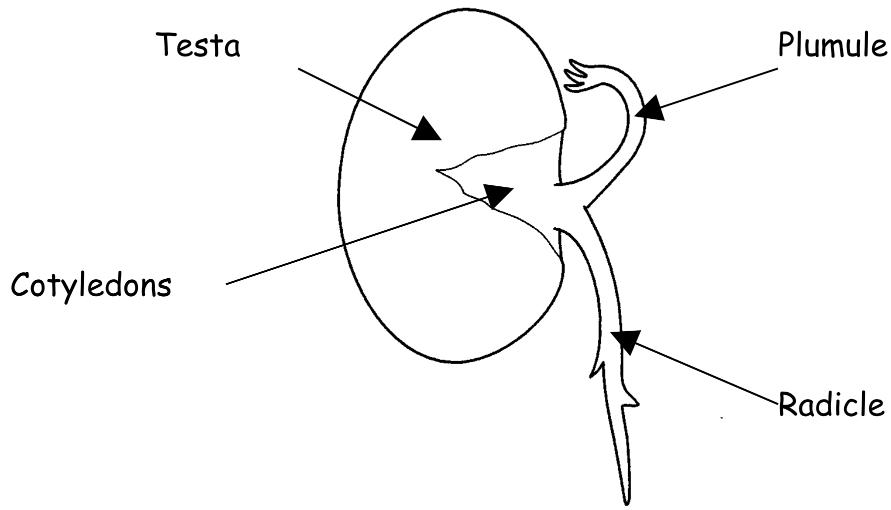


The pollen grain lands on the stigma and absorbs nutrients from it. (1) A pollen tube grows from it, which passes down the style (2) and penetrates the ovary. Inside the ovary the tube continues to grow until an ovule is reached (3). The pollen tube pierces the ovule and the male nucleus in the pollen grain fuses with the female nucleus from the ovule. Once the ovule is fertilised it can develop into a seed.

The Fruit and Seed

The fertilised ovule becomes the seed from which an embryo can grow into a seedling. The layers around the ovule become the testa or seed coat. The ovary begins to swell to make room for the developing seeds and to change into a fruit.

Seeds



Testa: the tough outer coat, which protects the seed from fungi and bacteria. It splits when the seed germinates.

Cotyledons: they contain food for the growing seed.

Radicle: the young root

Plumule: the young shoot

Germination

When provided with the correct conditions an embryo plant will start to develop. This is called germination. All seeds require the following conditions before they will germinate:

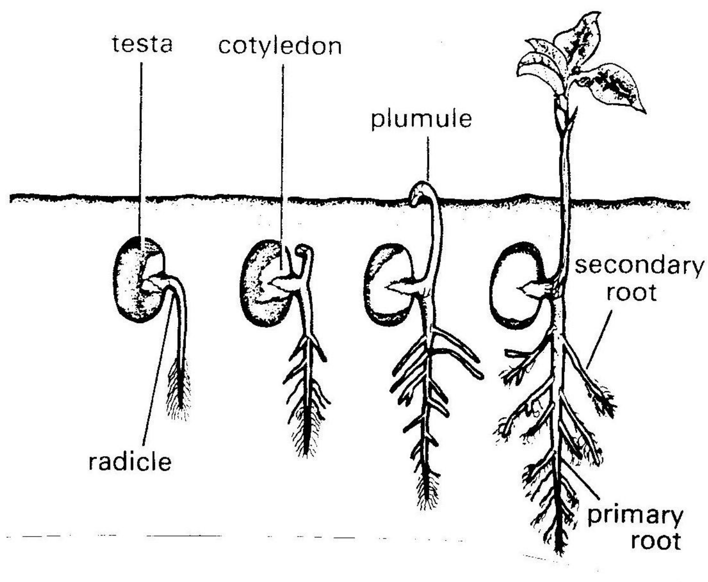
- **Moisture** in order to swell the seed and break open the seed coat. This water enters the seed through the micropyle. Also water is needed to dissolve the food stores to provide energy.
- **Warmth** to enable the enzymes necessary for respiration to work.
- **Oxygen** for respiration to provide the energy needed for growth.

Most seeds do not require light for germination – it is dark in the soil. A few, however, such as lettuce, will only germinate in the light. Seeds germinate better in cultivated plots because there are more air spaces to provide oxygen and improve drainage. They germinate best just below the surface where it is dark and warm and they cannot be eaten. If seeds are planted too deep they can run out of food reserves before their first leaves are produced for photosynthesis.

Stages of Germination

eg. Broad bean

- The seed absorbs water mainly through the micropyle. The seed swells and the testa bursts.
- The radical grows downwards forming the primary root.
- In the second stage of growth the plumule thrusts upward in the form of an arch to prevent the important growing tip from damage while pushing through the soil.
- More roots come from the primary root. The plumule straightens up and the first leaves unfold.



Inheriting Characteristics In Plants

Genes control the development of inherited characteristics. They always work in pairs called **alleles.** One allele is always **dominant** over the other, which is **recessive.** During sexual reproduction, male gametes (pollen) containing half the genes of the father, combine with female gametes (eggs) containing half the genes of the mother, to form a new individual or offspring.

Example:
T = allele for tallness in peas is dominant. Dominant alleles are always expressed in the heterozygous form
t = allele for shortness in peas is recessive. Recessive alleles are only expressed in the homozygous form.
A tall pea plant is crossed with a short pea plant.

Gametes for Short pea plant	**Gametes for Tall pea plant**		
		T	**T**
	t	**Tt**	**Tt**
	t	**Tt**	**Tt**

The **F1 (first) generation** are all tall. These are known as F1 hybrids.

Genotype This is the genes that the plant has eg. Tt

Phenotype This is what the plant looks like eg. tall

Homozygous This is when the animal contains two alleles that are the same eg. BB or bb. These are also called pure breeding

Heterozygous This is when the plant contains two alleles are different eg. BbThese are also called hybrids

If the F1 generation are crossed:

Gametes	**Gametes**		
		T	**t**
	T	**TT**	**Tt**
	t	**Tt**	**tt**

Ratio of Genotypes: **1:2:1** **TT:Tt;tt**

Ratio of Phenotypes: **3:1** **tall:short**

Plant breeders know that pure breeding plants will always produce similar offspring however hybrids will show genetic variation.

Risk Assessments

When carrying out practical work it is important that any risks are minimised.

Hazard	Control
Use of chemicals eg. pesticides	• Wear protective clothing, goggles and a mask • Work in a well ventilated area • Ensure there is no-one else around
Carrying heavy objects	• When lifting any object, bend your back not your knees
Soil Pathogens	• Wash hands thoroughly after gardening
Using machinery	• Wear sturdy, non slip footwear and remove any loose fitting clothes

Using ICT

Plants will only grow at their fastest rate if all the conditions are right for photosynthesis. Growers often use ICT in large glasshouses or polytunnels to monitor conditions. Sensors, connected to a computer, detect changes and this causes equipment to be switched on or off.

Sensor	Effect
Humidity sensor	• Humidity is controlled by switching mist propagators on/off. • If humidity is too high plants can develop fungal infections • If humidity is too low plants lose too much water through transpiration and wilt
Temperature probe	• Temperature is controlled by switching heaters on/off • The temperature needs to be correct for enzymes which control photosynthesis to work at their fastest rate • If temperature is too low plants will grow slowly and seeds will not germinate • If temperature is too high plants will lose too much water
Carbon dioxide probe	• If carbon dioxide levels are too low the plants will not be able to photosynthesise as quickly and therefore will not grow as fast
pH meter	• If pH is too low (acidic) or too high (alkaline) different nutrients become unavailable to plants leading to stunted growth
Light sensor	• Light is controlled by switching fluorescent lights on/off or by opening and closing blinds • Plants need light to photosynthesise so too little light will result in poor yield

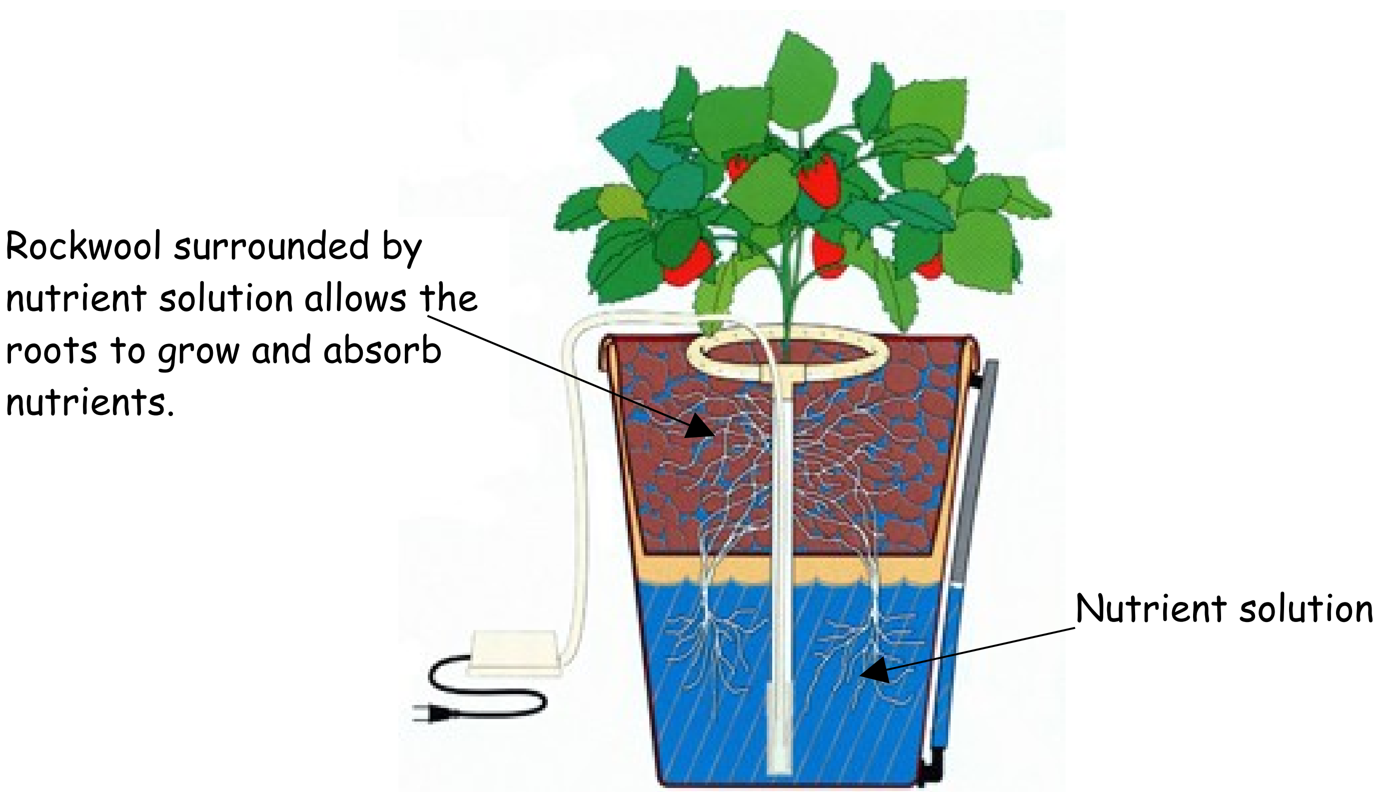
If the temperature and light levels in a glasshouse are too high then this can lead to higher costs for the grower and therefore less profit. It is also bad for the environment because it is wasting electricity which is generated using fossil fuels.

Watering and Feeding Plants

Water and fertiliser can be supplied to plants in a number of different ways.

Hydroponics:
This is a method of growing plants using mineral nutrient solution instead of soil. Plant roots absorb nutrients when they are dissolved in water. In natural conditions the soil is a source of these dissolved nutrients. However if the nutrients are supplied in the plants water artificially then soil is no longer required.

The plants may be grown with their roots in the mineral solution only or using an inert medium such as rock wool. It is in the form of lightweight balls with the water circulating between them. This technique allows water temperature to be controlled and saves water. It is often used for growing strawberries and tomatoes on a large scale.



Liquafeed

This can be used to feed flowers in borders, planters and hanging baskets. A bottle of nutrient solution is attached to the hosepipe so plants can be fed at the same time they are being watered. The plant food and water are automatically mixed so plants are not over or under fed.

Crop Storage

Crop plants often have to be stored either, because they are being transported long distances, or before use. Controlling the following can extend the length of time crops can be stored for:

Condition	Effect
Medium Humidity	• If humidity is too high then the crop may develop a fungal infection • It humidity is too low the crop may dry out and become unsuitable for use
Cool Temperature	• If temperature is too high fruits will ripen rapidly. This is because the enzymes work faster to speed up respiration • If temperature is too cold the crop could be damaged by freezing
No Pests and Diseases	• Pests must be kept away from the crop by storing in a sealed container • Pests and diseases must be prevented from spreading by disinfecting the container between uses and removing the old crop before new crops are added.

On a small scale **carrots** from the garden can be stored in a cool place like the garage in dry sand.
Farmers storing **wheat** for a long time must dry it to 13-14% before it is stored and then maintain humidity at this level.

Controlled atmosphere storage is used when transporting crop plants long distances. It involves using low O_2 and high CO_2 levels to prevent respiration and therefore slow down ripening. In addition ethylene can be removed because this is responsible for ripening of fruit.