Plant classification

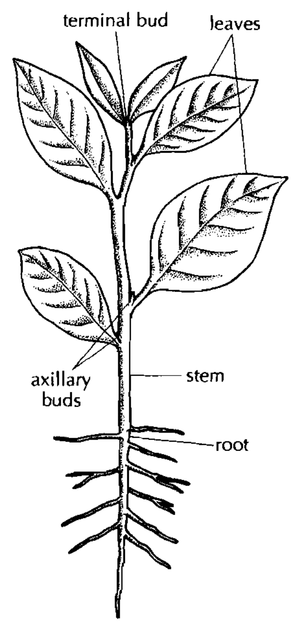
There are four main groups of plants, which can be easily distinguished by studying their external structure.

	Roots, leaves and stems	Maximum height	Reproductive structures
Bryophytes – mosses	Bryophytes have no roots, only structures similar to root hairs called **rhizoids** Mosses have simple leaves and stems Liverworts consist of a flattened thallus	**0.5 metres**	Spores are produced in a capsule. The capsule develops at the end of a stalk
Filicinophytes – ferns	Ferns have roots, leaves and short non-woody stems. The leaves are usually curled up in bud and are often **pinnate** – divided into pairs of leaflets	**15 metres**	Spores are produced in sporangia, usually on the underside of the leaves
Coniferophytes – conifers	Conifers are shrubs or trees with roots, leaves and woody stems. The leaves are often narrow with a thick waxy cuticle	**100 metres**	Seeds are produced. The seeds develop from ovules on the surface of the scales of female **cones**. Male cones produce pollen
Angiospermophytes – flowering plants	Flowering plants are very variable but usually have roots, leaves and stems. The stems of flowering plants that develop into shrubs and trees are woody	**100 metres**	Seeds are produced. The seeds develop from ovules inside **ovaries**. The ovaries are part of **flowers**. **Fruits** develop from the ovaries, to disperse the seed

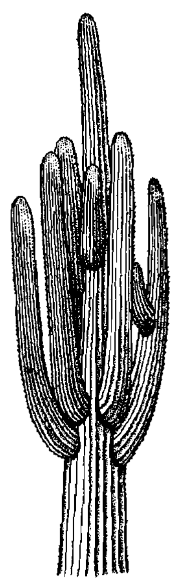
ADAPTATIONS OF PLANTS TO THEIR HABITATS

Flowering plants can be found growing in a wide variety of habitats. The structure of each type of plant is closely related to the amount of water available in the habitat. The figure (below left) shows the structure of *Atropa bella-donna,* a dicotyledonous plant that is adapted to growing in a habitat with moderate supplies of water. The figure (below right) shows a plant adapted to grow in deserts and the figure (bottom) shows a plant adapted to grow in water.

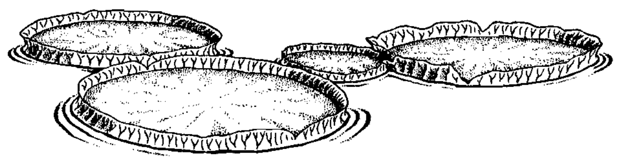
***Atropa bella-donna* – a dicotyledonous plant**



***Cereus giganteus* – a xerophyte**



***Victoria amazonica* – a hydrophyte**



XEROPHYTES

Plants that are adapted to grow in very dry habitats are called **xerophytes.**

Cereus giganteus, the saguaro or giant cactus is a example of a xerophyte. It grows in deserts in Mexico and Arizona and shows many xerophytic adaptations.

- Spines instead of leaves, to reduce transpiration.
- Thick stems containing water storage tissue.
- Very thick waxy cuticle covering the stem.
- Vertical stems to absorb sunlight early and late in the day but not at midday when the light is most intense.
- Very wide-spreading network of shallow roots to absorb water after rains.
- CAM physiology, which involves opening stomata during the cool nights instead of in the intense heat of the day.

HYDROPHYTES

Plants that are adapted to grow either submerged in water or floating on the surface are called **hydrophytes.**

Victoria amazonica, the Amazon water lily is an example of a hydrophyte. It grows on the water surface in shallow pools at the edge of the Amazon River and shows many hydrophyte adaptations.

- Air spaces in the leaf to provide buoyancy.
- Stomata in the upper epidermis of the leaf, which is in contact with the air, but not in the lower epidermis.
- Waxy cuticle on the upper surface of the leaf, but not on the lower surface, which is in contact with water.
- Small amounts of xylem in stems and leaves.

Leaf structure and function

LEAVES AND PHOTOSYNTHESIS

The function of leaves is to produce food for the plant by photosynthesis. The leaf is adapted by its structure to carry out photosynthesis efficiently. On page 3 is a scanning electron micrograph of a leaf. The figure (below) is a plan diagram of tissues in part of a leaf of a dicotyledonous plant to show the adaptations for photosynthesis.

LEAVES AND TRANSPIRATION

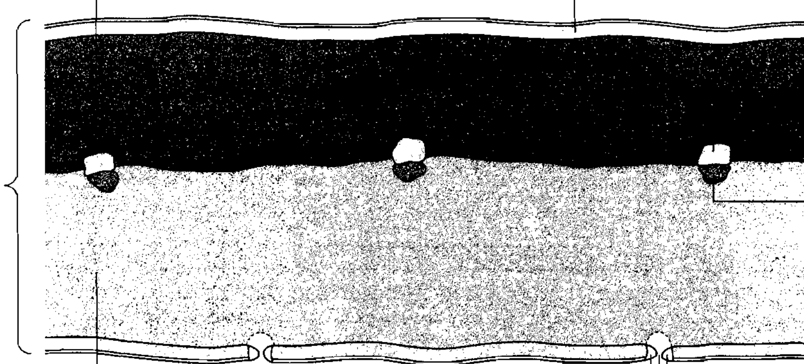
Photosynthesis depends on gas exchange over a moist surface. Spongy mesophyll cell walls provide this surface. Water often evaporates from the surface and is lost, in a process called transpiration. *Transpiration is the loss of water vapour from the leaves and stems of plants.* The figure (below) shows adaptations to minimize the amount of transpiration.

Tissues of the leaf and their functions

Palisade mesophyll–consists of densely packed cylindrical cells with many chloroplasts. This is the main photosynthetic tissue and is positioned near the upper surface where the light intensity is highest

Upper epidermis–a continuous layer of cells covered by a thick waxy cuticle. Prevents water loss from the upper surface even when heated by sunlight. Lower epidermis in a cooler position has a thinner waxy cuticle

The main part of the leaf is the leaf blade or lamina. It has a large surface area to absorb sunlight but is very thin–only about 0.3 mm. It is composed of four thin tissue layers with veins at intervals.



Xylem–brings water to replace losses due to transpiration

Phloem–transports products of photosynthesis out of the leaf.

Vein is centrally positioned to be close to all cells.

Spongy mesophyll–consists of loosely packed rounded cells with few chloroplasts. This tissue provides the main gas exchange surface so must be near the stomata in the lower epidermis.

Stoma–a pore that allows CO_2 for photosynthesis to diffuse in and O_2 to diffuse out.

Guard cells–this pair of cells can open or close the stoma and so control the amount of transpiration.

TRANSPORT IN PHLOEM

Sugars, amino acids and other organic compounds produced in photosynthesis are transported out of the leaf by phloem tissue. Phloem is located in all of the veins of the leaf. The structures within phloem tissue that transport organic compounds are called **sieve tubes**.
Columns of cells develop into sieve tubes by breaking down their nuclei and cytoplasm and making large pores in their end walls to allow a flow of sap. The plasma membranes in sieve tubes remain, and have the important task of pumping organic compounds into the sieve tube by active transport. Transport in phloem is thus an active process, involving the use of ATP. A high solute concentration is created inside the sieve tubes of the leaf, which causes water to enter by osmosis. This creates a high enough pressure to pump the sap inside the sieve tube, containing dissolved organic compounds, to any part of the plant that is using them.

Phloem also transports some spray chemicals if they are absorbed into the leaf after being sprayed onto it.
The transport of any biochemical in phloem whether produced by the plant or not is called **translocation**.

ABIOTIC FACTORS AFFECTING THE RATE OF TRANSPIRATION

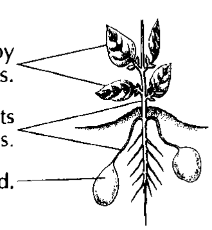
Four abiotic factors have an effect on the rate of transpiration.

- Light – guard cells close the stomata in darkness, so transpiration is much greater in the light.
- Temperature – heat is needed for evaporation of water from the surface of spongy mesophyll cells, so as temperature rises the rate of transpiration rises. Higher temperatures also increase the rate of diffusion through the air spaces in the spongy mesophyll, and reduce the relative humidity of the air outside the leaf.
- Humidity – water diffuses out of the leaf when there is a concentration gradient between the air spaces inside the leaf and the air outside. The air spaces are always nearly saturated. The lower the humidity outside the leaf, the steeper the gradient and therefore the faster the rate of transpiration.
- Wind – pockets of air saturated with water vapour tend to form near stomata in still air, which reduce the rate of transpiration. Wind blows the saturated air away and so increases the rate of transpiration.

FOOD STORAGE IN PLANTS

Many perennial plants develop a food storage organ in which food is stored during a dormant season and then used in the next growth season. The food is transported to and from the storage organ in the phloem. Potato tubers are an example of a storage organ. Tubers are swollen underground stems. The figure (right) shows a potato plant with tubers forming.

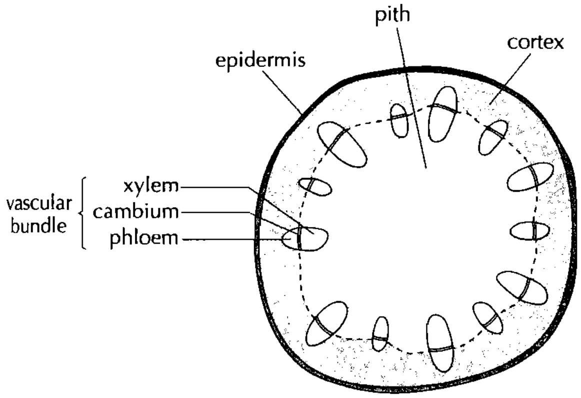
Food storage in potato tuber



STRUCTURE AND FUNCTION OF STEMS

Stems connect the leaves, roots and flowers of plants and transport materials between them using xylem and phloem tissue. Stems support the aerial parts of terrestrial plants. Xylem tissue provides support especially in woody stems. Cell turgor also provides support, with both pith and cortex containing many cells that are usually turgid. The figure (below) is a plan diagram to show the position of the tissues in the stem of a young dicotyledonous plant.

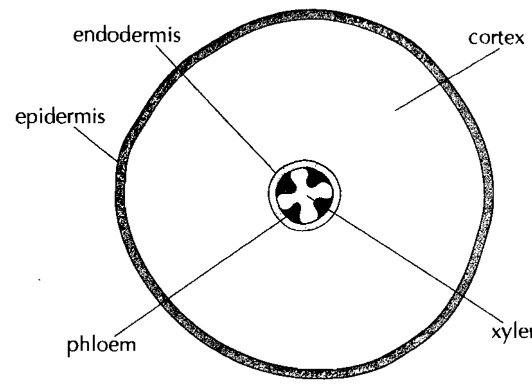
Transverse section of a stem



STRUCTURE AND FUNCTION OF ROOTS

Roots absorb mineral ions and water from soil. They anchor the plant in the soil and are sometimes used for food storage. The figure (below) is a plan diagram to show the position of tissues in the root of a young dicotyledonous plant.
The structure of root systems gives them a large surface area for absorption – by branching, by the growth of root hairs and by having a large surface area of cortex cell walls.

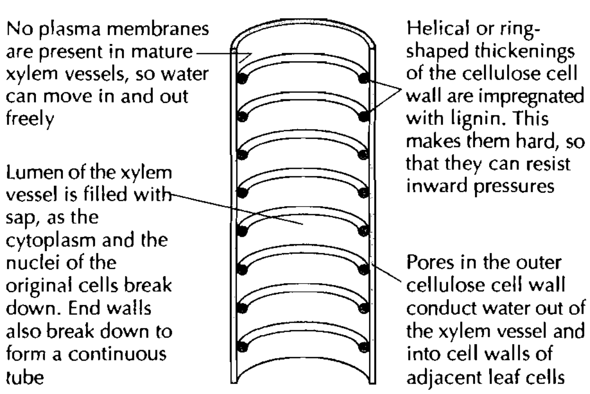
Transverse section of a root



TRANSPORT OF WATER THROUGH THE PLANT

Transpiration causes a flow of water from the roots, through the stems to the leaves of plants. This flow is called the **transpiration stream**.
The process starts with **evaporation** of water from the cell walls of spongy mesophyll cells in the leaf.
The water that evaporates is replaced with water from xylem vessels in the leaf. The water is pulled out of xylem vessels and through pores in spongy mesophyll cell walls by capillary action. Low pressure or suction is created inside xylem vessels when water is pulled out. This is called the **transpiration pull**.
Xylem vessels contain long, unbroken columns of water and the transpiration pull is transmitted down through these columns of water to the roots. The figure (below) shows the structure of a xylem vessel. Mature xylem vessels are dead and the flow of water through them is passive.
The transmission of the transpiration pull through xylem vessels depends on the **cohesion** of water molecules, due to hydrogen bonding.

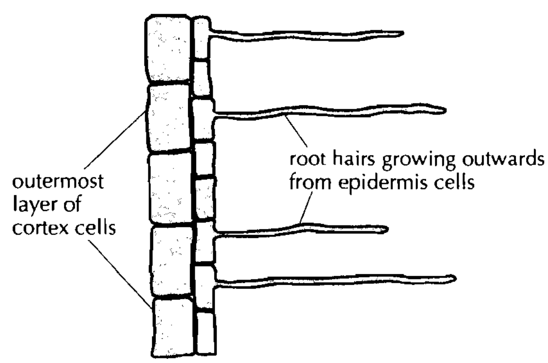
Structure of xylem vessels



MINERAL ION UPTAKE BY ROOTS

Plants absorb potassium, phosphate, nitrate and other mineral ions from the soil. The concentration of these ions in the soil is usually much lower than inside root cells, so they are absorbed by **active transport**. Root hairs provide a large surface area for mineral ion uptake. The figure (below) shows the structure of root hair cells. Cortex cells can absorb ions that are dissolved in the water that is drawn by capillary action through cortex cell walls.

Vertical section of periphery of root



WATER UPTAKE BY ROOTS

The cytoplasm of root cells usually has a much higher total solute concentration than water in the surrounding soil, as a result of active transport of mineral ions. Water therefore moves into root cells from the soil by **osmosis**. Most of the water absorbed by roots is eventually drawn by the transpiration pull into xylem vessels in the centre of the root. To reach the xylem, water has to cross the cortex. There are two possible routes. The water could move from cell to cell through the cytoplasm – the **symplastic route**. It could also move by capillary action through cortex cell walls until it reaches the endodermis – the **apoplastic route**.

Reproduction of flowering plants

STRUCTURE AND FUNCTION OF FLOWERS

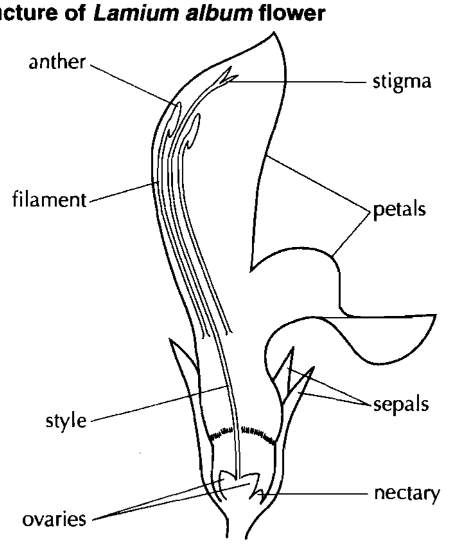
Flowers are the structures used by flowering plants for sexual reproduction. Female gametes are contained in ovules in the ovaries of the flower. Pollen grains, produced by the anthers, contain the male gametes. A zygote is formed by the fusion of a male gamete with a female gamete inside the ovule. This process is called **fertilization**.

Before fertilization, another process called **pollination** must occur. *Pollination is the transfer of pollen from an anther to a stigma.* Pollen grains containing male gametes cannot move without help from an external agent. Most plants use either wind or an animal for pollination. The structure of a flower is adapted to its method of pollination. The figure (below) shows the structure of a flower of *Lamium album,* which is adapted to bee pollination.

Pollen grains germinate on the stigma of the flower and a pollen tube containing the male gametes grows down the style to the ovary. The pollen tube delivers the male gametes to an ovule, which they fertilize.

Fertilized ovules develop into seeds. The figure (bottom) shows the structure of a seed of *Phaseolus multiflorus.* Ovaries containing fertilized ovules develop into fruits. The function of the fruit is **seed dispersal.**

Structure of *Lamium album* flower



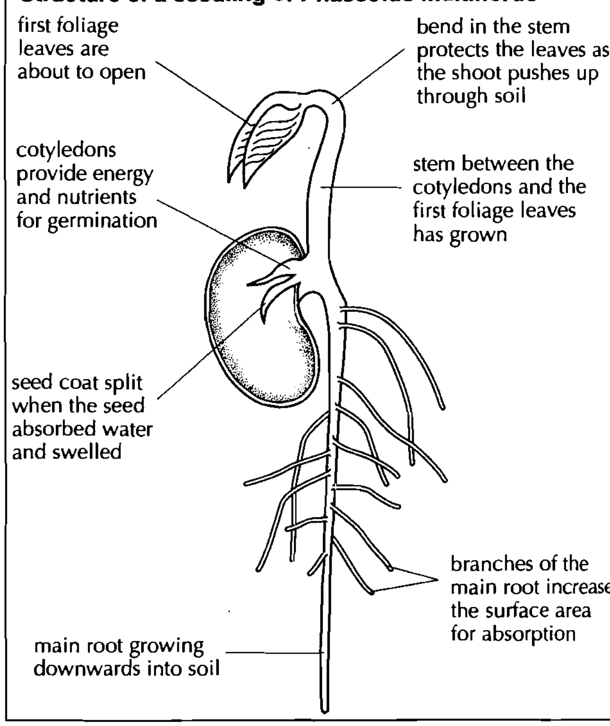
FACTORS NEEDED FOR SEED GERMINATION

Seeds will not germinate unless external conditions are suitable.

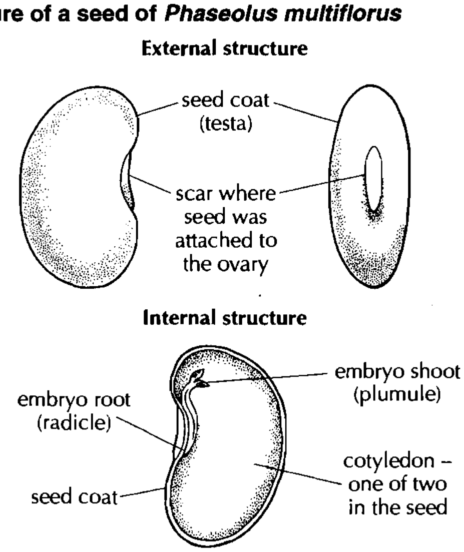
- Water must be available to rehydrate the dry tissues of the seed.
- Oxygen must be available for aerobic cell respiration. Some seeds respire anaerobically if oxygen is not available but ethanol produced in anaerobic respiration usually reaches toxic levels.
- Suitable temperatures are needed. Germination involves enzyme activity and at very low and very high temperatures enzyme activity is too slow. Some seeds remain dormant if temperatures are above or below particular levels, so that they only germinate during favourable times of the year.

The figure (below) shows the structure of a seedling of *Phaseolus multiflorus,* about 2 weeks after the start of germination.

Structure of a seedling of *Phaseolus multiflorus*



Structure of a seed of *Phaseolus multiflorus*



METABOLIC EVENTS DURING GERMINATION

- The first stage in germination is the absorption of water and the rehydration of living cells in the seed. This allows the cells to become metabolically active.
- Soon after absorbing water, a plant growth hormone called **gibberellin** is produced in the cotyledons of the seed.
- Gibberellin stimulates the production of amylase, which catalyses the digestion of starch into maltose in the food stores of the seed.
- Maltose is transported from the food stores to the growth regions of the seedling, including the embryo root and the embryo shoot.
- Maltose is converted into glucose, which is either used in aerobic cell respiration as a source of energy, or is used to synthesize cellulose or other substances needed for growth.

As soon as the leaves of the seedling have reached light and have opened, photosynthesis can supply the seedling with foods and the food stores of the seed are no longer needed.