ESSENTIAL PLANT BIOLOGY

Plant Morphology

This booklet looks at the external morphological features of dicot and monocot plants and how they relate to the plant's life cycle type.

LEARNING OUTCOMES

On completing this session learners will be able to:

- Identify the external features of a range of plants.
- Describe a range of modifications in plant structure and relate these to their function.
- Describe the structure and function of flowers, fruit and seed.
- Describe the differences between monocotyledon and dicotyledon plant structure.
- Relate plant morphology and structures to management practices.
- Describe a number of plant life cycles and relate these to plant morphology.

Plant Morphology

Introduction

This topic introduces the names and functions of the different external structures of plants. It relates closely to the topic of Plant Anatomy which is concerned with the internal structure of plants.

Throughout the topic there will be references to the two classes of flowering plants or Angiosperms, monocotyledons (**monocots) and dicotyledons (dicots)** and just occasionally to the non-flowering, cone bearing Gymnosperms such as pines and spruce. The differences between the two classes of flowering plants are summarised towards the end of this morphology section but basically the split between the two groups, **monocots** and **dicots**, based on the **number of cotyledons** present in the **seed**. Monocots have one cotyledon and dicots have two.

Plants living on land obtain water and minerals from the soil. CO_2 is available from the air and light is also available above ground. The plant has two main systems to allow it to gather all these essential resources, the underground **root system** and the aerial **shoot system**.

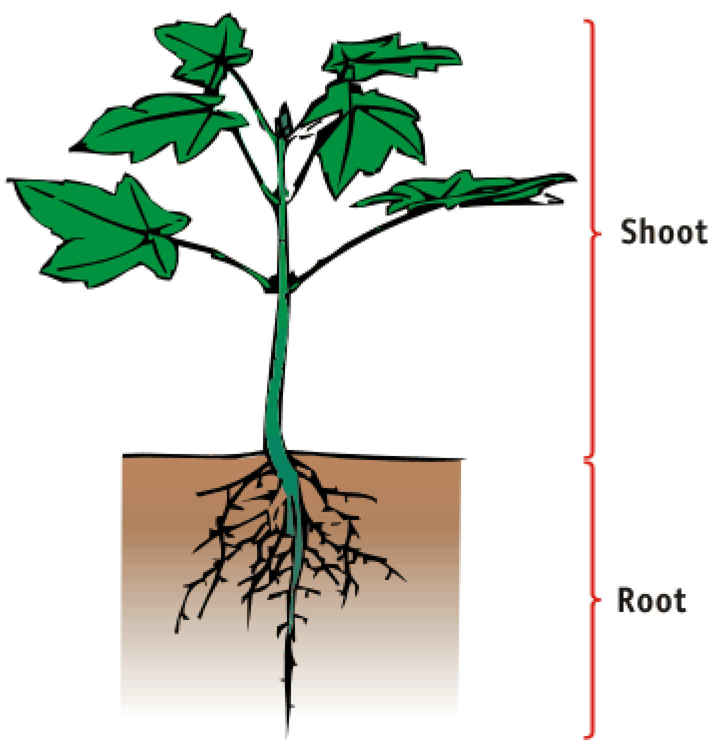


Figure 1: Basic Morphology of a flowering plant

Roots

Main Functions:

- **Anchor the plant in the soil**
- **Take up water and nutrients from the soil**
- **Conduct water and nutrients to the shoot**
- **Act as food storage organs in some plants**
- **Vegetative propagation**

Tap roots and Lateral roots

Figure 2: Dandelion plant with tap root

Tap roots develop from the embryo root or radicle. They are particularly good at anchoring a plant in the soil. Try to pull up a dandelion, a dock or even a smallish tree seedling!
They are also very good at penetrating the soil and in some plants the tap root can go down several metres. The taproots of some trees may be used to penetrate soil pans. A deep tap root allows a plant to get water from deep in the soil even in dry conditions. **Lateral roots** are roots that grow off the side of tap roots. In some plants they may make up most of the root system.

Root hairs are single celled roots, about 1mm in diameter, which grow out from young roots just behind the root tip. These increase the surface area of the root for water uptake tremendously and penetrate between soil particles so aiding both nutrient and water absorption. More information on root hairs will be given in the Plant Anatomy booklet.

Fibrous and adventitious roots

Fibrous rooted plants have multi branched roots with no main tap root. They are often **adventitious**, i.e develop from stems either under or above ground. Plants with fibrous roots include monocots such as grasses, as well as numerous dicot plants, including many herbaceous perennials.

Fibrous roots give the plant access to water and nutrients throughout the soil and are very good at anchoring the plant in the ground. These roots do not go down far into the soil but occupy a large amount of soil around the base of the plant and so are very effective in preventing soil erosion. They rely on surface draining water and so plants with fibrous roots are the first to suffer in droughts.

Figure 3: Grass plant showing fibrous roots

Root adaptations for Storage and Over Wintering

Taproots

Taproots are commonly used as storage and over wintering organs. This may be due to swelling of cortex tissues as in the dandelion or sometimes phloem tissues swell giving high levels of sugars stored and a sweet taproot such as in carrots.

Figure 4: Swollen taproot of a carrot

Root Tubers

Root tubers are under ground root swellings employed by some plants for storage and to survive adverse conditions. The classic root tuber plants are dahlias but many others do exist! Eucalyptus trees have lignotubers that help them to survive forest fires.

Figure 5: Dahlia Root tubers

Other Root Adaptations

Adventitious aerial roots

Adventitious roots produced from aerial stems usually grow downwards to the ground and then function as extra support for the plant. They are found in a range of plants including mangrove trees, climbing figs (*Ficus spp*) and Himalayan balsam.

Figure 6: Aerial roots

Pneumatophores

Swamp cypress trees growing in wet conditions send some roots up out of the water as "knees", with special pores for breathing.

Root Nodules

Some plants have root nodules on their roots that contain bacteria capable of fixing nitrogen from the air. These include legumes such as clover as well as other plants such as alder trees (*Alnus glutinosa*). This makes these plants particularly well adapted for growing in low nutrient soils.

Figure 7: Root nodules

Stems

Main Functions:

- **Support leaves and flowers**
- **Transport water, nutrients and sugars around the plant**
- **Catch light and produce food by photosynthesis (if green)**

Basic Structures

The leaf joins the stem at the **node** and has in its angle with the stem (the axil) an **axillary bud**. An axillary bud may grow to form a lateral shoot. The length of stem between one node and the next is the **internode**. Buds at the end of a shoot are called **terminal buds**.

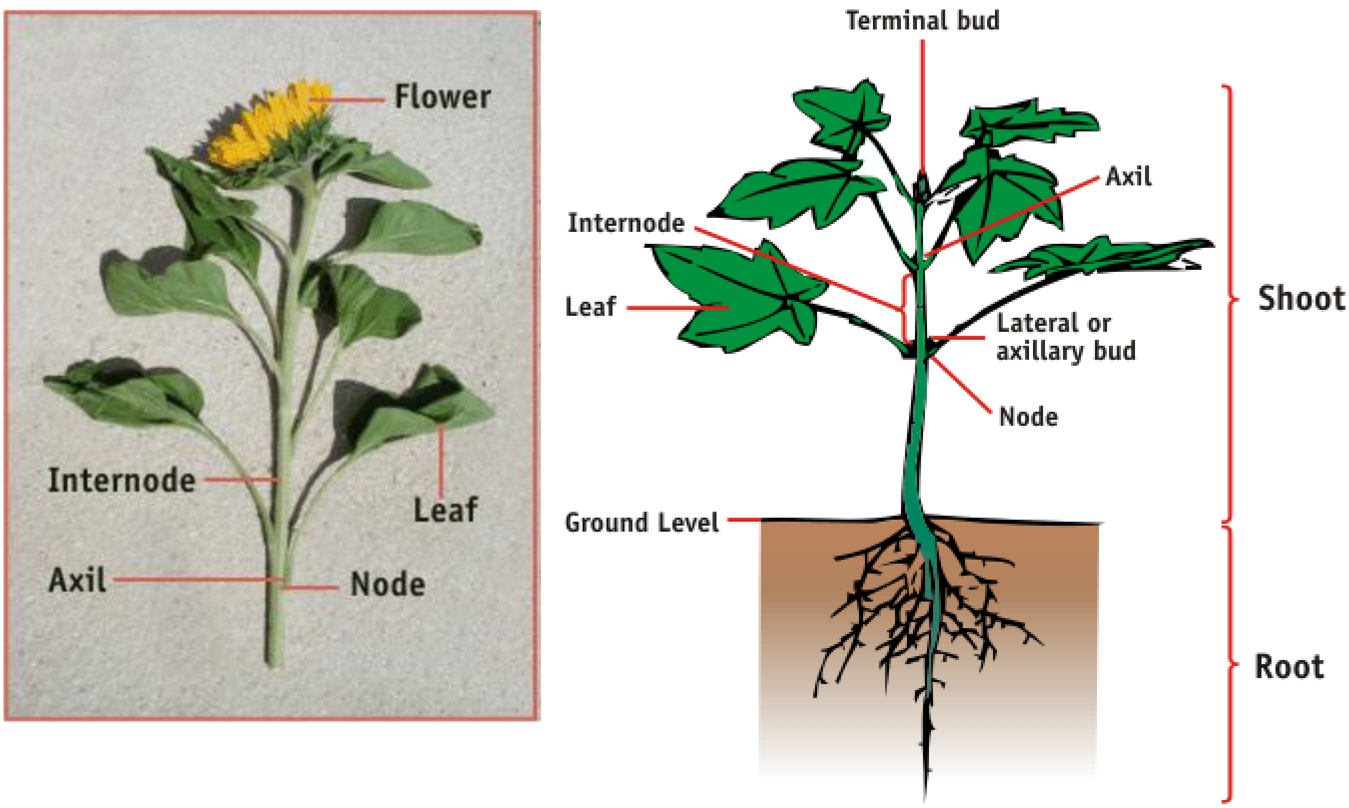


Figure 8: Dicot stem structures

In **grasses** and many **other monocots** the situation is slightly different from dicots. Leaves still come off at **nodes** but these may be very low down near to ground level and it is easy to confuse the **leaf sheath** (lower section of the leaf) with a stem. The way to find a node is to unwrap the leaf sheaths (which often overlap giving several layers) and 'peel' them back to find the leaf base. (NOTE: The node is at the **bottom of the leaf sheath** not at the base of the leaf blade.) This is also where you will find the axillary buds capable of producing new shoots. Lateral shoots that grow from the base of the shoot in grasses are called **tillers**.

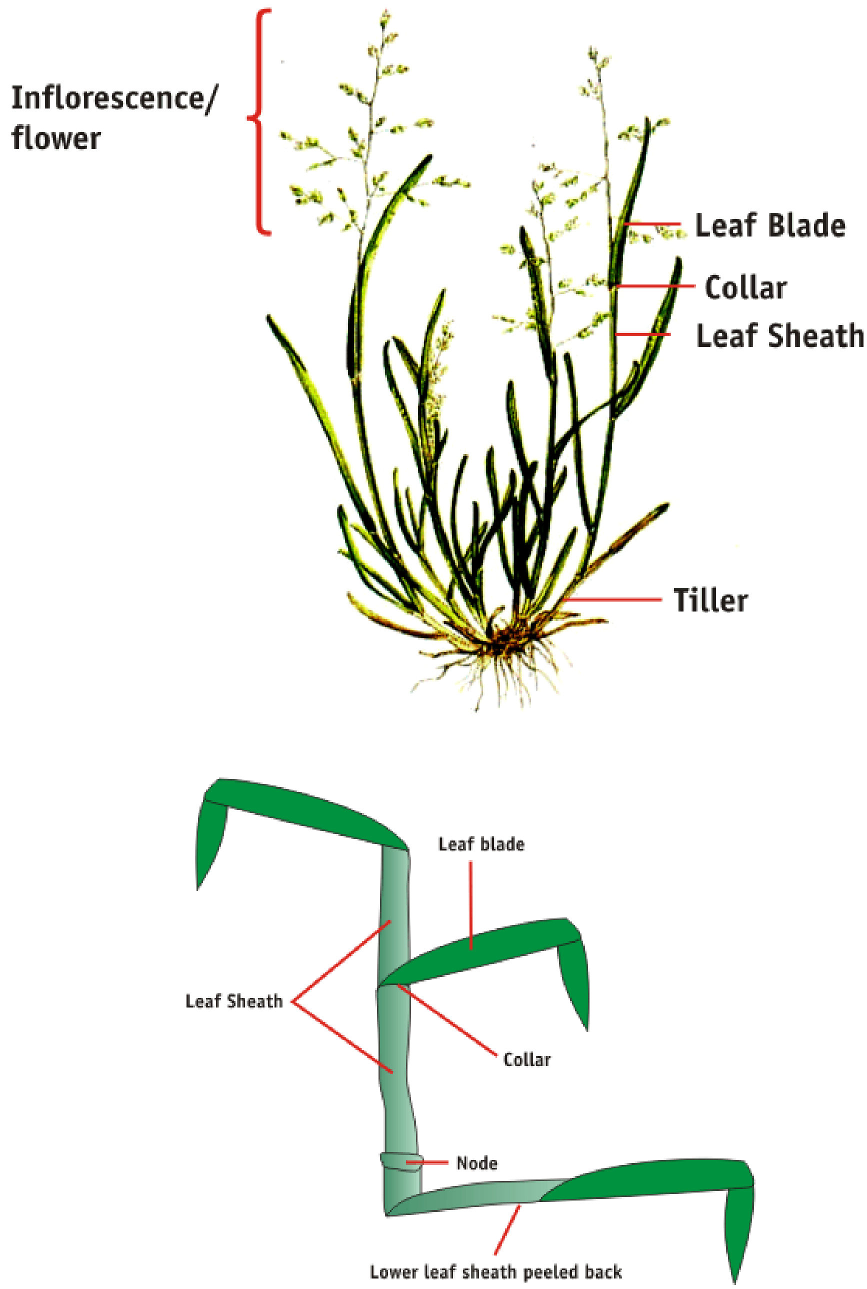


Figure 9: Grass plant structures (a monocotyledon)

Learning Activity

Find a grass plant. See if you can find a node by peeling back leaf sheaths. Count the number of tillers that emerge from the base.

Young woody stems of dicot plants have nodes and internodes as well as terminal and axillary buds. They also have rough patches or **lenticels** in the bark, which may or may not be easily visible to the naked eye. Lenticels are thinner areas in the bark, which allow air in and out of the stem. **Leaf scars** mark the former attachment of a leaf or petiole to the stem.

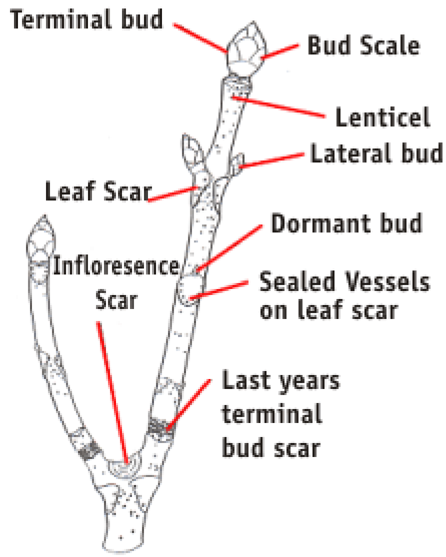


Figure 10: Woody stems

Learning Activity

Find a twig from a tree or bush, look for the lenticels. Hazel (Corylus spp) shows them particularly well. Can you spot the other feature shown here?

Stem Modifications

Stolons

Stolons or runners are horizontal stems growing **above the ground** along the soil surface. They allow the plant to **spread** producing adventitious roots at the nodes and eventually new plants. They have all the normal stem structures, nodes, internodes, leaves (often as scales) and axillary buds in leaf axils.

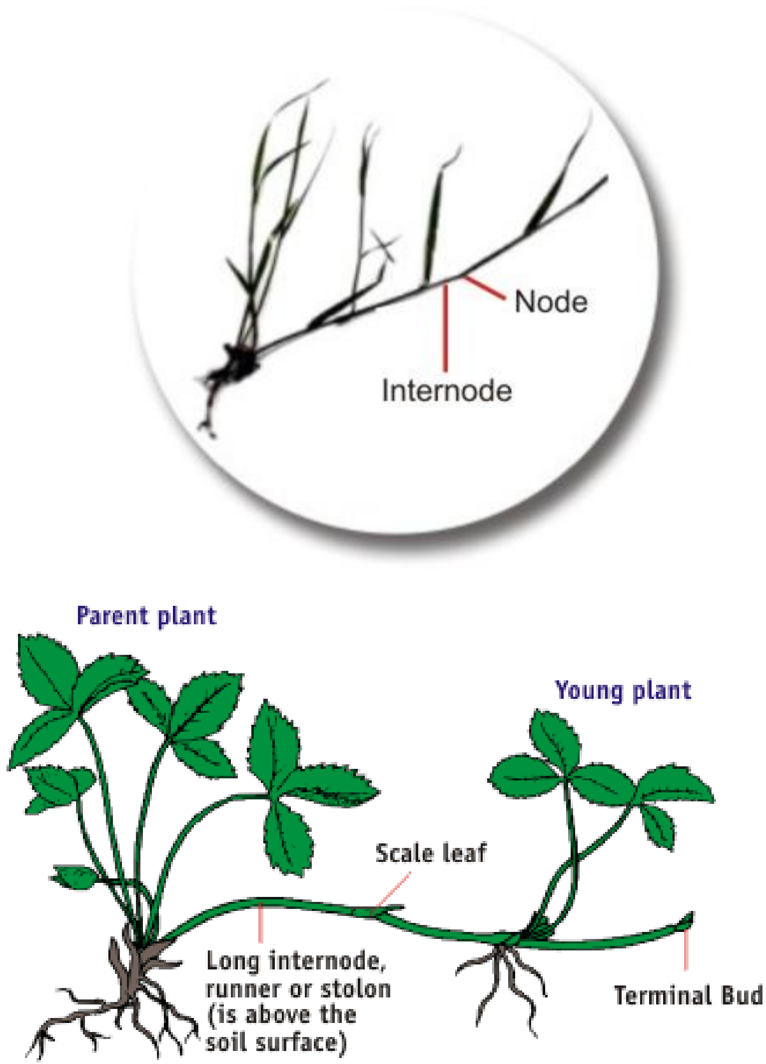


Figure 11: Stolons

Rhizomes

Rhizomes are stems that grow horizontally just below the soil surface. They maybe long and thin, like couch grass, or swollen with food, like an iris. They may function as under ground "runners" producing adventitious roots and **new plants**, or act as **storage or overwintering organs** (eg Iris spp). Again they show most of the normal stem structures.

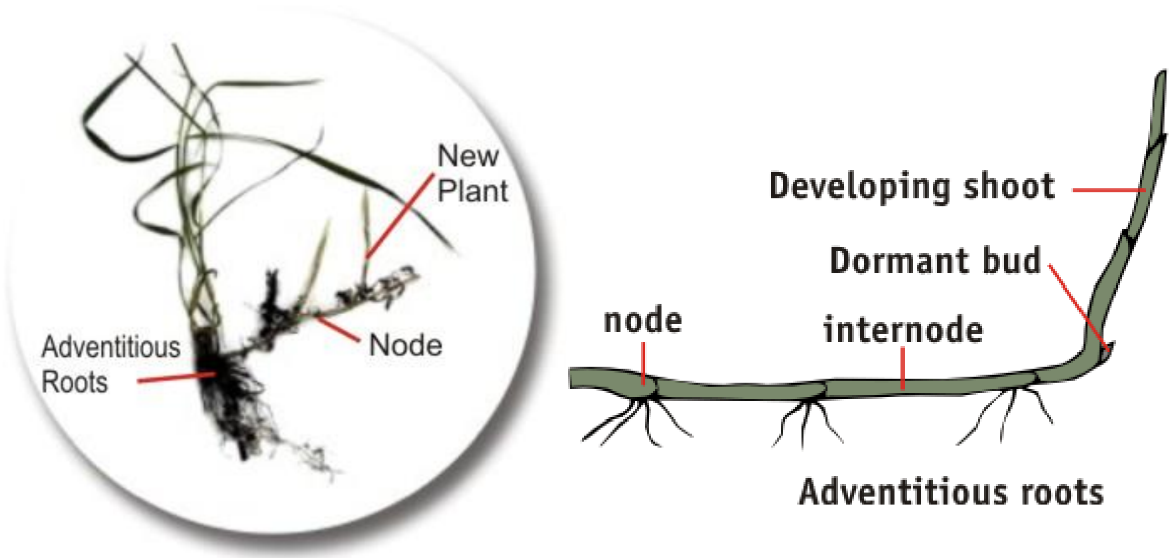


Figure 12a: Rhizomes

Figure 12b: Iris Rhizome (nodes very close together)

Corms

Corms, such as crocus bulbs, consist mainly of a stubby, vertical, swollen stem which stores food, surrounded by a few papery leaves.

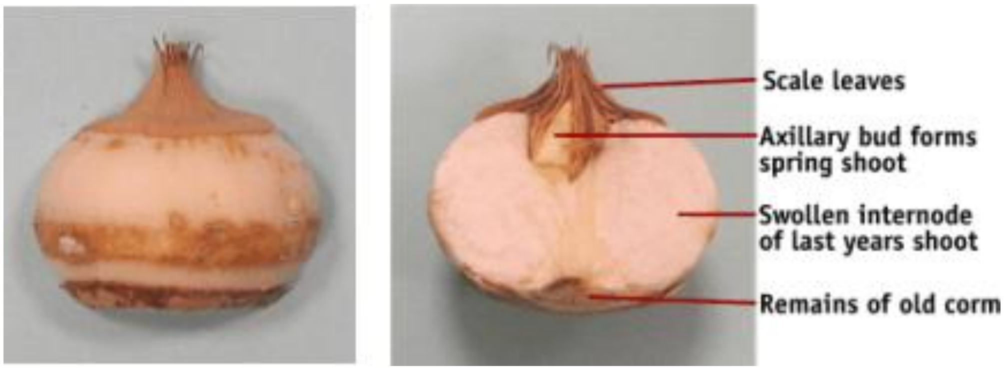


Figure 13: External and internal structure of a corm

Stem Tubers

Stem tubers are swollen sections of underground stems (rhizomes) that store food. In appropriate conditions new shoots can grow from lateral buds. Potatoes are perhaps the most common example.

a) Sweet Potato **b) Potato**

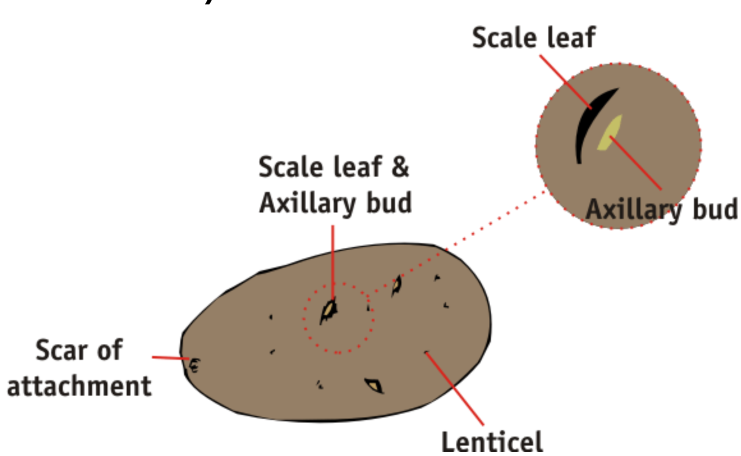


Figure 14: Stem Tubers

Bulbs

Bulbs, such as daffodils and tulips, consist of a small underground stem surrounded by large fleshy underground leaves that store food. The outer layers are formed by thin, brown, papery leaves. New bulbs develop from lateral buds.

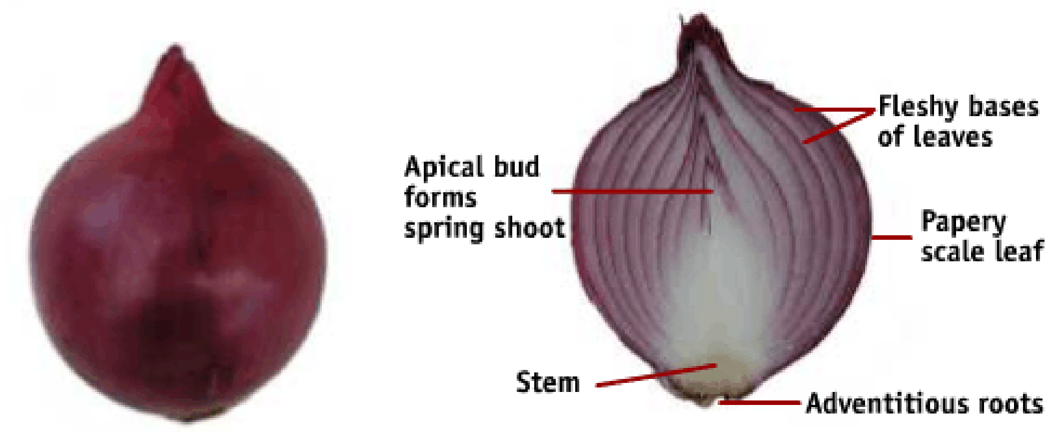


Figure 15: External and internal structure of a bulb

Learning Activities

Now go and try the **'Plant Morphology Quiz 1'** and the **'Grass, Leafy Twig and Rhizome Labelling Activities'** to check your knowledge of the terminology and adaptations of plant roots and shoots. You can find these in the Plant Morphology 'Interactive Learning Activities' folder.

Leaves

Main functions:

- **Catch light and produce food by photosynthesis**
- **Release excess water from the plant through transpiration**
- **Allow carbon dioxide and oxygen to enter and leave the leaf**

General Structure

Leaves of dicots vary in form but they generally consist of a flattened **blade** and a stalk, the **petiole**, which joins the leaf to a node of the stem. The main vein that continues from the petiole is known as the **midrib**. The thinner area each side is the **lamina**. The large area of the flattened lamina allows the leaf to intercept lots of light for photosynthesis. The veins support the lamina and transport nutrients and water to the leaf and sugar away to the rest of the plant.

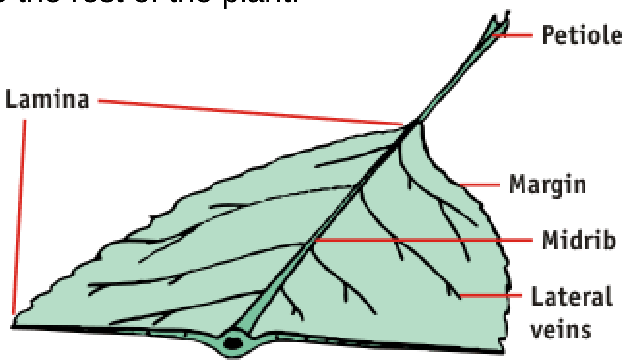


Figure 16: Dicot Leaf structure

Some monocots, including palm trees, do have petioles. However, grasses and many other monocots do not have a petiole; instead the base of the leaf forms a sheath that envelopes the stem. The **collar** is where the leaf sheath and leaf blade join. Here you may find a **ligule**, a membranous layer that wraps around the underneath leaf sheath, or **auricles**, two flaps of tissue that extend from the collar and clasp the stem. Both of these are very important features for grass identification.

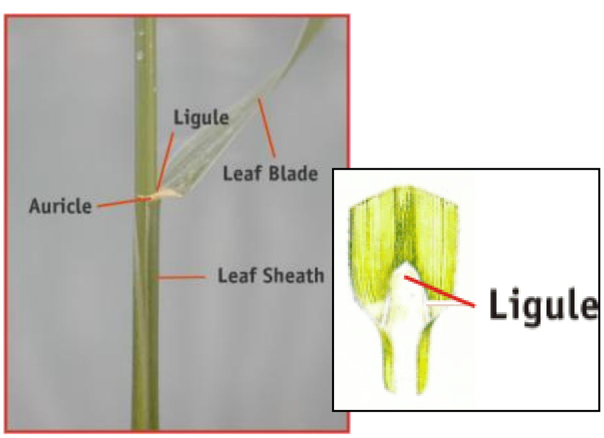


Figure 17: Grass leaf structure

Figure 18: Palm leaves

Leaf venation and shapes

Monocots differ from **dicots** in how their major veins are arranged. Most monocots, such as grasses, have parallel veins that run the length of the leaf blade. Most monocots have long thin strap like leaves. Dicots generally have a net like arrangement of main veins and the leaf shape varies more.

Dicot leaf with netlike arrangement of veins

Monocotyledon leaf with parallel veins

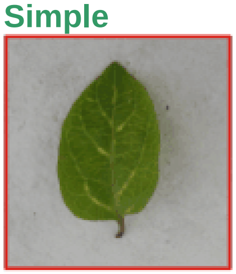
Figure 19: Types of Venation

Name that Leaf Shape!

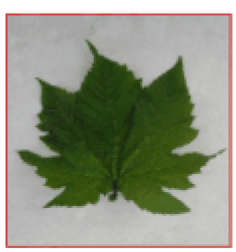
There are many variations in leaf arrangement shape, size and venation/pattern of veins. These are important in identification of dicotyledonous plants such as trees.

- A **simple leaf** is where the blade of the leaf occurs as one unit and not divided into leaflets, it may be lobed or toothed.
- Most simple leaves have **pinnate venation** with veins coming off a single mid rib, either in opposite pairs or alternately.
- Simple leaves with **palmate venation** have main veins all radiating from the top of the leaf stalk and usually a lobed margin (edge).
- A **compound leaf** is where the blade of the leaf is divided into separate leaflets without (any flange of lamina tissue) joining them together along their common stalk.
- A **pinnate leaf** is a compound leaf with separate leaflets arranged along the leaf-stalk, usually in opposite pairs and often with a terminal leaflet as well.
- A **palmate leaf** is a compound leaf with more than three leaflets arising together from the top of the leaf stalk in a hand like fashion.

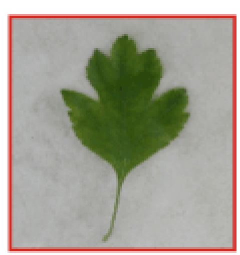
Simple



Simple Oval Leaf - Pinnate Venation



Simple Leaf - Palmate Venation



Simple Lobed Leaf

Figure 20a: Simple Leaves

Compound

Compound Leaf

Pinnate
Compound Leaf

Palmate
Compound Leaf

Figure 20b: Compound Leaves

Many differences in leaf shape are due to plants adapting to the environmental conditions where they live. For example, "drip tips" on leaves in plants with heavy tropical rainfall, or small narrow leaves to conserve water in more arid conditions. Divided or compound leaves with narrow leaflets are less likely to be damaged by wind or water movement.

Learning Activity

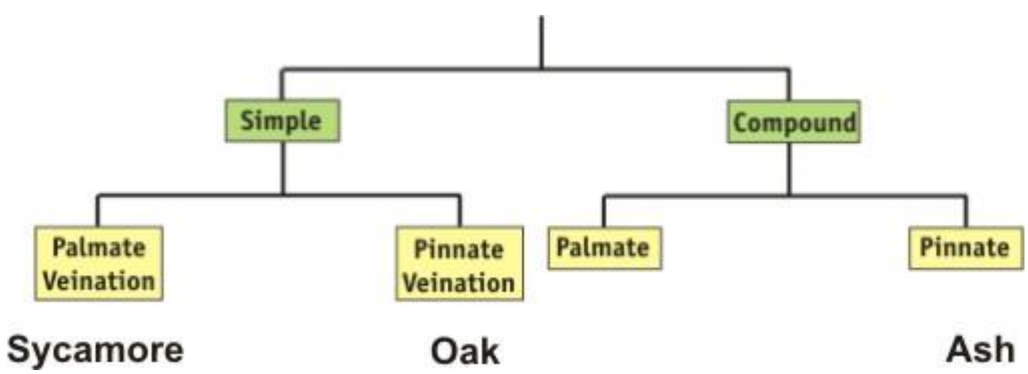
Match these 3 pictures of leaves A, B & C to the name of the tree they come from using the simple key below.

(See last page of booklet for answers)

A) 

B) 

C) 



Leaf Modifications

Leaves are generally specialised for photosynthesis but some have also been modified for other purposes.

a) Leaflets of peas are modified as **tendrils** to help them cling to the supports. Petioles of clematis curl for a similar reason.

Figure 21: Stems for climbing (petiole of Clematis)

b) Succulents use **swollen leaves** to store water

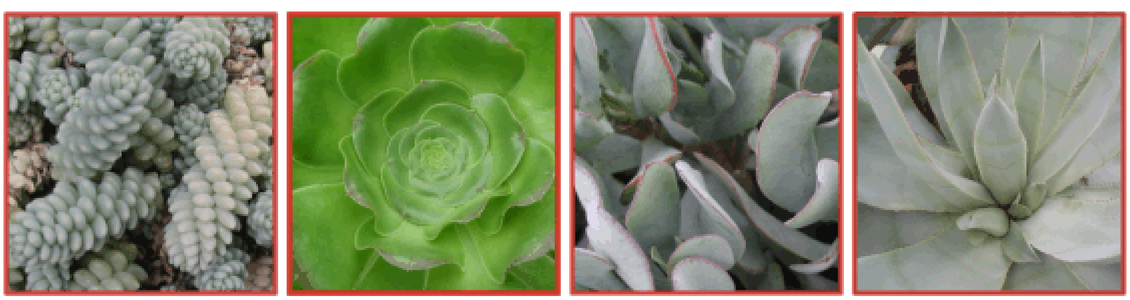


Figure 22: Succulents with swollen leaves

c) **Spines** on a cactus are actually leaves. They act as defense as well as reducing the surface area for water evaporation in a hot, dry climate.

Figure 23: Examples of various Cacti with spines

d) **Brightly coloured leaves** may be used to help attract insects for pollination for example the red ‘petals’ of poinsettia and hydrangeas.

Figure 24: Coloured foliage of hydrangeas

Flowers

The main function of flowers is to produce seeds i.e. a flower is the reproductive organ of the plant.

Basic Flower Structures

A) The **male** part of the flower, the **stamen or androecium** consists of the pollen producing anther and the narrow filament that holds it up.

B) The **female** part of the flower, the **carpel or gynoecium**, which will eventually develop into the fruit (containing seeds that develop from the ovules) varies in shape depending largely on the type of fruit it produces. The pollen is caught by the stigma then travels down the style to the ovules.

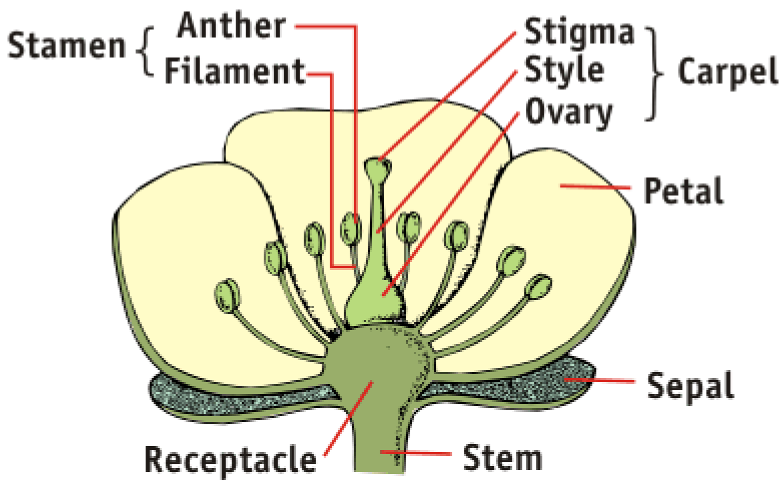


Figure 14: Symmetrical Dicot flower

The position, size and shape of flower structures will vary depending their means of pollination and seed dispersal.

Insect Pollinated Flowers

Insect pollinated flowers have big **bright petals** to attract insects; whereas wind pollinated flowers do not need these. Stamens and the pollen catching stigma of insect pollinated flowers are held inside the ring of petals where they can give or receive pollen from an insect. The stigma may well be sticky to help it catch pollen. The dicot flower labeled above is a typical insect pollinated flower.

Some insect pollinated flowers (see below) are not symmetrical cups, but they still have basically the same structures. The ring of petals is sometimes referred to as the **corolla**, the ring of sepals as the **calyx**. These terms are particularly useful when petals or sepals are fused to form a tube.

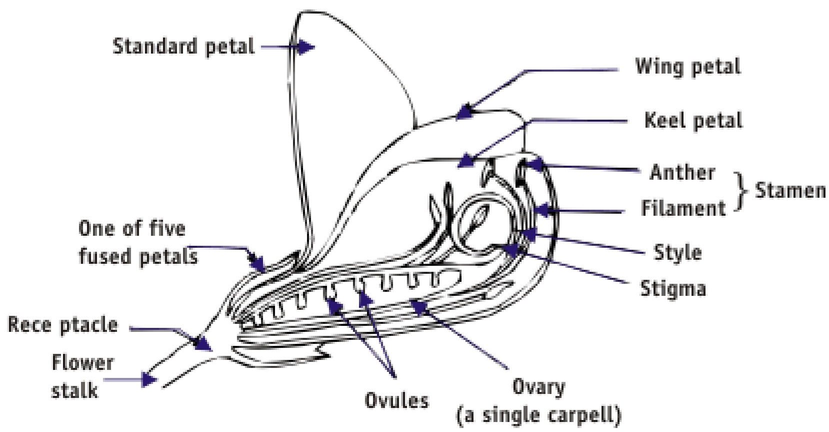


Figure 15: Unsymmetrical Dicot flower

Wind Pollinated Flowers

Wind pollinated flowers do not have bright coloured petals. They often hold the stamens, the pollen producing male structures, **outside the flower** where they are more **exposed to the wind**. Wind pollinated flowers hold the stigma outside the flower where it is more likely to have pollen land on it. The stigma of a wind pollinated flower is often feathery and netlike to help catch wind blown pollen.

Grasses and some trees are wind pollinated. Many trees have separate male and female flowers and produce male and female catkins with *either* stamens *or* carpels. These may be on the same plant (**monoecious**) or on separate plants (**dioecious**).

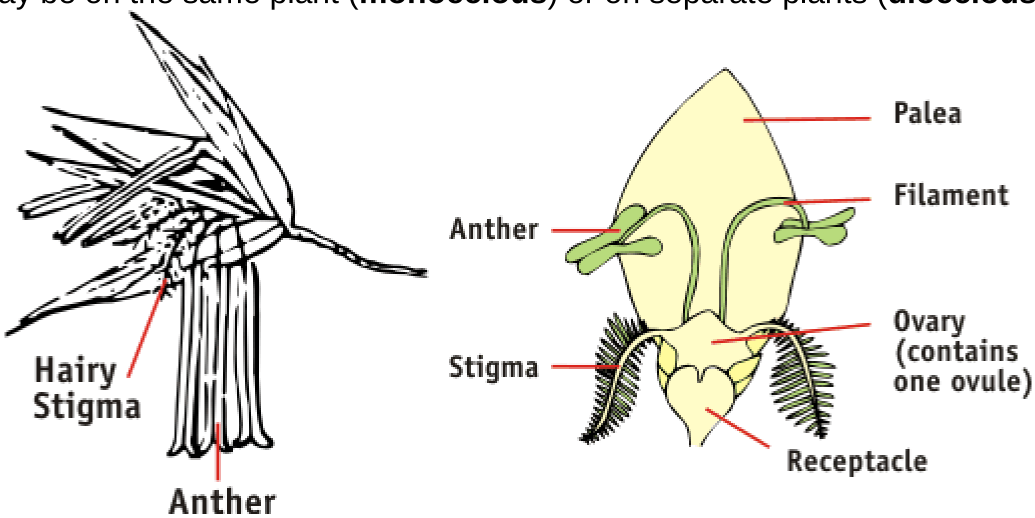


Figure 16: A Grass spike and floret

Learning Activity

Now try the '**Parts of a Flower Labeling Activity'** in the 'Interactive Learning Activities' folder to check your ability to identify flower structures.

Cross Pollination

For sexual reproduction to work most effectively and produce a variety of different plants in the next generation a plant needs to have **cross pollination**, with the pollen of one plant pollinating a flower of another plant.

- This is sometimes done **structurally**, the stigma is above the stamen for instance, or male and female flowers are on different plants.
- It may also be achieved by **timing** the maturity of male and female parts of the flower so that the plant produces pollen when its own carpels are not receptive. This method is also used by many monoecious trees and grasses.

However, many plants do carry out self pollination quite effectively with less problems of in-breeding, it seems, than in some animal species.

Learning Activity

Which of the following trees are;

a) monoecious
b) dioecus

a. Holly - *Ilex aquifolium*
b. Hazel – *Corylus spp*
c. Pine – *Pinus spp* (& other conifers)
d. Service Tree – *Sorbus domestica*
e. Ash - *Fraxinus excelsior*
f. Ginkgo
g. Willow – *Salix spp*
h. Silver Birch – *Betula spp*

(See last page of booklet for answers)

Fruit

After the female gamete, the **ovule**, is **fertilized** by the male gamete, the **pollen**, the resulting cell will undergo cell division and develop to form the **seed**. Seeds will then be supplied with food by the parent plant so that they can build up storage reserves for later use in respiration and germination.

At the same time as the seeds are forming from the ovules, the rest of the **ovary** develops to form the **fruit**. The ovary wall thickens, forming the **pericarp,** which may come in various forms, for example the pod of a pea, the outside of barley grain (a single seeded fruit) or the fleshy part of a tomato. The fruit is, biologically speaking, the structure that develops from the ovary. So whilst a cereal grain is therefore a fruit, an apple is not, as the fleshy part develops from the receptacle on which the ovary sits, rather from the ovary (the fruit bit is just the apple core)!

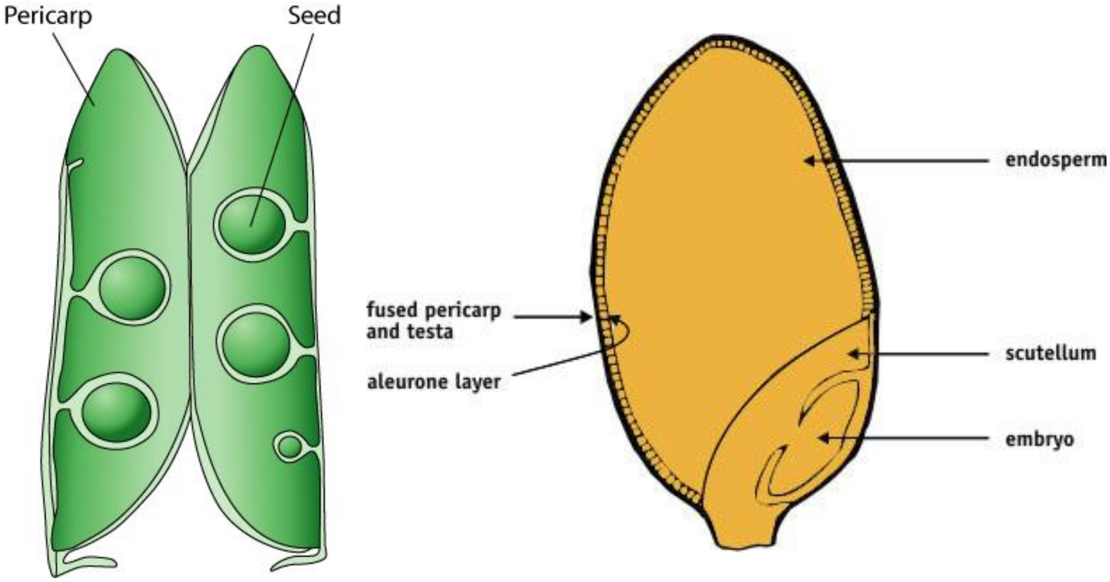


Figure 17: Pea and barley fruit

The initial role of the fruit is **protective**, but once the seeds are mature the function of the fruit is to **aid seed dispersal**. In non fleshy fruits (e.g. a pea pod) ripening is little more than controlled death or **senescence** of fruit tissues allowing the fruit to open and release the seeds. For fleshy fruit, complex changes in **colour, smell, texture and flavour** are involved. These are obviously important to the plants in attracting animals to the fruit to aid seed dispersal and their commercial significance is fairly evident.

Figure 18: Tomato fruit

Seeds

Main functions:

- **Germinate to produce next generation of plants**
- **Store food for first stages of plant grow**
- **Protect the embryo plant**
- **Survive adverse growing conditions**

General structure

There are two basic types of seed:

- **Dicotyledonous** or **dicot** seeds with two cotyledons or seed leaves

- **Monocotyledonous** or **monocot** seeds with only **one** cotyledon

Seeds also vary in where they **store** most of the food for growth of the new embryo plant. Many store the food in the seed leaves (**cotyledons**); whilst others store the food outside the embryo in the **endosperm**, this group includes most monocotyledons.

Dicot Seed Structure

The outside of the seed is the protective seed coat or **testa**. In a single seeded fruit the fruit wall, or **pericarp**, surrounding, and often fused with the testa, performs this role. A small hole in the testa, the **micropyle**, marks the point of entry of the pollen tube before fertilisation and is the first point of entry for water at the start of germination. The **hilum** shows the point of attachment to the fruit.

Inside the seed the embryo root is called the **radicle**, the embryo shoot is the **plumule**. The **cotyledons** are the embryo seed leaves and often full of stored food. In some species, such as castor oil beans, most of the food is stored in the endosperm.

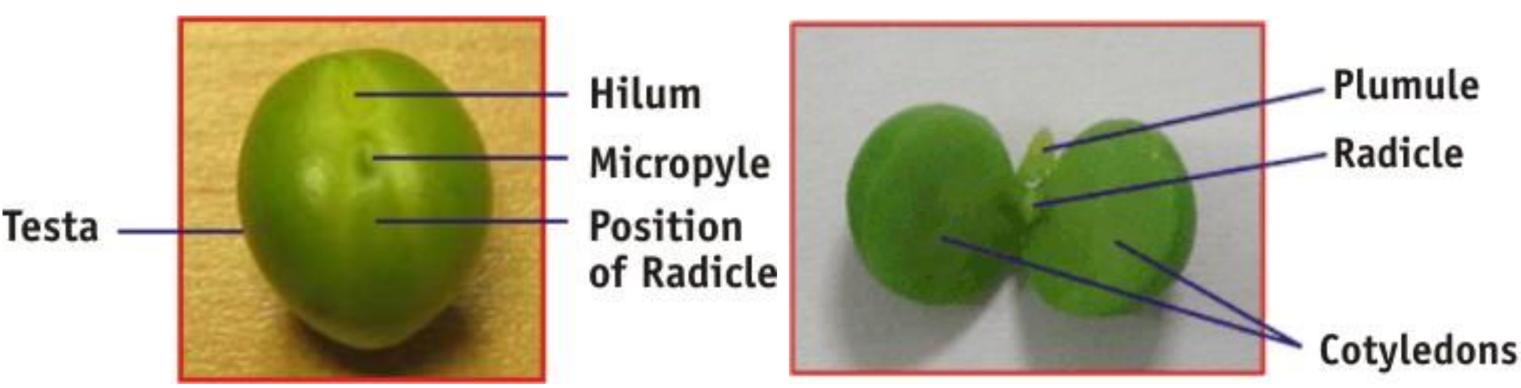


Figure 1: Structure of a Dicot seed (Pea)

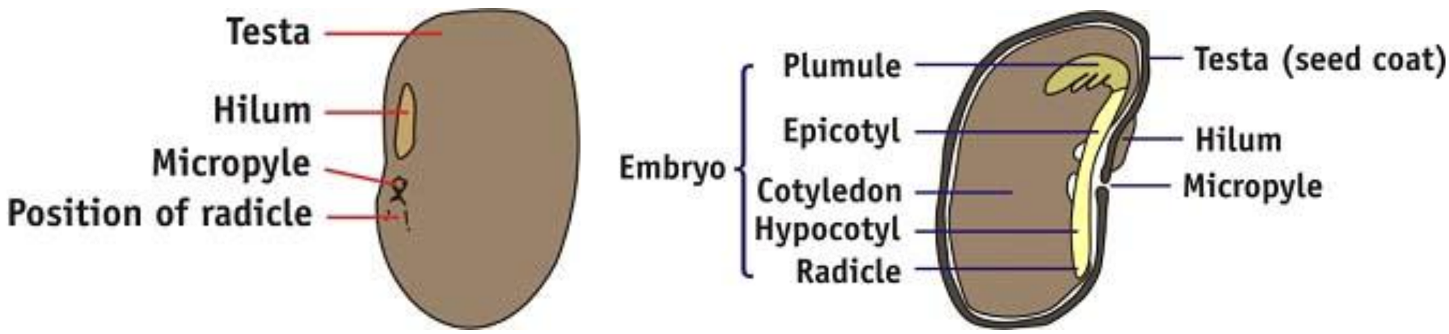


Figure 2: Structure of a Dicot Seed (Bean)

Monocot Seed Structure

Most **monocots**, including grasses, have most of their food stored in an **endosperm** rather than in their **single cotyledon or scutellum**. In monocots the plumule is enclosed within a hollow tube called the **coleoptile** which protects the plumule as is grows upwards through the soil. Growth of the coleoptile is mainly from its base called the mesocotyl. Once through the soil surface the coleoptile stops growing and the first leaves burst through its tip. Adventitious roots grow from the mesocotyl and form a fibrous root system.

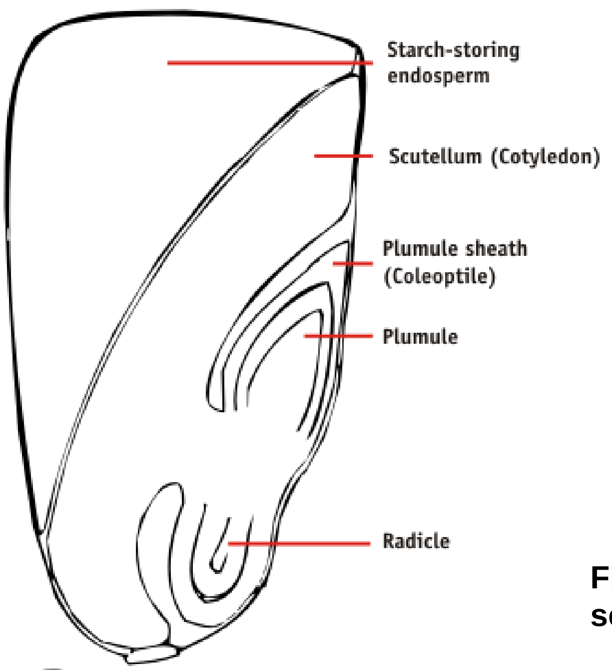


Figure 3: Structure of a Monocot seed (Maize (sweetcorn))

Learning Activity

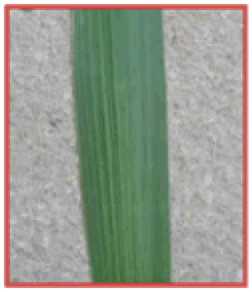
Now go and try the **'Bean Seed Labelling Activity'** in the Plant Morphology 'Interactive Learning Activities' folder.

Monocotyledons and Dicotyledons

Flowering plants are split into two groups, **monocots** and **dicots**, based on the **number of cotyledons** present in the **seed**. Monocots and dicots have several other structural differences as well.

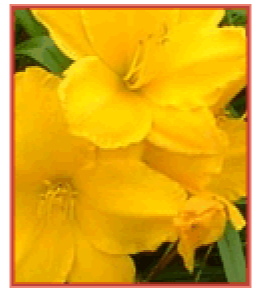
Monocotyledons

Seed with one cotyledon

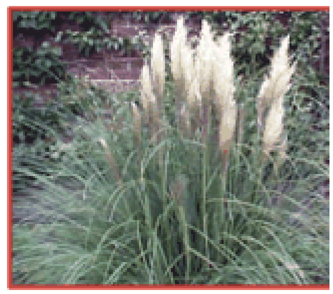


Leaves with Parallel veins & Sheathing base

Fibrous roots



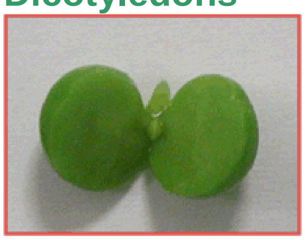
Flower parts in multiples of 3



Examples of Monocotyledons

Figure 28: Characteristics of Monocotyledons

Dicotyledons

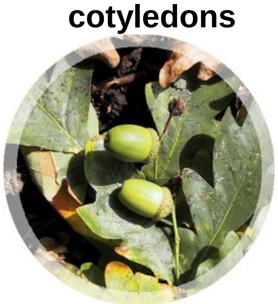


Seed with two cotyledons

Leaves with Net veins & Petiole

Tap root

Flower parts in multiples of 4 or 5



Examples of Dicotyledons

Figure 29: Characteristics of Dicotyledons

Learning Activity

Which of the following characteristics belong to Monocotyledons and which to Dicotyledons?

Characteristics	Monocotyledons	Dicotyledons
Seed with one cotyledon		
Tap root		
Fibrous roots		
Seed with two cotyledons		
Leaves with net veins & petiole		
Flower parts in multiples of 3		
Leaves with parallel veins & sheathing base		
Flower parts in multiples of 4 or 5		

(See last page of booklet for answers)

Plant Life Cycles and Plant Morphology

Annuals

Most plants produce seeds at some stage in their lives. These germinate and the new plants grow, flower and produce more seed for the next generation. Many plants grow, flower and die, that is complete their **Life Cycle,** in one year. These are known as **Annuals**.

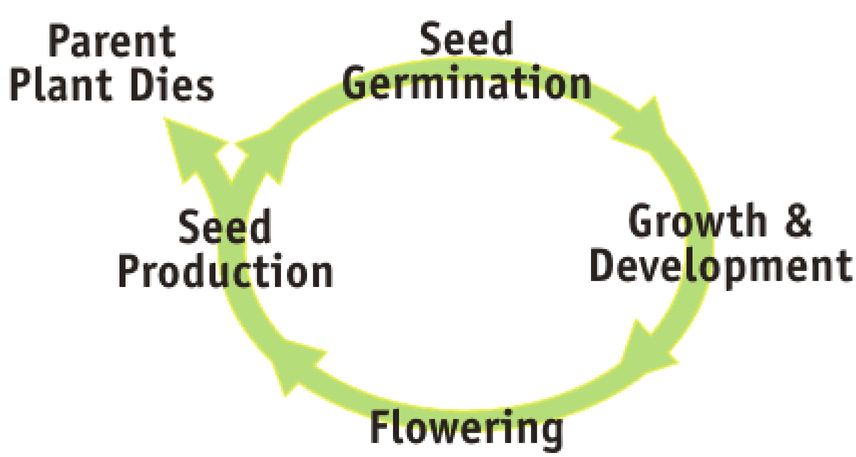


Figure 30: Annual life cycle

For such plants the main investment is in the **seeds** that allow them to survive the winter and **produce the next generation** of plants, rather than in vegetative structures. Annuals are often smaller and most do not have significant secondary growth. They have large numbers of flowers and seeds. Examples include many weeds of open ground such as annual meadow grass and groundsel.

Figure 31: Annual bedding plant *Rudbeckia '*Becky Mixed'

Perennials

Perennials go through the same stages in their life cycle as an annual plant but they **do not die each year** leaving only seeds to over winter. Some or all parts of the plant itself are adapted to over winter and this allows survival of the plant for a number of years.

- In trees and shrubs secondary growth allows the plant to survive as **woody tissues** above and below ground and so have a "head start" in the spring. Trees will often flower only after several years of vegetative growth.
- In many plants the above ground organs die back and the plants survive as **underground survival or perennating organs** which contain a store of food to allow quick growth in the spring or when suitable conditions for growth return. Examples of such organs are bulbs, corms, tubers, rhizomes and swollen tap roots. This is the strategy adopted by many herbaceous perennials.
- Grasses often have survival organs underground but the dense mass of tissue near the base of the shoot allows intercalary and apical meristems to survive above ground as well. Plant growth can begin again as soon as temperatures begin

Figure 32: Perennial plant *Zantedeschia aethiopica*

Biennials

Some plants have a life cycle that lasts two years; these are known as **Biennials**. Such plants build up stores of food in the first year which may be stored in an over wintering organ such as a **swollen tap root** or in a **rosette of leaves** close to the soil. They flower during the second year using the food stored the previous year. They produce seed and then die. Examples include carrots, foxgloves and Forget-me-not.

Figure 33: Biennial Plant *Digitalis purpurea*

Ephemerals

Plants that complete more than one life cycle in a year are known as **Ephemerals**. These are generally small with no main tap root and put most of their energy into **reproductive** rather than vegetative structures.

Figure 34: Hairy bitter cress *Cardamine hirsute*

Learning Activities

Now go and try the **'Plant Morphology Quiz 2'** and the **'Plant Life Cycle Activity'** in the Plant Morphology 'Interactive Learning Activities' folder.

Answers to Leaf Key activity (page 15)

A)	**ASH**
B)	**SYCAMORE**
C)	**OAK**

Answers to Learning Activity (page 20)

Dioecius	**Monoecius**
Holly – Ilex Aquifolium	Pine – *Pinus spp* (& other conifers)
Willow – *Salix spp*	Hazel – *Corylus spp*
Ginkgo	Ash - *Fraxinus excelsior*
Service Tree – *Sorbus domestica*	Silver Birch – *Betula spp*

Answers to Monocot v Dicot activity (page 23)

Characteristics	
Seed with one cotyledon	Monocotyledons
Tap root	Dicotyledons
Fibrous roots	Monocotyledons
Seed with two cotyledons	Dicotyledons
Leaves with net veins & petiole	Dicotyledons
Flower parts in multiples of 3	Monocotyledons
Leaves with parallel veins & sheathing base	Monocotyledons
Flower parts in multiples of 4 or 5	Dicotyledons