Topic 1. Plant Science 1.

1.1 Naming Plants.

All living organisms on the planet, including plants, are given a series of Latin names that place them in a hierarchy of groups. As you move down the groups the organisms become more similar in their genetics and appearance. It is referred to as **classification**. An example using a sunflower:

Taxonomic Group	**Example:** Sunflower	**Extra info about each group**
Domain	*Eukarya*	Broad group encompassing all life except bacteria
Kingdom	*Plantae*	All plants fall within this tier. Other taxonomic groups include animalia and fungi
Phylum	*Tracheophyta*	Smaller group including all plants with a vascular system (most plants, not moss)
Class	*Angiospermae*	Group comprising all flowering plants, (so not conifers, ferns or moss)
Order	*Asterales*	Originally grouped plants by flower structures but they're now classified via DNA
Family	*Asteraceae*	The daisy family. These generally have flower heads with large petals around the outside and many individual flowers within the centre
Genus	*Helianthus*	A group with similar features; first part of the binomial name
Species	*annuus*	Second part of the binomial name called the 'specific epithet'

These are not typically used in day-to-day horticulture, but it's important you understand the bigger picture

It's useful to know plant families to appreciate relatedness of plants

Genus and **species**.
Very important and the names you must learn plants by.
It's the **binomial system** (bi = two, nomial = name)

Plant **families** are commonly used to link plants into larger groups, e.g. sunflower, daisy, dahlia and dandelion are in the same family, *Asteraceae*. **Family names always end in *aceae*** (Aceae is Latin for 'a family' or 'a group')**.**

Family names are used in day-to-day horticulture to some degree, but it's most important to learn the **binomial name**:

Binomial names consist of both **Genus** and **species**: bi = two, nomial = name

Helianthus annuus (sunflower)

***Helianthus* is the genus, *annuus* is the species.**

annuus means annual, indicating this plant has a life cycle of one year.

Carl Linnaeus was a Swedish botanist who, in the 1700's, invented the system of classification we use today.

He classified plants according to their floral structures, grouping those with similar flowers and separating groups by their distinctly different floral structures.

He is responsible for creating the binomial naming of plants (genus + species name), as well as all other organisms.

1.2 Parts of a Plant.

This section will overview the structure and function of flowers, leaves, stems and roots, and compare monocots and eudicots where necessary. You only need to know details of angiosperms for RHS level 2.

Flowers:

Angiosperms are flowering plants, with floral parts that are designed for wind or animal (usually insect) pollination. The production of **flowers** is purely for **sexual reproduction** (asexual reproduction is the opposite, producing clones – this is how cultivars are propagated), where ideally pollen from one plant is transferred to a different plant of the same species (cross-pollination), maximising **genetic variation in the offspring**. Many plants can pollinate themselves (self-pollination) so only one plant is required for pollination to occur, however this reduces the genetic diversity of the offspring.

Pollen is produced on the **male** parts of the flower, the **stamens**.
The **female** part is called the **carpel**, including **ovules** that lie within an ovary (see labelled image, below).

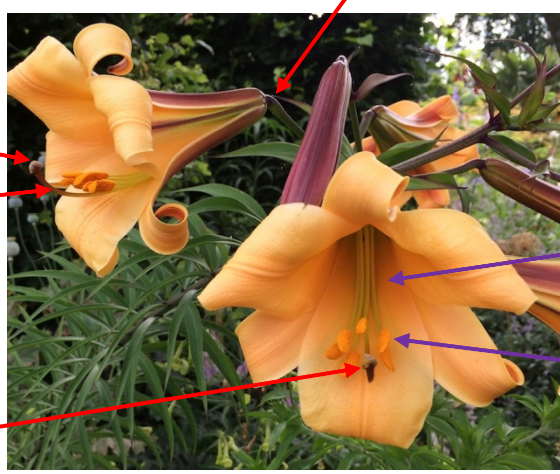
Many plants, for example lilies (e.g. *Lilium regale*), produce stamens and a carpel within the same flower. These types of flowers are called **bisexual, hermaphroditic, or perfect**, containing **both male and female parts**.

Some plants produce **separate male and female flowers** on the **same plant**, for example *Zea mays* (sweetcorn) and *Cucurbita pepo* (pumpkins). These types of plants are called **monoecious**.

Lastly, **dioecious** plants have completely **separate male and female plants**. *Ilex aquifolium* (holly) and *Taxus baccata* (yew), are both dioecious.

<u>Flower parts:</u>

Flowers of bisexual plants have both male and female parts. *Lilium spp.* flowers show this very clearly, as illustrated:



Lilium 'African Queen'

Key flower terms:

Petals: usually colourful, large structures
Corolla: collective term for petals
Corona: petals fused to form a tube, e.g. in *Digitalis purpurea* (foxglove)
Sepals: protective function, often green outer whorl; not always present
Calyx: collective term for sepals
Tepals: in many monocotyledonous flowers, petals and sepals are indistinguishable and instead called tepals
Perianth: includes both the corolla and calyx
Receptacle: holds all the flower parts
Pedicel: flower stalk (ends with the receptacle)

1.3 Transport in Plants

Plants must transport substances essential to life from roots to shoots and vice versa. **Water, minerals, sugars, hormones** and other substances **are transported**, primarily via xylem (or tracheid's) and phloem, and short distances via tiny openings between cells (called plasmodesmata).

Water is an essential compound required by plants; around 90% of a plant is water:

- Water maintains **turgidity** of cells, which ensure stems remain upright, leaves are held out in an optimum position for photosynthesis, and cell processes function normally. **If a plant lacks water it will wilt** and growth stops.
- Water is a medium in which **chemical reactions** can happen in a plant.
- Water is a reactant in **photosynthesis** (although only 1% of water taken up by the roots is used this way).
- Water is a **solvent**, carrying dissolved substances like minerals (nutrients) from the roots. Sugar made in photosynthesis and plant hormones are also soluble and transported around the plant via water movement.

Water uptake in a plant:

Water is absorbed into root cells from the soil by a passive process called **osmosis**. Osmosis is defined as:

The <u>movement</u> of <u>water</u> from an area of <u>higher water concentration</u> (/lower solute concentration) **to an area of <u>lower water concentration</u>** (/higher solute concentration)**, through a <u>semi-permeable membrane</u>.**

[you can correctly define osmosis without mentioning solutes, which makes it easier to remember]

Key terms:

- **Passive** = does not require energy.
- **Concentration** = how many particles per unit volume.
- **Solute** = dissolved substances in water, like salts, sugars, etc.
- **Semi-permeable membrane** = only allows very small molecules, like water, to pass through; dissolved substances like salts and sugars cannot freely pass through. All cells have a semi-permeable membrane around them; this is called the cell membrane.

All water entering a plant is via osmosis. There is always a net movement of water into a plant as long as there's a higher concentration of water in the soil than in the plant. If the soil begins to dry, the concentration of water in the soil is no longer higher than in the plant, so water stops entering the roots. This leads to wilting.

There are **two routes** through which water enters the roots. **Symplastic** movement of water is **within cells**, following uptake by osmosis; there are tiny openings between each adjoining cell in a plant called plasmodesmata that allow water, along with other substances, to move through via diffusion (movement of a substance from a higher concentration to a lower concentration). **Apoplastic** movement of water is through the cell walls **between cells**. Water can travel from the soil into the root without entering the cells this way until it reaches the **Casparian strip**, an impermeable layer that forces water to enter the root cells via osmosis and continue via the symplastic route.

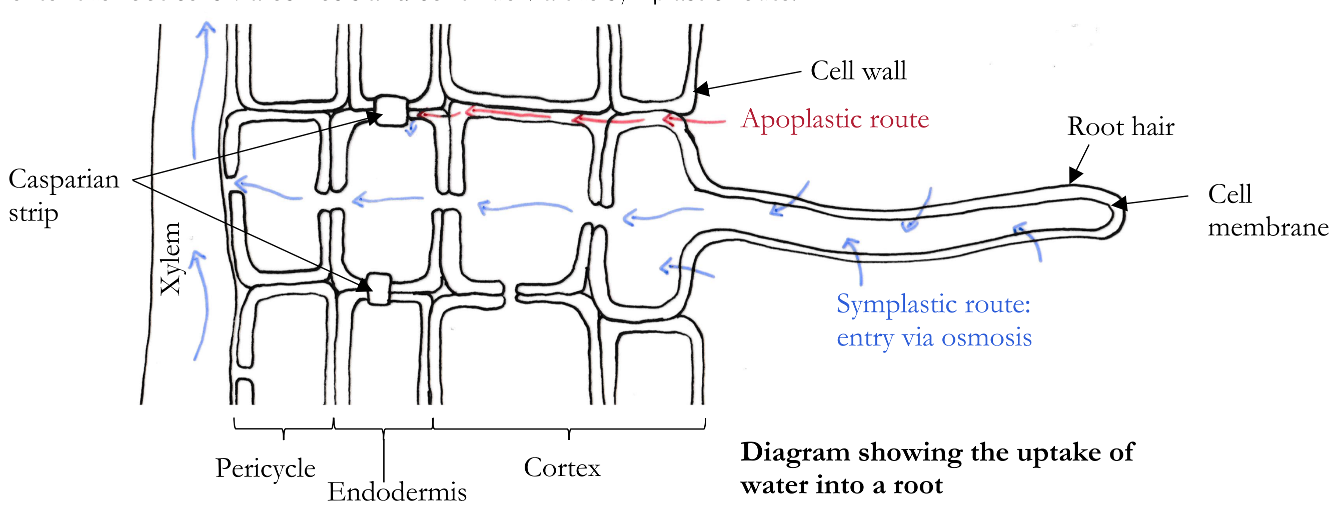


Diagram showing the uptake of water into a root

1.4 Photosynthesis and Respiration

Photosynthesis:

This is the most important chemical reaction on the planet that enables photosynthetic organisms, namely plants (but also green algae and cyanobacteria) to make food using light energy. Organisms that can synthesise their own food molecules are called **autotrophic**, which includes all plants, and form the base of all food chains. Organisms that need to eat food (complex organic molecules) and cannot synthesise their own are called **heterotrophs** and include animals, fungi, some bacteria and protists.

Photosynthesis is a **chemical reaction** that has the following **formula**:

Reactants → **Products**

Carbon dioxide ($6CO_2$) + **Water** ($6H_2O$) $\xrightarrow[\text{Chlorophyll}]{\text{Light energy}}$ **Glucose** ($C_6H_{12}O_6$) + **Oxygen** ($6O_2$)

- Carbon dioxide: From the atmosphere
- Water: From soil water via xylem
- Light energy / Chlorophyll: Usually sunlight/ Chlorophyll is found in chloroplasts
- Glucose: **Useful product**: high in energy, a type of sugar
- Oxygen: Waste product

Photosynthesis happens in the **chloroplasts** of photosynthetic plant cells: found primarily in **leaves**, but also in young stems. Any part of a plant that is **green** can undertake photosynthesis **when there is sufficient light** (i.e. not in the dark).

Photosynthesis, like all chemical reactions in living organisms, is **enzyme controlled**. Enzymes are types of protein that speed up chemical reactions. Each type of enzyme has an **optimum temperature** (and pH) that it operates in.

Plants cannot control their temperature, which will fluctuate through day/night and season. Depending on where a plant has evolved, its optimum photosynthetic temperature might be higher (e.g. tropical plants) or lower (e.g. alpine plants).

In a **greenhouse** or **conservatory**, **temperatures below the optimum can be raised to increase rate of photosynthesis**, leading to faster growth. This is important for **maximising yield** of crops, e.g. tomatoes, or readiness of garden plants for sale, e.g. the warmer conditions in a polytunnel. Conversely, in summer they might need to be cooled to maintain optimum temperature for the crop.

This is one way of tackling a **limiting factor** of photosynthesis – meaning the factor that is most limiting to the rate of photosynthesis and therefore growth of the plant. Other limiting factors:

- **Light intensity:** increase during autumn/winter/spring with artificial lighting in a greenhouse
- **Carbon dioxide concentration:** increase concentration from CO_2 canisters in a greenhouse
- **Water:** if in short supply the **stomata close**, preventing entry of carbon dioxide, which limits photosynthesis. Note: water is never a limiting factor as a reactant in photosynthesis; a plant would be dead from desiccation by this point.

Tomato plants in a greenhouse. The higher temperature increases photosynthetic rate, speeding growth.

<u>Commercial Greenhouses</u>

Growers carefully alter the temperature, light intensity and duration, carbon dioxide concentration and maintain sufficient soil water and humidity to maximise the rate of photosynthesis. This ensures maximum growth and ultimately, profit made from growing plants for sale, food crops or cut flowers.

1.5 Plant Lifecycles

The Life of a Plant:

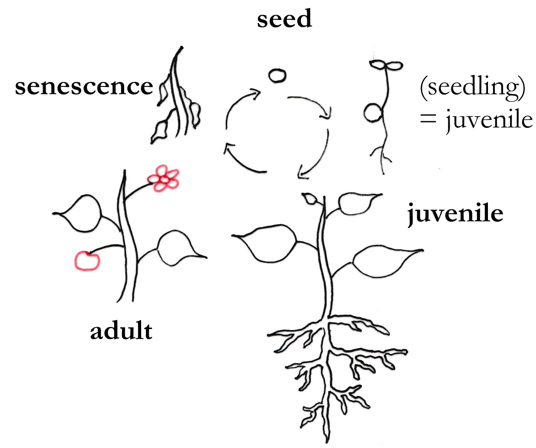
Every plant goes through **three stages** in its life:

1. After germination of a seed, a plant enters its **juvenile phase** when it is **not sexually reproductive** (doesn't produce flowers and seeds) and undertakes **vegetative growth only**. A minority of plants, such as *Eucalyptus gunnii*, produce different foliage at this stage, called '**juvenile foliage**' and need to be pruned regularly to maintain their juvenile state for aesthetic horticultural purposes.

2. The next phase is **mature/adult**, when the plant starts producing structures such as flowers in angiosperms. At this point the plant is **sexually reproductive** and is able to produce seeds.

   [Note that stating a plant is 'reproductive' at maturity is incorrect as juvenile plants can be reproduced, e.g. via cuttings, which doesn't require flowers; plants are <u>sexually reproductive</u> at maturity].

3. Later in a plant's life it enters **senescence**, when the plant no longer flowers and slowly declines, ending in **death**.



The lifecycle of a plant

Lifecycle Adaptations:

There are four types of lifecycles in plants, each of which have evolved in response to environmental pressures such as short growing season, regular disturbance, consistent conditions, etc.

All reference to lifecycles means the entire journey of a plant's life from germination → juvenile → adult → senescence

Ephemeral:

- **Lifecycle** is completed **within a few months**.
- Self-seed readily and germinate quickly when conditions are suitable.
- Successful in highly disturbed habitats such as gardens where soil is often exposed.
- Usually considered weeds in a garden, these are small, fast growing plants with little ornamental value.
- E.g. *Cardamine hirsuta* (hairy bitter cress), *Senecio vulgaris* (Groundsel).

Cardamine hirsuta (hairy bitter cress), a common ephemeral.

Helianthus annuus 'Velvet Queen', an annual.

Annual:

- Completes its **lifecycle within one year.**
- Evolved in response to disturbance and limited growing season.
- Annuals are popular for one season of colour and are always herbaceous (not woody).
- They can be sown direct into or onto the ground (this is typical for wildflower meadows), or started in pots and transplanted (popular in the nursery trade, e.g. with *Helianthus annuus*, sunflowers).
- Are either hardy (survives temperatures below -5°C/H4-H7 RHS hardiness rating), half-hardy (killed by frost/H3 RHS hardiness rating) or tender (cannot survive temperatures below 1°C/H2-H1 RHS hardiness rating – see topic 4.1).
- Hardy annuals, such as *Centaurea cyanus* (cornflower) or *Delphinium consolida* (Larkspur) can be sown or planted out before the last frost date in spring. Hardy annuals can also be sown or planted in the autumn for earlier flowering and seeding the following year – this makes them more resilient to summer droughts that might limit spring-sown annuals' ornamental display, or require additional irrigation, which is less sustainable.

1.6 Flowers and Pollination

Plants have evolved ways of **cross-pollination** to ensure that a mix of genes from either parent is expressed in the offspring as a result of **sexual reproduction**. This essential mixing of genes results in **variation** within a species. As environments incrementally change over time, e.g. become warmer, cooler, wetter, drier, new competition, etc., individuals that happen to have genetics better suited to the slightly altered conditions will survive better, live longer, reproduce more and pass on their better adapted genes. Less well adapted individuals will not, thus species slowly change over time.

A bee pollinating an *Echinops ritro* flower.

This is called 'natural selection' and was theorised by Charles Darwin; it's our scientifically accepted explanation of why life evolves, slowly changing over time. It also explains why some species go extinct and how new species can evolve.

Sexual reproduction is a huge advantage to plants. As well as the ability for a species to **adapt** to a **changing environment**, it also allows plants to **colonise new areas** via **dispersal** of their **seeds** (angiosperms/flowering plants and gymnosperms/conifers) **or spores** (pteridophytes and bryophytes). It means that new plants can grow so that older plants that are entering the senescent phase of their lifecycle are replaced. Without this a species would go extinct as no individual plant can live forever.

There are two main strategies for pollination: **animal pollination** (mostly insects) and **wind pollination**. A small number of species are water pollinated.

This *Eryngium giganteum* has rigid bracts (modified leaves that look like petals) as a landing pad which are a bright silvery-white colour to attract pollinating bees.

Wisteria floribunda is often strongly fragrant with bright petals to attract pollinators.

Animal (insect) Pollination:

Most animal pollination in the UK is undertaken by insects, but in other countries plants are pollinated by birds, mammals or other animals. Pollinators, e.g. bees, are attracted by the bright petals and (if produced) fragrance of flowers. They are seeking the nectar held within the flower and collect some of the protein-rich pollen. As they travel from flower to flower they transfer pollen around, thereby cross-pollinating flowers. As pollinated flowers develop into seeds and fruits, pollinators are absolutely crucial for human survival as **many food products are the result of animal pollinated flowers**.

Animal pollinated flowers have some general commonalities that improve their chance of being successfully cross-pollinated:

- Flowers have large, **brightly coloured petals**.
- **Flowers are held high on the plant** so they're more visible.
- Flowers can have **fragrance** to attract pollinators.
- Flowers produce **nectar** to attract pollinators.
- **Guidelines on petals** (visible under UV light) to direct pollinators to nectaries.
- Many flowers have a **landing pad** for pollinators to rest on (a petal).
- **Anthers are held in a position to maximise contact with pollinators**.
- **Pollen grains are sticky** so they attach to pollinators.
- **Stigma and style are rigid and robust** to withstand pollinators brushing past.