The information in this document covers the IB Syllabus for Topic 9.

Structure of a Dicotyledenous Plant

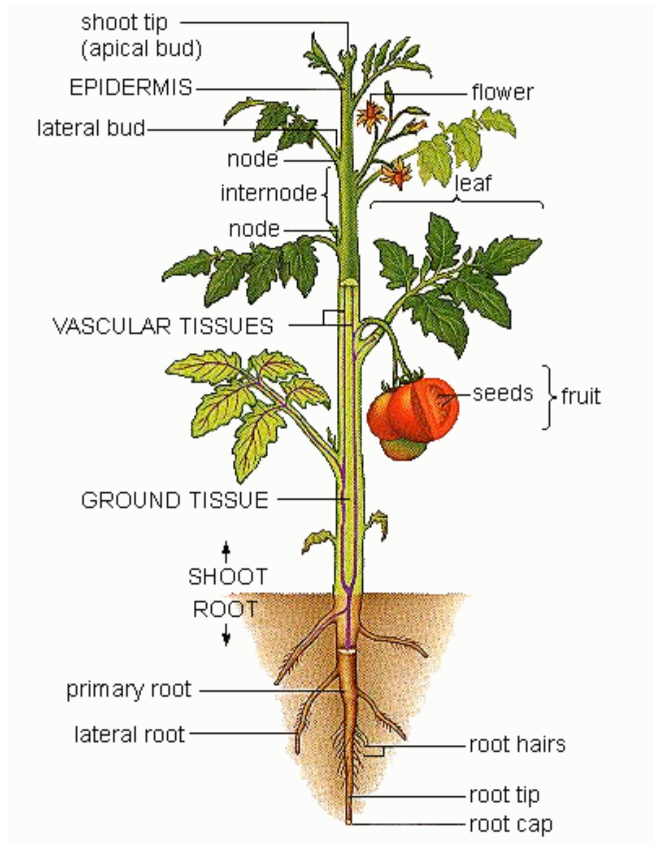


Image from http://www.uic.edu/classes/bios/bios100/labs/plantbod.gif

The "Typical" Plant Body

The Root System

- Underground (usually)
- Anchor the plant in the soil
- Absorb water and nutrients
- Conduct water and nutrients
- Food Storage

The Shoot System

- Above ground (usually)
- Elevates the plant above the soil
- Many functions including:
    - photosynthesis
    - reproduction & dispersal
    - food and water conduction

Characteristic	Monocot	Dicot
Leaves	Veins parallel	Veins branched
Stems	Vascular bundles scattered	Vascular bundles arranged in a ring
Roots	Fibrous roots	Tap root
Flowers	Petals in multiples of 3	Petals in multiples of 4 or 5
Seeds	One cotyledon (seed leaf)	Two cotyledons (seed leaves)

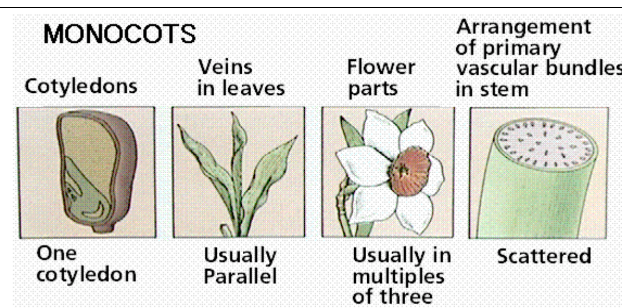


Image from http://www.emc.maricopa.edu/faculty/farabee/BIOBK/monocots_1.gif

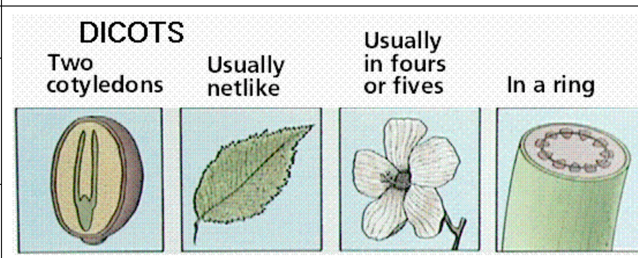


Image from http://www.emc.maricopa.edu/faculty/farabee/BIOBK/DICOTS.gif

Types of Plant Cells

- Parenchyma
  - the most generalized cell in a plant
  - thin, flexible cell wall and large vacuole
  - carry out most of the plant's metabolic functions (e.g. Photosynthesis)
- Collenchyma
  - thicker primary cell wall than parenchyma
  - grouped in strands or cylinders (e.g. “strings” on celery)
  - support the young plant
- Sclerenchyma
  - main function is support
  - thick secondary cell wall contains *lignin*
  - dead at functional maturity
  - may be in strands/fibres (e.g. Hemp) or in clumps called sclereids (like the grains in pears)
- Tracheids
  - water-conducting elements
  - dead at functional maturity; found along with vessel elements in xylem
- Sieve-tubes
  - food-conducting elements
  - kept alive and nourished by companion cells
  - found in phloem

Types of Plant Tissues

- Dermal
  - single layer of cells
  - tightly-packed; covered with a waxy material called cuticle
- Vascular
  - xylem and phloem
  - functions in both support and transport of food (phloem) and water (xylem) throughout the plant
- Ground
  - makes up the bulk of a young plant
  - fills the space between dermal and vascular tissues
- Apical Meristem
  - regions of cell division in the root/shoot tips
  - responsible for *growth and elongation of the root and shoot*
- Lateral Meristem
  - cell division in lateral meristem *increases diameter of the stem*
  - e.g. cambium
    - layer of cells between xylem and phloem
    - produces new xylem and phloem

Distribution of Tissues in a Dicot Leaf, Stem and Root

Leaf

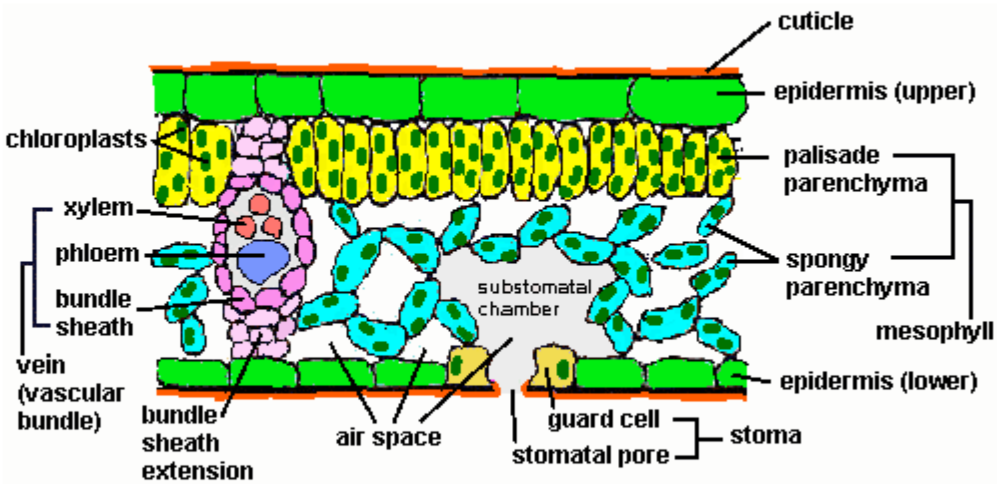
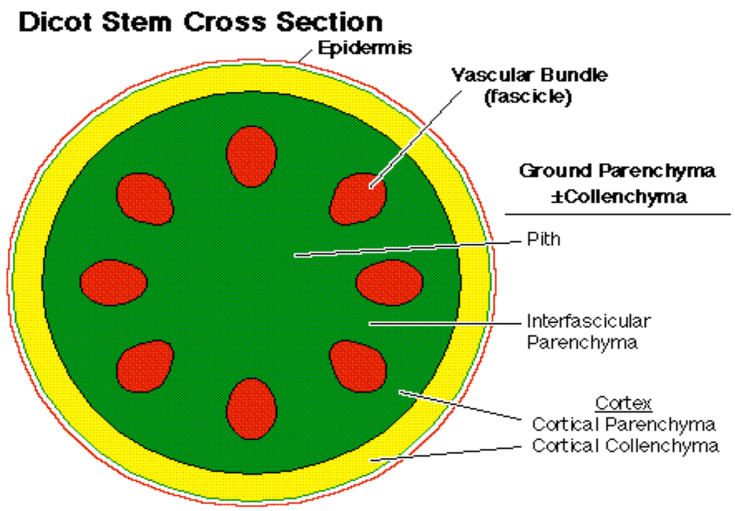
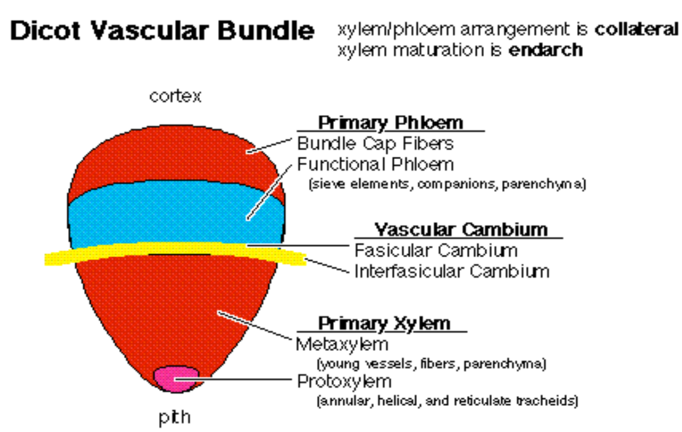


Image from http://generalhorticulture.tamu.edu/lectsupl/anatomy/P16f1.GIF

Stem





Images from
http://www.cartage.org.lb/en/themes/sciences/BotanicalSciences/PlantsStructure/StemShoot/distemlec.gif

Root

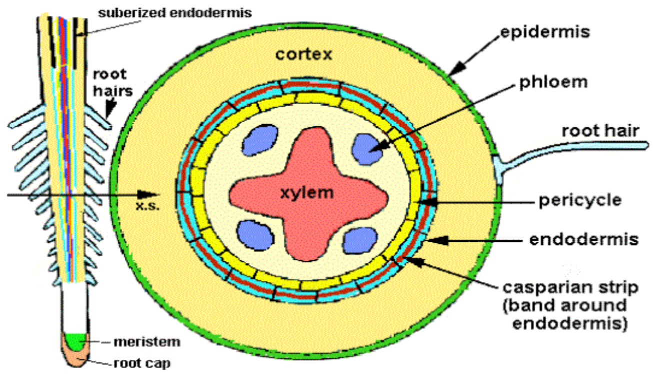


Image from http://www.ualr.edu/botany/root_diagram.gif

Leaves, Stems & Roots

Leaves are adapted to perform certain important functions: *photosynthesis*, *respiration*, and *transpiration*. A leaf typically consists of a blade (lamina), stalk (petiole) and a base, which is the point of attachment to the stem.

The arrangement of tissues in the leaf helps it best perform photosynthesis:

- Upper epidermis cells are transparent, allowing light to pass through.
  - This means the palisade mesophyll receives light that hasn't had any energy absorbed from it yet.
- Palisade mesophyll cells are tightly packed to maximize light absorption.
- Spongy mesophyll cells have air spaces connected to stomata for gas exchange with the atmosphere.
- Vascular tissue (veins) brings water from roots & takes away sugars.

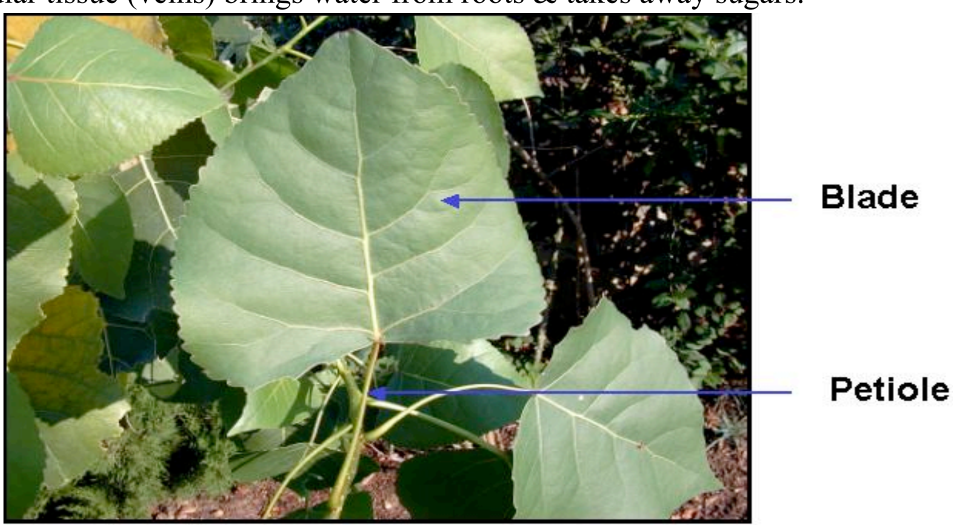


Image from http://www.botany.hawaii.edu/nlc_biology/2470/lab/LeafLab/slide1.jpg

The leaf blade may have indentations or clefts (e.g. oak or maple). If these indentations reach the midrib (the main vein down the middle of the leaf) so that the leaf blade is divided into leaflets, the leaf is called a compound leaf (next pg.). A leaf that is not divided into leaflets is a simple leaf (above).

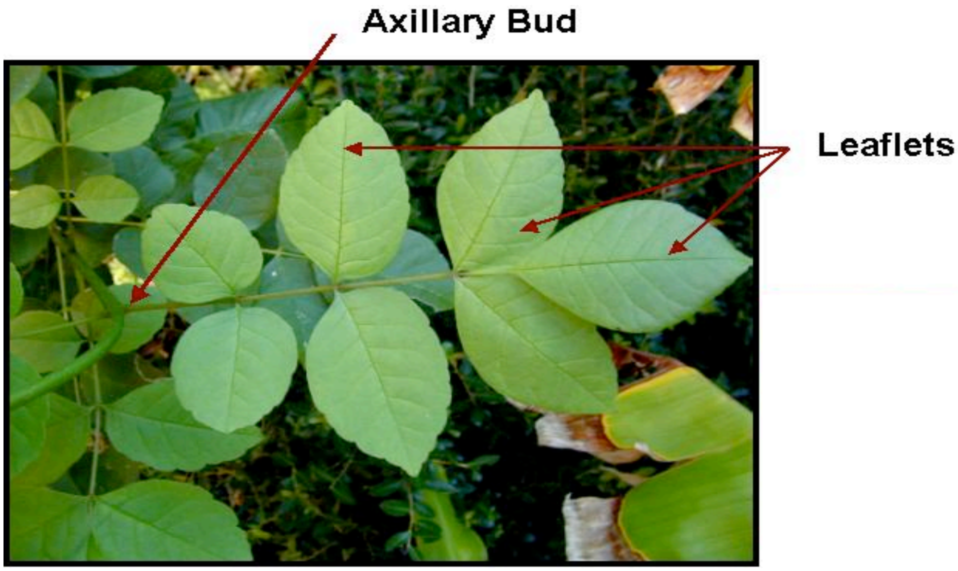


Image from http://www.botany.hawaii.edu/nlc_biology/2470/lab/LeafLab/slide3.jpg

Recall that leaf structure is often unique to a tree species, and can be used as a means of identifying it (via dichotomous keys).

Stomata (sing: stomate) are openings in the epidermis of a leaf. Guard cells, which are a pair of specialized epidermal cells, control the opening and closing of the stomata. When the guard cells swell, the stomate closes, and when they shrink, the stomate opens. When the stomata are open, CO_2 from the atmosphere can enter the leaf, while O_2 and $H_2O_{(v)}$ exit due to concentration differences between the atmosphere and the air spaces in the leaf.

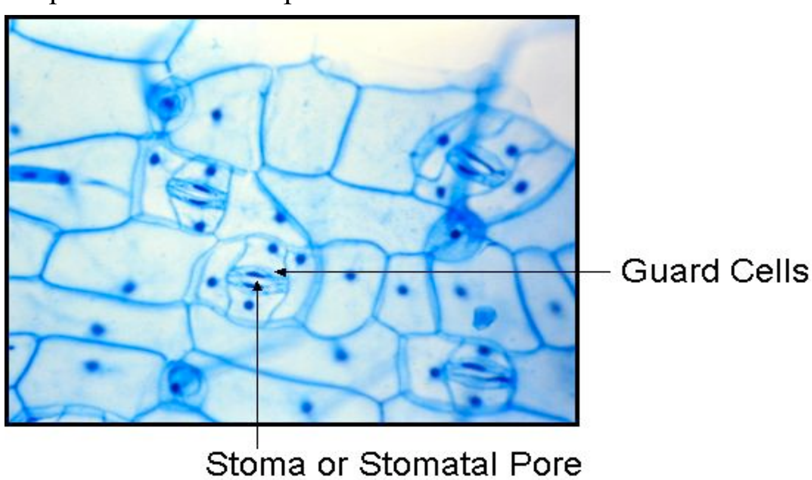
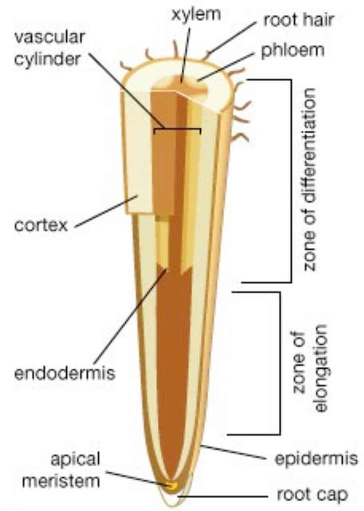
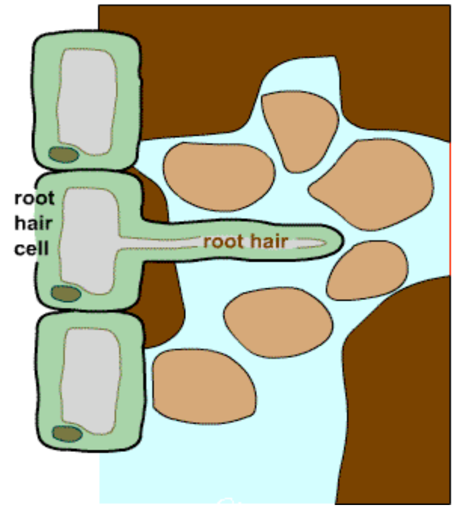


Image from http://www.botany.hawaii.edu/nlc_biology/2470/lab/Leaflab/slide11.jpg

Stems normally grow above ground. They grow towards light (positively phototropic) and against gravity (negatively geotropic). The main stem develops from the plumule of the embryo (in the seed), with lateral branches developing from axillary buds.

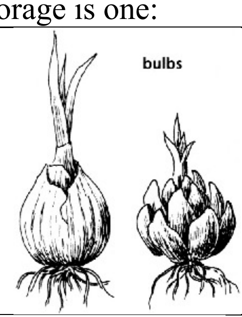
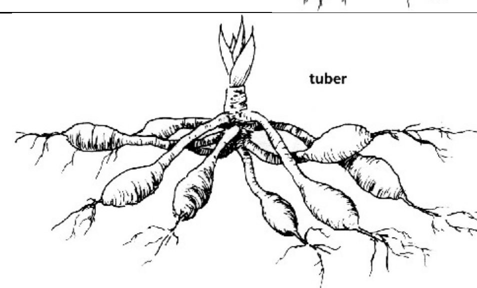
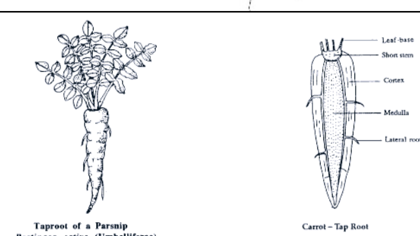
Monocots have herbaceous stems, and a random arrangement of vascular bundles. Dicots can have herbaceous or woody stems, and have vascular bundles arranged in rings.

<u>Roots</u> grow underground, supporting the plant, and providing it with water and minerals from the soil. Root growth occurs primarily at the root tip, in the meristem tissue. <u>Root hairs</u> are outgrowths of the root's epidermal cells. They serve to increase the surface area of the root, thus increasing the absorption of water from the soil. Root hairs' length may be hundreds of times their diameter.

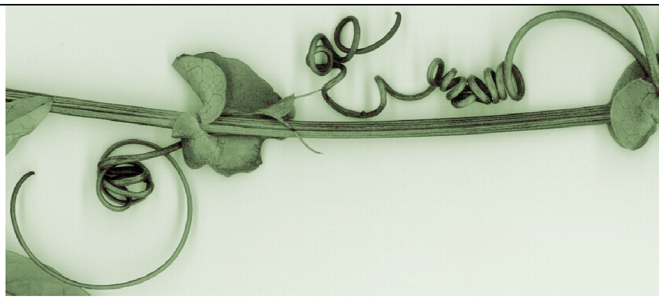
 http://cache.eb.com/eb/image?id=72219&rendTypeId=35	 http://www.macleans.school.nz/students/science/F4/plants/Plants2002/RootHair.gif

Structural Specializations

Leaves, stems and roots may be modified in structure for specific purposes. Food storage is one:

Leaf	<u>Bulbs</u> are leaves that have been modified for food storage. They are found underground, and are attached to a flattened, modified stem. Onions are bulbs. Image from http://content.answers.com/main/content/img/Gardeners/f0040.jpg	
Stem	<u>Tubers</u> are modified underground stems. They are used to store starch – outermost cells will also have protein. Potatoes are tubers. Image from http://content.answers.com/main/content/img/Gardeners/f0261.jpg	
Root	The <u>main tap root</u> of a plant may be modified to store food. A carrot is an example of a storage root. Image from http://www.nccpg.com/Images/MH82.gif	

Some plants do not fully support themselves – they have leaves or stems that are modified as tendrils to secure them to other plants, or structures (e.g. a fence or trellis). Grape vines have stem tissue that becomes modified as tendrils, and sweet peas have leaflets that become modified as tendrils.

Stem Tendrils – Passion Flower	**Leaf Tendrils – Garden Pea**
 http://easyweb.easynet.co.uk/~iany/patterns/images/passion_flower_tendrils.jpg	 http://easyweb.easynet.co.uk/~iany/patterns/images/pea_tendrils.jpg

Plant Adaptations

Many plants have adapted to environments with varying degrees of water availability:

Xerophytes are plants that are able to live in very dry environments. They can have any of the following adaptations so that they can obtain the maximum amount of water and not lose it:

- reduced leaves
  - reducing the leaf surface reduces the amount of water loss
    - "spikes" on cacti are reduced leaves
    - needles on pine trees are rolled leaves (also reduces surface area)
- thickened, waxy cuticle will reduce water loss through the cuticle even further
- reduced number of stomata will reduce water loss but also the amount of gas exchange, and therefore photosynthesis
- stomata may be found in pits or surrounded by hairs
  - reduces air flow past the pore which reduces the concentration gradient (water stays near the stomata instead of being taken away by wind)
- deep roots may allow the plant to reach water deep in the soil
- specialized water storage tissues (e.g. in cacti) allow the plant to survive long, dry periods
- small plants, close to the ground, have less water loss
- some plants germinate, grow and flower in the wet season, leaving seeds that are dormant until the next wet season

Hydrophytes are plants that live in water. They may be floating, emergent (rising up out of the water) or submergent (completely under water).

- air spaces allow the plant to float on the surface so it can obtain the most light
- very little strengthening tissue, since water provides the upward force
- roots limited in size, since they are chiefly there to anchor the plant
- plants that float on the water's surface will have their stomata on the upper epidermis, since it is in contact with the atmosphere

Transport in Vascular Plants

At the same time that water is moving up the stem in the xylem (from its "source" in the roots to a "sink" in the leaves), sugars are moving down the stem in the phloem (from the "source" in the leaves to a "sink" in the roots):

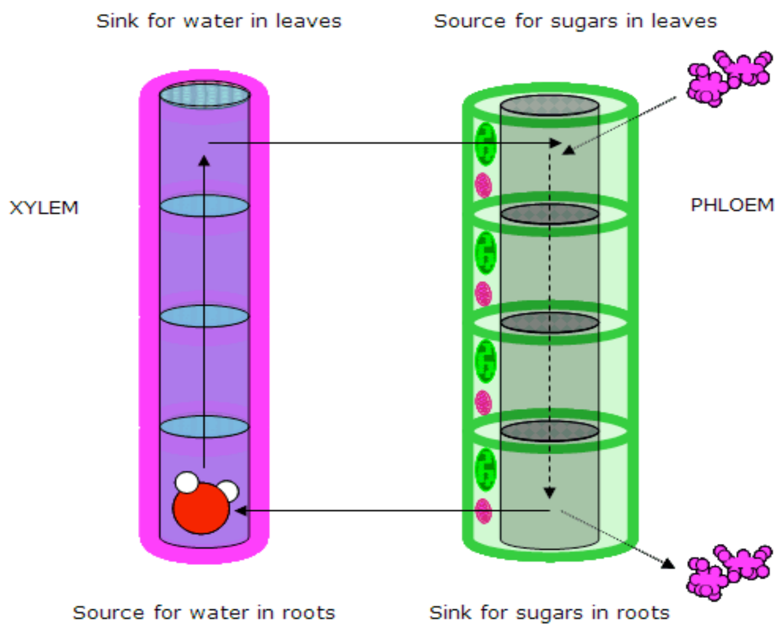
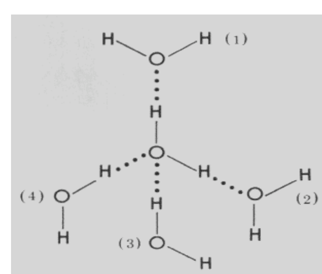


Image adapted from http://www.steve.gb.com/images/science/phloem_xylem_water_potentials.png

Transport of Water and Nutrients in the Xylem

Xylem is the water-conducting tissue in plants. Xylem cells are dead at functional maturity. Tracheids are long, tapered xylem cells that have end plates of crossbars. Vessels are shorter xylem cells that have greater diameter and no obstructions (crossbars).

Water is pulled up the xylem by the force of transpiration (water loss by evaporation; occurs via stomata). Since water molecules are weakly bonded to each other by hydrogen bonds, water lost from the leaves causes additional diffusion of water from the leaf xylem. This creates a "pull" on water molecules in the columns of the xylem. This "pull" causes water molecules to rise up the xylem from the roots, eventually reaching the leaves. Loss of water from the root system allows more water to enter the roots from the soil.



Cohesion-Adhesion Theory

Cohesion: the ability of molecules of the same kind to stick together.

Water molecules are polar, with slight positive and negative charges, which causes their cohesion (by hydrogen bonding). Inside the xylem, water molecules form a long chain extending from roots to leaves.

Adhesion: the tendency of molecules of different kinds to stick together.

Water sticks to the cellulose molecules in the xylem walls, which counteracts the force of gravity and aids in the rise of water up the stem.

Transpiration: the loss of water vapour from the leaves and stems of plants. Occurs mainly by evaporation through the stomata.

Water molecules lost by transpiration are replaced by water from the xylem of the leaf veins. This "pulls" on the chain of water molecules in the xylem. Adhesion of water to the cell walls of the xylem facilitates movement of water upward within the xylem.

Factors Affecting Transpiration in Terrestrial Mesophytes
A mesophyte is a plant adapted to conditions of average water supply. Rate of transpiration depends on several factors:

- temperature: rate of evaporation is doubled for every 10ºC increase in temperature
- humidity: evaporation is much higher in dry air than in air which already contains water
- wind: air currents will take water vapour away from the leaf; this maintains the concentration gradient & increases transpiration
- light: plants generally open their stomata in the light to allow diffusion of carbon dioxide into the leaf for photosynthesis; this also greatly increases transpiration

Roots

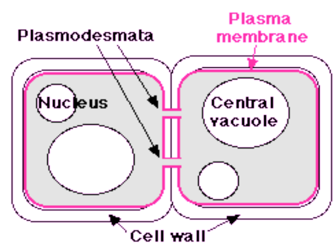
- adapted for water absorption
  - branching of roots increases surface area
  - presence of root hairs on epidermal cells greatly increases surface area

- mineral uptake by active transport
  - mineral concentration inside the root often exceeds that of mineral concentration in soil water
  - energy requirements for mineral uptake are one reason why roots require sugar (food)
- mineral ions may also enter the root by diffusion, with assistance of mutualistic fungal hyphae, or mass flow of water carrying the ions

Water Uptake by Roots

Water enters the root by osmosis, primarily through root hairs. From the epidermis, the water molecules may follow three pathways to the vascular bundle (at the centre of the root):

1. *Apoplast Pathway*:
   - water does not enter the cell
   - travels through cell walls until it reaches the endodermis
   - Casparian strip around the endodermis is impermeable to water, so water then enters the symplast pathway



2. *Symplast Pathway*:
   - water enters the cytoplasm but not the vacuole
   - passes from cell to cell via plasmodesmata, which are tiny connections of cytoplasm that pass through the cell walls

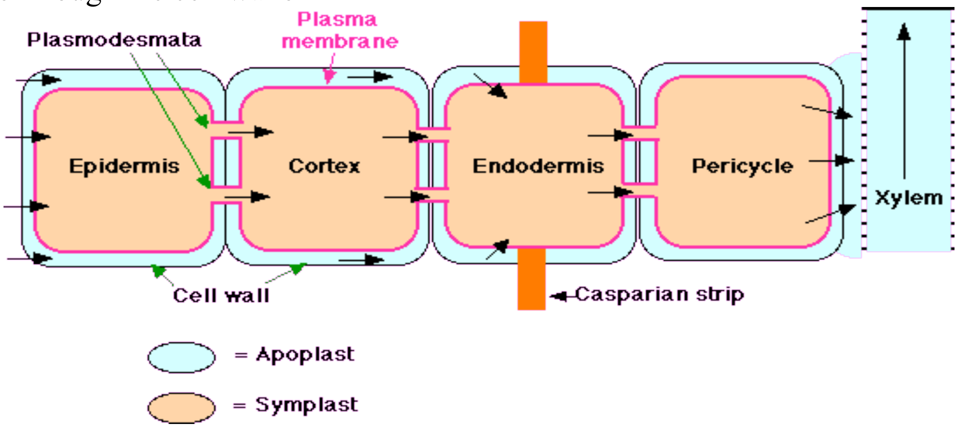


Image from http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/S/sym_apoplast.gif

Added Bonus!

Since terrestrial plants do not have a skeleton, they need other means of support. Trees and shrubs have woody stems that support them. Herbaceous stems depend mainly on turgor for their support. As the vacuole takes up water, the cell swells up. This will stretch the cell wall until it has reached its limit, which in turn limits the size and shape of the cell – the vacuole will continue to draw in water due to differences in water potential. Cellulose in the cell walls provides a good deal of support as well.

Xylem vessels also have lignified supporting tissue that will assist in the process of keeping the cell upright – this is insufficient on its own (just think of that limp celery from the back of your fridge!)

Carbohydrate Transport in the Phloem

Carbon compounds produced by photosynthesis in the leaves are distributed throughout the plant by the phloem. This process is called **translocation**. Sucrose and other organic molecules are produced in the leaves during photosynthesis, and are translocated through the phloem to other parts of the plant (e.g. developing leaves, roots, fruits).

Pressure Flow Hypothesis

Translocation in the phloem is an active process, depending upon the metabolic activity of phloem cells (companion cells, primarily). Pressure flow hypothesis suggests that:

- water containing sugars and other organic molecules flows under pressure throughout the phloem
- pressure is created by a difference in water potential of the phloem sap vs. water in xylem
- at their source in the leaves, sugars are pumped by active transport (requires ATP) into the companion cells and sieve tube elements of the phloem
- as these organic molecules accumulate in the phloem, water follows by osmosis
- turgor pressure builds up in the sieve tubes

- as fluid is pushed down (and up) the phloem, sugars are removed by cells at the sinks by active transport
- sugars are either consumed by metabolism or converted to starches for storage; this decreases osmotic pressure at the sink
- pure water is left in the phloem, and exits by osmosis or is drawn into the xylem by transpiration pull

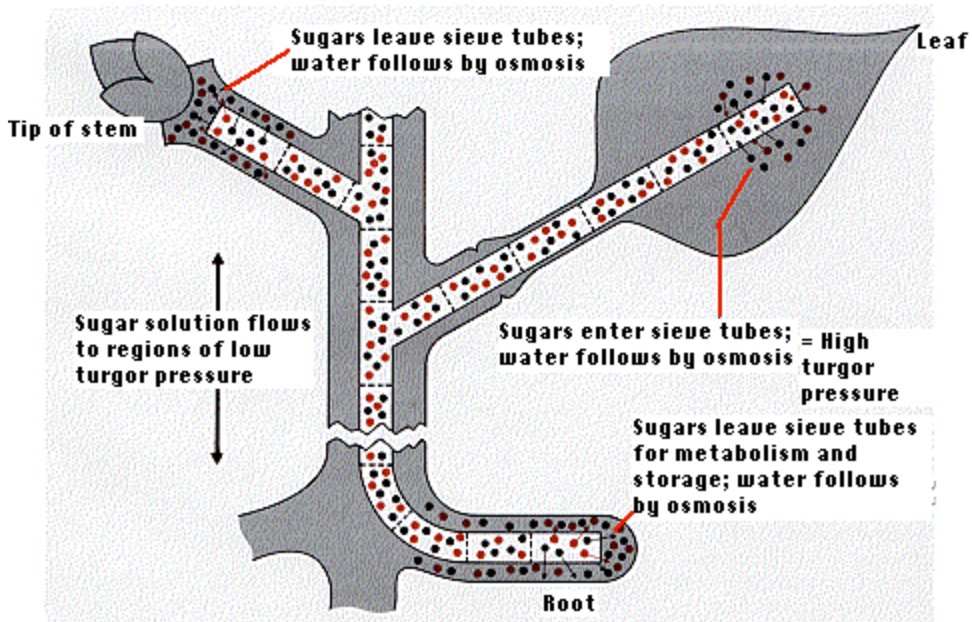


Image from http://www.ualr.edu/botany/phloem.html

Phloem	Xylem
1. conduits are **living cells** ○ sieve tubes in gymnosperms ○ sieve tube members in angiosperms **2.** used for transport of **organic compounds** 3. **bidirectional movement** (up or down, can change seasonally) 4. **slow (**maximum flow rate of 1 m/hr)	**1.** Conduits are **dead cells** ○ **tracheids** ○ **vessel elements** 2. used for transport of **water** and **minerals** (inorganic compounds) 3. **unidirectional movement** (up) 4. **fast** (maximum flow rate of 15 m/hr)

Plant Hormones

- ➢ Auxins promote stem elongation, and inhibit growth of lateral buds. They will move to the dark side of the stem, causing elongation of cells on that side – the stem grows towards light (phototropism)
- ➢ Abscisic acid promotes seed dormancy by inhibiting cell growth. It is also involved with opening & closing of stomata.
- ➢ Ethylene is a gas produced by ripe fruits. It causes ripening in other fruits that haven't ripened yet – which is why one rotten apple spoils the whole bag.
- ➢ Giberellins promote stem elongation. Cytokinins promote cell division.

Reproduction of Flowering Plants

Flowers are the reproductive parts of plants. Flowers can have male organs, female organs, or both. After fusion of the male and female gametes, a zygote is produced, which develops into an embryo within the seed.

Flower structure can be divided into four whorls (layers):

- **calyx**
  - the outermost whorl
  - consists of sepals, which are green leaves
  - encloses and protects the inner whorls in the bud stage
- **corolla**
  - most conspicuous part of the flower → brightly coloured
  - consists of petals, which are larger than sepals
  - attracts agents of pollination, such as birds or insects
  - encloses and protects the stamens and pistil
- **stamens**
  - consist of a flexible, slender filament, with an anther at the end
  - the anther is the male reproductive organ of the flower, producing pollen
- **pistil**
  - the innermost whorl
  - consists of a swollen ovary, and a style, which supports the stigma
  - the ovary contains ovules, which contain egg cells
  - the style bears the stigma in the most suitable position for pollination
  - the stigma produces a sticky substance which traps pollen

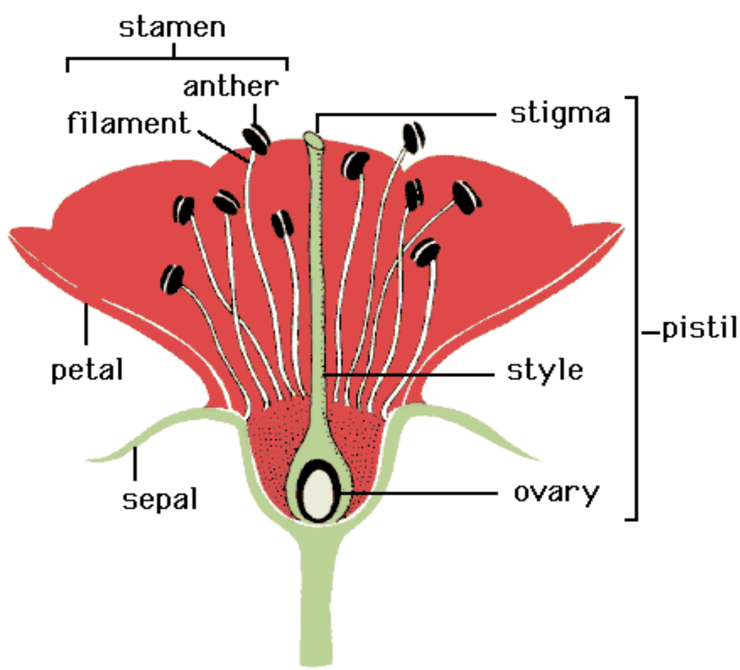


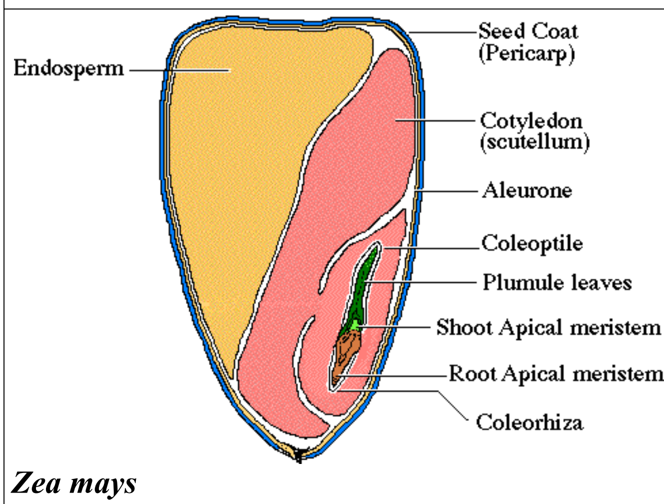
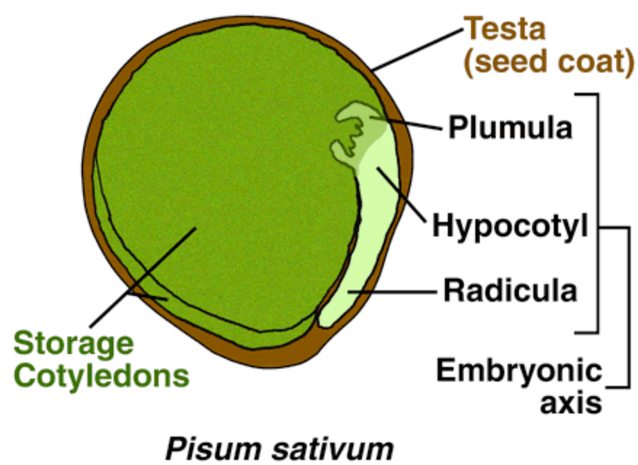
Image from http://www.agen.ufl.edu/~chyn/age2062/lect/lect_15/22_62.GIF

Pollination is the movement of pollen from anther to stigma. Fertilization occurs after pollination. Flowers have evolved many methods of ensuring pollination, often involving structural and behavioural modifications in the pollinating agent. Pollinating agents may be insects (beetles, ants, bees), birds (hummingbird) or mammals (mice, pygmy possum).

Wind-pollinated plants produce vast quantities of pollen. This can cause problems for humans, as the pollen is light and easily inhaled, causing allergic reactions. These plants generally have small, inconspicuous flowers, and include ragweed, grasses, conifers and other trees such as birch and aspen.

Some flowers self-pollinate, while others cross-pollinate – this increases the genetic variation within the plant population. Some flowers that have both male and female reproductive structures have mechanisms in place to minimize the opportunity for self-fertilization – the stigmas may not be receptive when the anthers are producing pollen.

Fertilization is the fusion of male and female gametes. It leads to the production of an embryo within a seed. The seeds form within the ovary, which swells up in size, becoming the fruit. The purpose of the fruit is seed dispersal.

Monocot Seed	Dicot Seed
 Image from http://home.earthlink.net/~dayvdanls/cornkernel.gif	 Image from http://www.seedbiology.de/images/pea-4.gif

Germination is the process by which seeds develop into plants. A seed has very few metabolic processes occurring – it became dormant once it left the parent plant, and will remain that way until such a time that the conditions are suitable for germination. Germination is the resumption of growth or development from a seed.

Stages in Germination:

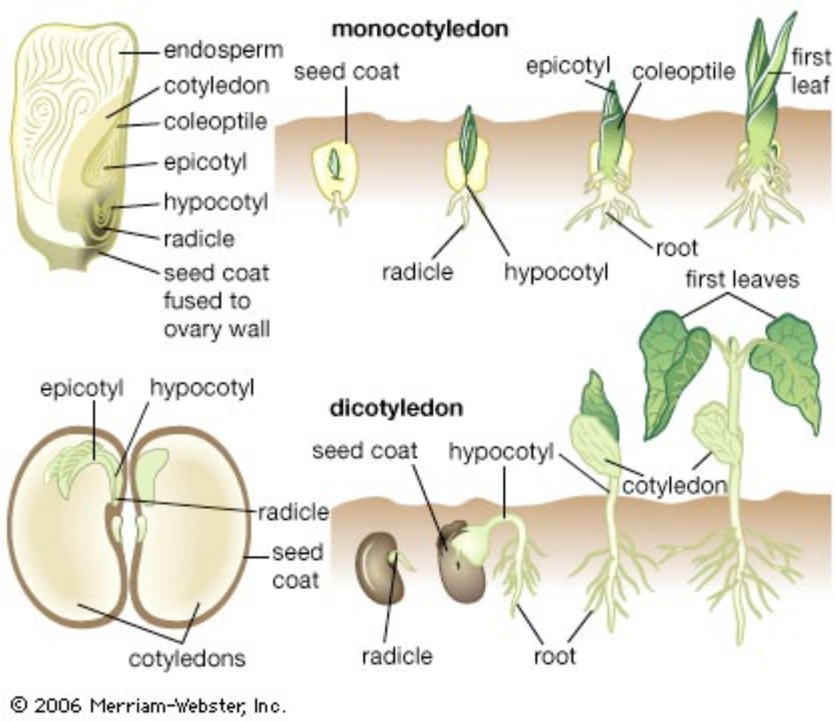
- absorption of water
  - seeds have very little water content
  - activates hydrolytic enzymes (e.g. amylase)
- amylase breaks down stored starch into maltose
  - moved to the embryo & used for cellular respiration
  - some used to make cellulose for new cell walls

- stored proteins & lipids are hydrolyzed
  - amino acids are used to make new proteins
  - fatty acids & glycerol are used to make new phospholipids for new cell membranes
  - hydrolysis of stored lipids also provides energy

Conditions Required for Germination:

The seed's dormancy must be broken. While seeds all have water and temperature requirements, the following are also possible ways of breaking a seed's dormancy:

- λ period of low temperature followed by a period of higher temperature
- λ light, for photosynthesis in the seedling
- λ wearing down the testa (e.g. by passing through an animal's digestive system)
- λ washing out of inhibitors from the testa (ensures sufficient water for xerophytes)



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