The Plant Transport System

2 types of plants

Monocotyledons	Dicotyledons / Eudicotyledons
One cotyledon in seed	2 cotyledons in seed
Parallel leaf veins	Netlike leaf veins (network of veins)
Petals and parts in multiples of 3	Petals and parts in multiples of 4 or 5
Fibrous System of roots (provide ground cover) – reduce soil erosion	Network of roots – tap root is the main root, that branches out.
Pollen grain has one furrow	Pollen grain has 3 furrows
Vascular bundles scattered throughout stem's ground tissue	Stem's vascular bundles arranged in a ring

Plant Organs

Plants have organs made of different tissues, which are made of different cells.
Roots cannot survive without shoots and vice-versa.

Roots

- Anchor plant into soil
- Absorb and transport minerals and water
- Store food
- Monocots – fibrous roots
    - Broad exposure to soil, water and mineral
    - Firm anchorage
- Dicot – tap root
    - Vertical with many small secondary roots growing outward
    - Large tap roots store food in form of starch
        - Carrot, turnip, sugar beets, sweet potatoes
        - Used during periods of active growth to produce flowers and fruit
- Have root hairs at tip of root
    - Increase the root surface area providing an extensive outer-layer for absorption of water and minerals.

- Each root hair is an outgrowth of a cell on the surface of a root.

Stems

- Above the ground
- Support leaves & flowers
- Has nodes – points at which leaves are attached
- Has internodes- portion of the stem between nodes

Leaves

- Primary sites of photosynthesis
- Has Flattened blade and a stalk, or petiole, which joins leaf to stem
- Can be simple or compound or doubly compound
- Grasses and most other monocots have long leaves without petioles
- Some dicots have enormous petioles that contain a lot of water and stored food, such as stalks of celery.

Simple leaves – single individual blade
Compound – one blade consisting of many leaflets
Double compounds – each leaflet divided into smaller leaflets

Plant Tissues and Tissue Systems

Each plant organ is made up of three tissue systems : the dermal, vascular, and ground tissue systems. Continuous throughout the entire plant body, but systems are arranged differently in leaves, stems and roots.

Dermal tissue system

- Forms an outer protective covering
- First line of defense against physical damage and infectious organisms
- On leaves and most stems, dermal cells secrete a waxy coating called the cuticle, which helps prevent water loss.

Vascular tissue system

- Provides support and long-distance transport throughout the plant; xylem and phloem are part of this system.

Ground tissue system

- Accounts for most of the bulk of a plant
- Has diverse functions, including photosynthesis, storage and support

All plant stems have vascular tissue systems arranged in numerous vascular bundles. The location and arrangement of these bundles differ between monocots and dicots.

Vascular Tissue System

Xylem tissue

- Long xylem vessels, adapted for rapid transport of water and dissolved mineral ions. Movement is always up the stem.
- Walls are thickened with lignin.
    - Waterproof and strong to prevent cells collapsing inwards.
    - In the shoot, xylem is on the inside of the vascular bundle, helping support the stem.
- No Cytoplasm or organelles
    - Cells are dead
    - There is no obstruction to the flow of water and mineral ions
    - End walls removed – cell join to form long tubes called xylem vessels.

Phloem tissue

- Contains sieve tubes and companion cells
- Adapted for transport of organic products of photosynthesis (transported as sucrose) and amino acids
- Transport is called translocation
- Sieve Tube
    - thin cytoplasm
    - cell must stay alive or sugar transport stops
    - no nucleus or organelles
    - pores in sieve plats (also known as plasmodesmata) allow sugars to pass from one cell to next
    - Companion cell does not transport sugar but carries out some life processes of sieve tubes.

Cortex – cells become turgid and help to support non-woody parts.
Epidermis – protects against infection by viruses and bacteria and dehydration.
Cambium tissue - contains cells which divide by mitosis to produce more phloem and xylem.

The Transport of Water

Mature water-conducting cells of xylem are arranged end to end to form very thin vertical tubes.

- Transports xylem sap
  - A solution of water and inorganic nutrients called xylem sap
  - Flows through tubes all the way from plant's roots to tips of its leaves.
- Xylem sap is pulled upward by transpiration, the loss of water from the leaves of a plant by evaporation.
  - Most transpiration occurs through stomata in leaves
  - Stomata open into air spaces fill with water molecules that have evaporated from surrounding mesophyll cells.
  - Water vapour diffuses out of the stomata because surrounding air is usually drier than inside of the leaf.
- Transpiration can pull xylem sap up a tree because of two special properties of water
  - **Adhesion** is sticking together molecules of different kinds. Water molecules tend to adhere to cellulose molecules in the walls of xylem cells.
  - **Cohesion** is the sticking together of molecules of same kind. For water, the hydrogen bonds make H_2O molecules stick to one another.
  - Together, adhesion and cohesion create a continuous string of water molecules running from the roots to the leaves. These molecules stick to each other and to the inside walls of the xylem tubes.

The Transpiration Stream (method of flow of water against gravity)

1. Before a water molecule can exit a leaf, it must break off from the top of the string of water molecules held together cohesively by hydrogen bonds. In effect, the water molecule is pulled off by a concentration gradient: The air outside the leaf is much drier than the moist interior off the leaf, causing the water molecule to diffuse outwards.
2. Cohesion resists this pulling force (because water molecules are attracted to each other and so don't want to be separated, but is not strong enough to overcome the force of evaporation.
3. The molecule breaks off, and the opposing forces of cohesion and transpiration put tension on the rest of the string of water molecules.
4. As long as transpiration continues, the string is kept tense and is pulled upward as one molecule exits the leaf and the one behind it is tugged up into its place.
5. Water molecules are thus pulled upward by this string, one at a time.

This is the transpiration-cohesion-tension mechanism.

Transpiration

Transpiration is the evaporation of water from parts of a plant exposed to the atmosphere. Greatest loss of water takes place through stomata.

- Usually more stomata on lower surface than upper surface
- Lower surface is less exposed to sunlight
- Water molecules diffuse from the air around the spongy mesophyll cells

Factors affecting rate of transpiration

Plant Parameters

- Cuticle
  - Thick → Transpiration rate decreases. Cuticle is a waterproof layer. The thicker it is the harder it is for water to pass through
  - Thin → Transpiration rate increases. A thinner layer will make it easier to for water to pass through the waterproof cuticle
- Stomata
  - Close → When closed, water vapour cannot leave the plant. Therefore, rate of transpiration drops.
  - Open→ When open, water vapour can leave the plant. Therefore the rate of transpiration increases
- Boundary layer of air
  - Thick → reduces **concentration gradient** of water vapour between the inside and outside of the leaf, making it more difficult for water vapour to diffuse through, resulting in a lower transpiration rate.
  - Thin → increases **concentration gradient** of water vapour between the inside and outside of the leaf, making it easier for water vapour to diffuse through, resulting in a higher transpiration rate.

Environmental Parameters

- Humidity
  - High → lowers concentration gradient of water vapour between inside and outside of the leaf. Decreases transpiration rate
  - Low → increases concentration gradient between inside and outside of leaf. Increases transpiration.
- Temperature
  - Low → water evaporates slower and hence rate of respiration drops. Air can hold less water vapour. So humidity levels in the air quickly become saturated. Concentration gradient of water vapour between the inside and outside of the leaf quickly drops and hence transpiration rate drops.

    - High → water evaporates faster and hence transpiration rate goes up. Air can hold more water vapour. So humidity levels in the air takes long time to become saturated. The concentration gradient of water vapour between the inside and outside of the leaf is maintained for a longer period and hence the transpiration rate rise.
- Light
    - Dark → stomata are closed due to lack of photosynthesis. So the rate of transpiration greatly reduces.
    - Bright → stomata are open due to photosynthesis. So rate of transpiration increases.
- Wind
    - Weak → weak/no wind cannot move the boundary layer on the leaf surface created by water vapour. This means there is more water vapour directly outside of the stomata so this decreases concentration gradient of water vapour between the inside and outside of the leaf and the transpiration rate decreases.
    - Strong → wind can move the boundary layer on the leaf surface created by water vapour. This means there is less water vapour directly outside of the concentration gradient of water vapour directly outside of the stomata so this increases concentration gradient of water vapour between the inside and outside of the leaf and the transpiration rate increases.

Transpiration also works against plants because it can result in the loss of a lot of water. Transpiration is greatest on days that are sunny warm, dry and windy because these weather conditions increase evaporation.

- If, transpiration exceeds the delivery of water, the leaves will wilt. Unless the soil, and leaves are rehydrated, the plant will eventually die.

Stomata in leaves help plants adjust their transpiration rate to changing environmental conditions.

- In the day
    - Stomata is open
    - Allow CO_2 to enter the leaf from atmosphere for photosynthesis while there is light
    - Plant also loses water through transpiration
- In the night
    - Stomata is closed
    - No need for CO_2
    - Save water by reducing transpiration
- Stomata may close during day if plant is losing water too fast
- Opening and closing of stomata – guard cells

- Changing shape of 2 guard cells flanking each stoma
- Change shape based on environmental signals
- Regulating rate of transpiration and CO_2 uptake
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Transport of Sugars
Phloem consists of living food conducting cells arranged end-to-end in long tubes. Sugary liquid called phloem sap moves freely from one cell to the next through plasmodesmata.

Phloem sap

- Inorganic ions
- Amino acids
- Hormones in transit from 1 part of the plant to another.
- Main solute is usually the disaccharide sugar sucrose!
- Can move throughout the plant in various direction

Source to Sink Movement
Sugar source – location in a plant where sugar is being produced either by photosynthesis or by breakdown of starch.

Sugar Sink – receiving location in a plant where sugar will be stored or consumed

1. Sugar moves within food conducting tubes of phloem from a source such as a leaf to a sink such as a root or a fruit.

Pressure Flow Mechanism

1. At the sugar source → sugar is loaded from a photosynthetic cell into a phloem tube via active transport. Sugar loading at the source end raises the solute concentration inside the phloem tube.
2. High solute concentration draws water into the tube by osmosis usually from the xylem. Raises the water pressure at the source-end of the phloem tube.
3. At the sugar sink → the beet root, both sugar and water leave the phloem tube. As sugar leaves the phloem, lowering the sugar concentration at the sink-end.
4. Water moves by osmosis back into the xylem. Exit of water lower water pressure in the tube.

The building of water pressure at the source-end of the phloem tube and the reduction of water pressure at the sink-end cause phloem sap to flow from source to sink. This **pressure flow mechanism** explains why sugar sap always flows from a sugar source to a sugar sink regardless of their locations in their plant.

In Summary,

1. Water and inorganic ions enter from the soil and are pulled upward through xylem by transpiration.
2. CO_2 enters leaves through the stomata and is incorporated into sugars which are distributed by phloem.
3. Pressure flow drives the phloem sap from leaves and storage sites to other parts of the plant where the sugarss are used or stored.