Transpiration - consequence of gas exchange

Definition: The loss of water vapor from the leaves and stems of plants.

Transpiration occurs because of gas exchange in leaves, as when stomata are open to let CO₂ in, H₂O vapor goes out. Guard cells minimize water loss as they control the aperture of the stomata, which can change from wide open to fully closed. The only plants without stomata are called hornworts. Stomata are necessary for CO₂ absorption because waxy cuticle permeability is too low.

Pipetteometer (as a measurement of transpiration):
- Air bubble moves along as water is absorbed by the sheet
- Shoot must be cut underwater to avoid macrophyte air bubbles
- cm/minute

Vascular bundles:
- Xylem: transports water and mineral nutrients
- Phloem: transports sucrose
- Cambium: produces new xylem and phloem cells
- Pith:
- Cortex:

Xylem features:
1) Thickened walls filled with lignin polymer to strengthen walls to handle low pressures - rigidity
2) Formed by files of cells, arranged end to end
3) When mature, xylem cells are non-living - no movement is possible
4) Pressure inside lower than atmospheric pressure

Adhesion:
Water molecules are polar, and the more electronegative O atoms in water act as a layer between the hydrophilic parts of xylem cell walls. Formation of hydrogen bonds with these O atoms causes adhesion.
Cohesion
- O atoms are attracted to the H atom in another water molecule
- attraction between H₂O molecules, allows water to be drawn up in a continuous stream

Surface tension is created by the cohesive forces between water molecules.

Models for water movement
- Capillary Tube
  - models adhesion between water molecules and glass molecules
  - Filter paper - adhesion

- Porous material - water fills the pores, adhesion to the clay demonstrated, movement of water through capillary tube as an uninterrupted chain demonstrates cohesion

Tension forces
- When water evaporates from the surface of the wall in a cell, adhesion causes water to be drawn from the xylem vessels in the leaf veins to replenish the water lost by evaporation.
- The forces of cohesion between water and cell walls further reduce pressure of the xylem water in the xylem and to the ends of the xylem in the roots.
  - This generates a transpiration pull, a passive force.

Active Transport in the Roots
- water is absorbed into the root cell by osmosis
- Minerals are more concentrated in the root cells than in the soil
- Minerals can only be obtained by active transport if they make contact with the appropriate protein pumps in membranes. They then make contact by diffusing into the protein or by mass flow (water carrying ions through the soil).
Adaptation:
1. Root hair cells - increase surface area
2. Root network that branches
3. Pump proteins and mitochondria to use ATP maximisation for use in active transport
4. Symbiotic/Mutualistic-fungi relationship which can absorb mineral ions bound to soil particles and pass the former to plants

Movement of water through the roots:
- Apoplastic pathway = movement of water to the xylem through the cell walls and plasmodesmata
- Symplast pathway = movement of water to the xylem through the cytoplasm
- Casparian strip = impermeable to water, so water must travel through the cytoplasm and endodermal cells (symplastic route), regulating the water entering the xylem

Support:
- Turgor pressure is created by vacuoles full of water pushing on cell walls. Lignin is a strong polysaccharide that strengthens plant. Support is necessary for growing towards sunlight. Turgor pressure maintains cell shape - prevents wilting.
How transpiration occurs

1) Water evaporates from spongy mesophyll cells into air spaces
2) Water vapour diffuses out of the stomata of leaves, down their concentration gradient
3) As spongy cells become more concentrated, water diffuses from xylem vessels into the spongy mesophyll cells

4) Water molecules are polar and its charged atoms are attracted to the hydrophylic parts of the leaf wall and these forces of cohesion further reduce pressure in the xylem

5) This generates a transpiration pull, affecting all water in xylem, since the cohesion between water molecules form an unbroken chain of molecules due to the hydrogen bonding in water.

6) Loss of water from the cortex and roots cause cells to become more concentrated, hence water from the soil enters through osmosis

Factors affecting rate of transpiration

1) Light → Light intensity. Rate of transpiration. Plants open their stomata in high light intensity to absorb CO₂ for photosynthesis that would occur faster because of higher light intensity, but water loss per unit time increases
2) Temperature → Temperature, rate of transpiration. Heat energy is converted into kinetic energy of water molecules. The greater motion breaks hydrogen bonds between H₂O molecules, allowing water to evaporate out of the stomata faster

3) Wind → Wind speed, rate of transpiration. Moving air removes water molecules surrounding the leaf, creating a steeper concentration gradient, which water moves down out of the leaf

4) Humidity → Humidity, rate of transpiration. There are more water molecules in the surrounding air, decreasing the conc. gradient between water in the air spaces and air outside the leaf. With a decreased conc. gradient, the rate of transpiration decreases
Transport in Phloem

Identifying xylem and phloem

- Phloem:薄壁组织
- Xylem:导管

Structure of the Phloem

- Sieve tube:筛管
- Sieve plate:筛板
- Companion cells:伴胞
- Phloem parenchyma:韧皮薄壁组织

Sieve tubes are elongated rows of individual cells that are arranged end to end to conduct food materials through all parts of the plant. A nucleus, reduced cytoplasm, and a membrane X-ray; resistance to flow of phloem

Sieve plates connect sieve tubes and sieve tube cells to support Companion cells provide ATP, proteins, and other sieve tube elements, whose structure cytoplasm allows for the sieve tube elements' structures needed for cell maintenance, wall maintenance, and cell wall.

Translocation

- Transportation of organic products of photosynthesis through the plant.
- Movement of phloem sap is from source (where sugar is made or mobilized) to sink (organ where sugar is used or stored).
- Phloem sap mainly consists of water, sucrose, hormones, and amino acids.

Pressure Flow hypothesis

1. Moving sucrose into the phloem from source increases the solute concentration in the sieve tube cells, hence the cells take up water from the surrounding xylem tissue by osmosis

2. The water absorption creates a hydrostatic pressure that forces the sap to move along the tube

3. The gradient of pressure in the sieve tube is reinforced by the use of sucrose and loss of water by osmosis (creating a lack of pressure)

Outline the translocation of biochemicals in the phloem:

1. Do the basics: amino acids, water, sucrose, and hormones
2. Transports from source (site of production or mobilization) to sink (site of use or storage)
3. Active transport from xylem to phloem
4. Xylem recycles the water used, as well as a lower solute concentration
Phloem Loading (Mass Flow)

- At the source, active transport is used to load organic compounds into phloem sieve tubes. 
- Organic compounds can load apoplastically or symplastically (through plasmodesmata).
- Protons are transported out of a companion cell using active transport through a pump protein. The build-up of proton then goes down its concentration gradient, through a co-transport protein. The energy released is used to carry sugar into the companion cell sieve tube complex.

Hydrostatic Pressure

- The build-up of sucrose and other carbohydrates draw water into companion cells. 
- Hence, water enters the cells through osmosis.
- The rigid cell walls, combined with the incompressibility of water, result in a build-up of pressure.
- Water flows from an area of high pressure to low pressure.

Aphids and Radioisotopes

- Aphids penetrate plant tissue to reach the phloem using mouth parts called stylets.
- If the aphid is anesthetized and has its stylets severed, phloem will continue to flow at the rate of the stylet, (only stylet attached to the stem).
- This lets us analyze the rate of flow and composition of the phloem sap.
- The closer the stylet is to the sink, the slower the rate of flow of phloem.

C-14

- Carbon in CO₂ can be fixed by plants during photosynthesis.
- As the carbon is metabolized, it is converted into many forms, such as sucrose.
- Hence, a geiger counter can track the movement of the radioactive molecule.
Growth in Plants

- Growth is confined to regions called Meristems
- Meristems are composed of undifferentiated cells that are undergoing active cell division
- Primary/Apical Meristems are at the tips of roots and shoots, and are responsible for root and shoot growth
- Secondary/Lateral Meristems are located along lengths of roots and stems and cause an increase of girth.

<table>
<thead>
<tr>
<th>Position</th>
<th>Apical Meristem</th>
<th>Lateral Meristem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of roots and stems</td>
<td>Primary system</td>
<td>Cambium, in vascular bundle</td>
</tr>
<tr>
<td>Products of growth</td>
<td>Primarily cells</td>
<td>Forms secondary xylem and phloem</td>
</tr>
<tr>
<td>Outcome of growth</td>
<td>Length + height</td>
<td>Increases girth and length of stem</td>
</tr>
</tbody>
</table>

Shoot Apical Meristem

- With each cell division, only one cell remains in the meristem
- The others differentiate into other groups of cells, like those that will develop into leaves and flowers, and increase in size due to their absorption of nutrients and water.
- All other cells move away from the meristem region.

Mini-Meristems (in Apical)
- Protoderm gives rise to the epidermis
- Proxobium gives rise to vascular tissue
- Ground meristem gives rise to parenchyma
Plant hormones

- A hormone is a chemical message that is produced and released in one part of an organism to have an effect in another part.

- Auxins can initiate root growth, influence fruit development, and regulating leaf development.

- IAA (indole-3-acetic acid) is the most abundant auxin, and it controls growth of the shoot.

- At high concs, it can inhibit growth. Produced in apical meristem of shoot.

Axillary buds

- Shoots cut from at the junction between the stem and the base of a leaf.

- As the shoot apical meristem grows, other meristems are left at the node.

- Axillary bud growth is inhibited by auxins produced by the shoot apical meristem (apical dominance).

- The function of the leaf is from the shoot apical meristem (SAM), the lower the auxin core, and the faster the growth of the axillary bud.

- Cytokinins, like cytokinins, hormones produced in the roots, promote axillary bud growth.

- Ratio of cytokinins to auxins determine if the axillary bud develops.

Tropism

- Directional responses to directional external stimuli.

- Phototropism is growth towards light.

- Geotropism is growth in response to gravitational force.

How Auxin works

- Auxin changes the pattern of cell expression.

- Light absorbed by phototropins in photoreceptors.

- When phototropins absorb light of the right wavelength, their conformation changes.

- They bind to receptors that control specific gene transcription (DNA-RNA-proteins).

- The gene activates the production of glycoproteins in plasma membrane to transport auxin from cell to cell.

- The glycoproteins are called PIN3 proteins.
**Intracellular Pumps**

**Phototropism**

- Phototropism detect greater light intensity on one side of the shoot.
- Auxin, by way of PIN3, is transported laterally from the side with brighter light to the shaded side.
- The higher auxin concentration on the shaded side prompts cell elongation on that side, so the stem grows curving towards the light.
- Hence, leaves get more light and photosynthesize at a faster rate.

**Geotropism**

- When a root is on its side, statoliths accumulate on the lower side of every cell, leading to the distribution of PIN3 transporters that bring auxin to the bottom of cells.
- The high concentration of auxin inhibits root elongation, so the root tip on the root grows faster than the bottom, causing the root to bend downwards.

**Micropropagation of plants**

- An in vitro procedure that produces large numbers of identical plants.
- Relies on totipotency of plants (ability to differentiate into any functional plant part) from plants are sterilized and cut into pieces called explants (sterilized using AgNO₃, H₂SO₄, H₂O₂).
- The least differentiated tissues (from meristem) serve as source tissue (comes).
- Explant placed into sterilized growth media including plant hormones and cytokinins.
- If A:C ratio is less than 1:1, it is called shoot media and shoots develop.
- If A:C ratio is more than 1:1, it is called rooting media and roots develop.

**Definitions**

- Meristem: regions of growth comprised of undifferentiated cells undergoing active cell division.
- Phototropism: directional response to light.
- Geotropism: directional response to gravity.
- PIN3: group of glycoproteins that transport auxin.
- Cytokinin: small molecules and Y produce new x + y.
- Auxin: plant hormone stimulating hypocotyl growth.
- Mitosis: cell division.
9.4 Plant Reproduction

Filament: The structure that holds the Anther
Anther: Part of stamen that holds the pollen
Sepal: Serves as protection for the bud, support petals in bloom
Petal: Attract pollinators and protect parts of the flower
Stigma: Provides receptacle for pollen to land on and rehydrate before entering the style
Style: Supports stigma and medium for pollen tubes to travel through
Ovary: Contains female gametes (ovules)

Pollination

Def: The transfer of pollen from the anther of one plant to the stigma of the same or another plant

Adaptations

Insect Pollinated Plants - stamens enclosed within flowers, so insect can make contact, stigma also enclosed in flower, stigma is sticky to catch pollen grains from insects. Large and colourful petals to attract insects, nectar present to attract insects. Pollen is sticky to attach to insects

Wind Pollinated Plants - stamens and stigma exposed to catch and blow pollen. Feathery stigma to catch pollen blowing in the wind. Small, green (not brightly coloured) petals. No nectar, small smooth pollen grains so wind can carry them

Anomocarpic growth - growth vertically
Lateral growth - horizontal growth
Undifferentiated cells
SEE 9.3 Rootlet for advantages
Mutualism between flowers and pollinators (transfer of pollen grains from anther to stigma)

- A relationship between plant and pollinator through which both parties benefit
- Pollinator gain food in the form of nectar and the plant gains a way to transfer pollen to other plants.

Fertilisation

- From each pollen grain on the stigma, a pollen tube grows down the style to the ovary.
- Male gametes are carried down to fertilise the ovule (tubes secrete enzymes that digest walls).
- The pollen tube enters the micropyle and the gametes eventually fuse, forming a zygote.
- The fertilised ovule becomes a seed and the ovary becomes the fruit.

Seed Structure

- Embryo shoot (plumule)
- Embryo root (radicle)
- Cotyledon (2 in a dicotyledonous seed)
- Hole through testa called micropyte
- Seed coat (testa)

Germination (process by which plant grows from seed)

- Aerobic cellular respiration begins after water enters through the micropyte (O2 needed)
- Synthesis of gibberellin begins (hormone that stimulates mitosis and production of amylase)
- Amylase breaks down starch in food reserves into maltose and maltose.
- Other enzymes convert maltose into glucose, so it can be transported to place in the germination seed.
- En Plunges and radicle use the glucose for growth.

Seed Disposal

- Prevents competition between parent and juvenile plant
- By wind, water, animals leaving or hooking onto animal then falling off.
Factors affecting Germination

- Water - must be present. Water washes out growth inhibiting hormones and aids in growth of plumule and radicle (needed for aerobic respiration), imbibition (swelling up of seed with water).
- Temperature - must be suitable as germination relies mainly on enzyme catalyzed metabolic reaction. Must be optimal.
- Oxygen - needed for aerobic respiration (that facilitate growth by ATP production).

Flowering

- Vegetative stage is before shoot meristems produce flowers instead of leaves.
- Reproductive phase is when shoot meristems produce flowers instead of leaves.
- Light plays a role in the production of activators or inhibitors of genes that control flowering.

Photoperiods and flowering

- A photoperiod is a the period of time each day over which an organism receives illumination.
- Phytochrome is a pigment that plants use to measure the lengths of dark periods.
- Long-day plants flower in summer, when there are short nights.
- Short-day plants flower in winter, when there are long nights.
- 2 types of phytochrome: P_{red} (for red) and P_{FR} (for far red).
- When P_{red} absorbs red light of wavelength 660 nm, it is converted into P_{FR}.
- When P_{FR} absorbs far red light (more common in night) at 730 nm, it becomes P_{red}.
- In darkness, P_{red} slowly becomes P_{FR} due to P_{FR}'s relative lack of stability.
- In long-day plants, lots of P_{FR} remain at the end of nights, and they bind to a receptor protein that promotes transcription of genes needed for flowering.
- In short-day plants, the receptor inhibits transcription of genes needed for flowering when P_{FR} binds to it. At the end of long nights, little P_{FR} remains so there is lack of inhibition and the plant flowers.
Xerophytic adaptations

1) Rolled leaves - reduced exposure to abiotic condition
2) Spine leaves - Lower S.A for transpiration
3) Fasciole - Access deeper water sources
4) Thickerened waxy cuticle - reduce water loss through cuticle
5) Reduction of stomata - reduce number of pores through which transpiration occurs
6) Stomata in pits surrounded by hair - moist or trapped outside stomata, ↑ humidity
7) Floppy stem - water storage
8) Shallow roots - take advantage of sporadic rain or overnight condensation
9) CAM - Crassulacean Acid Metabolism → CO₂ absorbed at night and converted into malic acid that release CO₂ during the day. This allows photosynthesis to take place even with closed stomata

Halophytes

- Plants adapted to live in saline conditions

Adaptations

1) Salt glands - salt transported to leaf surface, where it is crystallised and blown away. The salt is excreted from the leaf surface.
2) Salt avoiders - roots impervious to salt or salt can be pumped out of roots into soil
3) Salt storage vacuoles - they store salts
4) Sacrificial leaves - salt is concentrated in a leaf that dies, then drops from the plant
5) Vapory - seeds germinate while still attached to the tree, allowing parent to provide water and other nutrients needed

Stomata

Opening - ABA acts by concentrating potassium ions into the guard cells, followed by water. ABA is made in the roots and is released when roots detect a lack of water in the soil. This happens at night. This results in the closing of the stomata.
NOTE: These are just my random scribbles, feel free to ignore them—they just have the same information as the preceding page.

- Callenchyma - salt avoidance
- Parenchyma - tissues for storage of food
- Sclerenchyma - tissues for support

Apical Meristems are totipotent (can create a full organism) and create:
- primary vascular tissues (long and narrow)
- leaves that produce secondary vascular tissues (short)

Xerophytic Adaptations
Leaves - rolled (limit exposure to ablatic environment), spiny (↓ S.A. for transpiration), ↓ number of stomata, stomata located in pits surrounded by hair (trap moisture ↑ humidity). Thickened cuticle.
Stems - fleshy stems to store water.
Roots - shallow (take advantage of overnight condensation) or deep (access deeper sources).
CAM - CO₂ absorbed at night and converted into malic acid, stored, releases CO₂ during the day, photosyn can happen with stomata closed.

Halophytic
- Sacrificial leaves
- Vivipary
- Salt glands
- Salt avoidance

Halophyte
- Sunken stomata
- Sacrificial leaves
- Deep roots to gain water access
- Salt glands
- Salt avoidance

Water (amost tests by imbibition) [washes out growth inhibiting hormone]
[enzymes cell] [allows for hydrolysis reactions]
O₂ needed for aerobic cell, O₂ uses NADP to plunulate and reduce
T only ATP for enzymes activity.